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Exploiting an intermodal road-rail supply chain in a cooperative setting with multiple shippers

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**Exploiting an intermodal road-rail
supply chain in a cooperative setting
with multiple shippers**
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Michiel Diederen,

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Abstract

This thesis describes a research conducted at Bakker Barendrecht B.V. A model is constructed which determines the costs of an intermodal road-rail supply chain if a set of shippers collaboratively exploit such a route. The constructed model also suggests a distribution of the total costs using two allocation scenarios based on the Equal Profit Margin method. A base composition of a set of shippers is tested for which is shown that an intermodal route yields supply chain benefits and that a stable allocation of costs is possible. Additional insights into the sensitivity of the model and allocation rules are obtained. Moreover are both allocation scenarios compared. This analysis confirms the viability of collaboratively exploiting an intermodal supply chain and gives recommendations on how to set up an exploitation model in a cooperative setting with multiple shippers.

Management Summary

A big challenge for intermodal transport providers is to find enough cargo volume (critical mass) on both route directions in order to successfully implement new intermodal corridors that can compete with transportation by road. Rail operations endure high fixed costs in comparison with road transport. This makes it difficult and risky to organize new intermodal connections with a sufficiently high service level and frequency. Furthermore, have intermodal transport providers seldom a direct commercial relation with shippers. They often interact with intermediaries such as logistics service providers and forwarders of freight flows who on their turn interact with shippers that deliver the actual cargo volumes. This makes it more difficult to proactively bundle freight flows at the source and to create dense, balanced and synchronized transport volumes with long-term stability.

Many intermodal road-rail projects fail or even do not start because shippers will not commit sufficient volume needed for a rail operator to cover the exploitation risks. One way to solve this "chicken-and-egg" problem is for shippers to bundle their cargo and therefore start collaborations on a horizontal level. Bakker Barendrecht together with one other shipper are currently executing such a project and are implementing a new intermodal rail-road corridor between Valencia and Rotterdam, referred to as Cool Rail Spain.

The problem considered during this thesis is as follows: Bakker Barendrecht (and the project committee) needs an exploitation model that advices them how to exploit the Cool Rail Spain route once it is operational. To have a viable exploitation, possible savings have to be divided among all the involved shippers in such a way that the interests of all the parties are taken into account. Therefore the goal of this master thesis is to:

Design a cost model and subsequently an allocation model (=the allocation of total costs) reflecting the intermodal logistical process in a cooperative setting with multiple shippers.

This research validates the viability of this logistic concept by aggregating a cost model with a cooperative cost allocation model. The collaborative aspects that are necessary for exploiting an intermodal route are incorporated. Collaborations only are viable whenever the pain and gain sharing is incorporated in such a way that all participants agree on them. This research concentrates on this gain sharing mechanism by applying cooperative game theory in a cost allocation model. Finally this research gives some recommendations for the design of the exploitation model.

Since the Cool Rail Spain project concerns a complete new implementation it is interesting to determine the probability of certain outcomes (=cost savings) for participants in the cooperation in relation to the risks of the entire operation. That is why a cost model is constructed on which simulations in a stochastic environment are performed. The results generated with these simulations are subsequently used in the cost allocation model to determine viable and stable cost allocations among shippers.

The cost model is based on the processes that are directly related to the movement of containers from the shippers' cargo origin to cargo destination locations and vice versa. The processes can be grouped into three main activities and some rest activities that are needed for the exploitation of an intermodal supply chain. The main activities included in this cost model are:
- The long haul process relates to the movement of containers via rail. Relevant aspects are time and distance related costs.
- The drayage activities refer to the movement of containers by road. Time and distance related aspects are included in this type of costs as well. The intermodal route is exploited in a roundtrip setting. Synchronizing and efficiently planning these trucking activities is very important. The cost model is able to reflect costs in proportion to the efficiency level of the drayage activities.
- The other activities are handling activities that are necessary to transport the containers between the two modes of transportation and the time dependent costs to (un)load containers at locations.

- Finally the control tower costs that are needed to execute the centralized planning and control of the route, renting of reefers and fuel costs to transport cargo in cooled conditions are included as well.

These activities are used to determine the exploitation costs per roundtrip of the intermodal route given an uncertain accumulated amount of cargo availability. The choice to include the control tower costs was made because the project committee will use such an entity as well during the exploitation of the intermodal route. Subsequently these costs are compared with the costs in the current situation in which shippers transport containers separately by truck. In this way the costs caused by the intermodal exploitation can be compared to the current situation. The shipper specific costs in the current situation determine a shippers' stand-alone costs which play an important role in the cost allocation.

A cooperative game is built to allocate the exploitation costs between the shippers in a stable and viable way. Based on attended project meetings and interviews it is concluded that a collaboration is perceived as fair, if it strives for an equal relative savings among participants when allocating joint costs. The Equal Profit Method allocation rule, found in literature, satisfies this condition. Therefore the Equal Profit Method is applied within the allocation model. The relative saving of each shipper is determined by comparing its stand alone cost (current trucking costs) to the cost incurred while collaborating all together. To show what the impacts are on the cost allocations if the cooperation decides on certain boundaries of the cost allocation, also a modification on the Equal Profit Method is used. It is questionable whether shippers in a cooperation should be "penalized" for the locations of other shippers' psychical facilities. On the other hand, these locations are known in advance to the other community members, so it could also be negotiable to spread out the trucking costs across all shippers such that relative savings differences are minimized again. To reflect these alternatives in cost allocations, two allocation scenarios are constructed and compared:

- Allocation scenario 1 in which all costs are considered as shared costs. The total costs are allocated in such a way that the relative savings among shippers are minimized. In other words: everybody pays for everybody's costs.

- Allocation scenario 2 in which the shipper specific trucking costs are allocated to each shipper separately. In this scenario the shipper specific drayage costs are allocated directly to each shipper.

A base case is tested by performing simulations and an expected total supply chain benefit of €17,890 per roundtrip is determined. This is a cost reduction compared to trucking containers of 12.6%. The upper two allocation scenarios are used subsequently to allocate this joint benefit among the shippers such that the cooperation remains stable (i.e. total costs equal the accumulated costs per shipper and each shipper at least has a saving of 1%).

Both allocation scenarios result in cost allocations whereas shippers are better of cooperating than acting alone. This suggests that an orchestrated collaboration of shippers successfully can exploit an intermodal rail-road supply chain. It proved that there exists very influential factors on the expected supply chain benefits. These factors should be taken into consideration by the project committee to create the right expectations on expected cost savings among participants that join the exploitation of the route. The cost allocation comparison creates awareness that choosing for allocation scenario 2 could lead to allocations with big differences in relative savings between shippers in the cooperation. These might be considered as unfair by these shippers and this might lead to an unviable collaboration.

Based on the conclusions generated with the cost and cost allocation model the recommendations how to set up the exploitation model are the following:

1. Use cost allocation scenario 1 because of the long-term goals of Cool Rail Spain.
   o By applying an allocation rule that strives for similar relative cost savings among partners, the collaboration is made as attractive as possible for other shippers.

- The extra savings for shippers that gain from applying the second allocation scenario is negligible when put in perspective with the potential in extra benefits of an extra weekly train.

2. Use a central accountant to mitigate risks by sharing them between all stakeholders in the cooperation:
   - It is too simple to assume that the logistic service providers and rail operator that are hired by the cooperation will cover all unexpected extra costs. Shifting too many risks and costs to entities other than the shippers can lead to unviable situations for these entities which subsequently can lead to the withdrawal of key partners from the collaboration.
   - Instead of letting shippers pay amounts that are sufficient to cover the expected costs, let shippers pay a surplus per roundtrip. Whenever unexpected events occur during a season, the cooperation as a whole can determine how to cover the extra costs by using the surplus values that are already present at the central accountant or by designating a stakeholder who is responsible for the extra costs.

3. Use the control tower to "resell" empty container slots to (external) shippers outside the cooperation.
   - The analysis showed that it is more beneficial for the cooperation as a whole to sell empty container slots with losses (actual costs > than tariffs paid) to external shippers than leaving container slots empty during a roundtrip. For the base case scenario it proved that it is beneficial to sell containers up to a loss per container of €700 before leaving slots empty is the better option (cost-wise).
   - Shippers outside the cooperation can experience the potential benefits of intermodal transportation, get acquainted and may get convinced by the concept and start using the route on a recurring basis in the future (seeing is believing).

4. Use a "trustee" within the cooperation.
   - A good estimation of the trucking prices (stand-alone costs) of each shipper is crucial to estimate the total cost savings of the project and subsequently manage the expectations of the involved shippers.
   - The trustee can act as a reliable partner for all participants in the project by treating confidential information as such.

Table of Contents

List of Figures

List of Tables

1.   Introduction

Perishables are one of the main commodities in the trading corridor between Spain and The Netherlands. Research on origins in Spain and destinations in The Netherlands showed that on a yearly basis, more than 30.000 45ft container equivalents are transported from Spain to the Netherlands. More than half of the volume comes from the regions of Valencia and Murcia. In 2013, Bakker Barendrecht (BB) and two other shippers supported by the Port of Rotterdam Authority and the Dutch ministry of Infrastructure and Environment took the initiative to bundle their cargo and start the new development of an intermodal rail-road supply chain referred to as the Cool Rail Spain (CRS) project.

The CRS project concerns the fresh produce sector in the Netherlands, nowadays importing large volumes via the road from Spain. Spain is of great importance for the Dutch trade in F&V (fruits & vegetables). Apart from the Netherlands, Spain is the most important source of fruits and vegetables and an origin area that until now is almost completely served by road transport. However, the sector has to deal with rising fuel prices, higher toll, further restrictions on driving and rest periods, and increased attention to the environment (food miles / gas emissions etc.). The goal of the CRS project is to develop a new train connection between Valencia and the Rail Service Center in Rotterdam as an intermodal door-to-door connection by using two different modes: truck (road) and train (rail). After a growth period of three years the final goal is to have a daily train connection between Valencia and Rotterdam. The project should lead to substantial cost savings and CO_2 reductions by a partial modal shift from road to rail.

This master thesis is executed within BB. The status the project had at the end of February 2015 was seen as the starting point for this thesis. At that time the project committee was in the development phase of an exploitation model that reflected the exploitation of the route in a collaborative environment with multiple shippers. This thesis contributes to the knowledge on intermodal transportation in general and the CRS route in particular by taking market specific properties between Spain and the Netherlands into consideration, as well as BB's interest.

This report starts with a brief literature review (chapter 2) to get a basic understanding of the topics under study. Chapter 3 explains the used methodology and ends with stating the research assignment with the associated research questions. The current situation in which containers are transported by road is compared to the CRS route via an analysis reported in chapter 4. Chapter 5 and 6 on their turn concentrate on the design of the cost and cost allocation model. Chapter 7 reports the results and a deeper analysis by aggregating both models. The last chapter concludes this report by summarizing the conclusions which provide answers to the research questions, doing recommendations and by indicating some relevant topics for future research.

2. Literature Review

2.1. Introduction
This section is in support of the development of the intermodal cost evaluation and allocation model. It functions as a starting point of content discussed throughout this master thesis. A brief literature review is given for two subjects to gain some background knowledge. The first discussed topic is the one of the intermodal transportation market. The second topic focusses on horizontal collaboration partly explained from a game theoretic point of view.

2.2. Intermodal Transportation

2.2.1. Liberalization of Intermodal Market
Last decades economic growth is achieved because markets became more and more internationally oriented. A consequence of this economic growth is the huge increase of international trade. This led to the large growth of the freight transport over the last decades. In Western Europe, the rail freight industry is presently being liberalized. Many of the new intermodal services involve cooperation between various actors, including the port authorities, shipping lines, port terminal operators, logistics providers and even between shippers as is the case in project CRS. It is this liberalization process that is opening the industry to new forms of organizations and providing new market possibilities. However, opening the industry to more competition has been difficult because of the integrated nature of the industry. Railroads were providing their own rights of way (tracks), as well as the means of traction and the operation of services. To make rail services contestable, all that was required was for a new operator to possess the ability to request slots from the rail track provider, to pay the user fees, and observe standard rail operating and security procedures (Debrie & Gouvernal, 2006). Due to this liberalization alternative transport modes like rail transport are becoming more interesting. Rail transport can give rise to new opportunities due to larger capacities, safety and when used efficient, less polluting when compared to transporting the same amounts of cargo by truck. The freight transport making use of load units (like containers) and the combination of different modes (like truck and train) have led to the intermodal freight transportation market. Bontekoning, Macharis and Trip (2004) state that: "operations research has been used for various strategic problems and that almost all types of intermodal problems are covered, however, the number of studies in each category is still very limited". They also state that: "further development of OR techniques and heuristics is needed in order to develop applications that provide good solutions to intermodal problems."

2.2.2. Intermodal Rail – Road Transportation
Project Cool Rail Spain is an example of containerized intermodal transportation as it is broadly defined as: "the transportation of a load from its origin to its destination by a sequence of at least two transportation modes, the transfer from one mode to the next being performed at an intermodal terminal" (Crainic & Kim, 2005). A container is defined as a "generic term for a box to carry freight, strong enough for repeated use, usually stackable and fitted with devices for transfer between modes" (Anonymous, 1997). This transfer between modes is executed at an intermodal terminal which may be a sea port or an in-land terminal. In the case of the CRS project, products will be shipped in containers and transported at an in-land road-rail terminal. Since the CRS project is a way of containerized intermodal transportation a lot of different entities/parties are involved in the complete chain of making sure the products are transported from its origin to the destination. Based on literature of Macharis and Bontekoning (2004), Debrie and Gouvernal (2006) and Vandwerwegen (2008) the following list of actors that are active in an intermodal rail-road transportation setting is composed:

- Shippers. Shippers generate demand for transportation. They can be seen as the clients of the transportation chain.
- Consignees. The main interest of consignees is the follow up of the shipment and possible the costs of transport. Often the consignees are the receiving party of the products. However within the CRS

project no clear boundary exist between shippers and consignees. The shippers that will join the CRS project have for example suppliers in Spain and from these locations cargo is pick-up and transported to the shippers' locations in the Netherlands and vice versa. So within the CRS project the shippers are also the receiving parties in the supply chain.

- Logistic service providers (LSP). A logistic service provider is a provider of logistics services that performs a part or all of a shippers' and/or receiver logistics needs. For intermodal rail-road transport LSPs can also be the parties that purchase rail traction services and infrastructure access from railway companies. Debrie and Gouvernal (2006) state that LSPs for intermodal rail-road transport are clients of railway companies.
- Railway operator or traction providers (Debrie & Gouvernal, 2006). These companies gain access to the rail tracks by obtaining running rights and time slots from the rail track providers.
- Infrastructure providers. First there are rail track providers which in different countries are controlled by separate entities. These entities control rail access and provide traction providers with time slots and running rights. Second there are the terminal operators. They perform the terminal handlings at intermodal road-rail terminals. Terminal operators provide and operate infrastructure for the loading and unloading of containers as well as warehousing.

An extra entity that is used throughout this thesis is the following:

- Control tower. The essence of the control tower is to provide supply chain visibility across divisions, countries and modalities. The heart of the control tower is an information hub supported by a set of detailed decision-making rules. The big advantage of this central information hub is that it gathers and integrates data from a variety of sources and subsequently distributes it in a consistent format (www.nl.dsv.com). This function has to be executed by a party that is involved in the project. Within the exploitation of the route the entity that functions as the control tower also will be the center of the supply chain financing structure.

These listed actors display the multi actor setting in which the containers in intermodal rail-road transportation are transported from origin to destination. The intermodal transportation chain starts with the shipment that is picked up at the shippers' origin destination by truck, referred to as drayage operations. Drayage operations take place by truck via road transportation and are the transportation of products from the source to the intermodal terminal and vice versa (from the intermodal terminal to a shippers' destination). These activities can be performed by either the shippers themselves or by an LSP. Intermodal operators can be considered as an LSP since they organize the transportation of shipments on behalf of shippers and they buy the services offered by drayage, terminal and network operators and are therefore responsible for the intermodal transportation of the complete chain (Macharis & Bontekoning, 2004).

The long haul (via rail) is the terminal-to-terminal segment of the door-to-door intermodal trip. Contrary to the drayage operations, that are usually short distances traveled by truck from origin to terminal or from terminal to receiver, often the rail haul is characterized by covering much longer distances by train. The rail haul is made possible by a combination of the railway operator and infrastructure providers (Bontekoning et al., 2004).

Transshipments are the operations that separate the load units (in this case containers) from the truck and place them onto the train at the terminals or vice versa and are performed by the terminal operators.
Upon arrival of the trucks at the intermodal terminals, the containers need to be trans-loaded via an intermodal terminal onto the train. When all containers are loaded onto the train, the train will start its long haul to the other terminal. When the train arrives at the other terminal the trans-loading of the containers from the train onto the trucks is executed again. The last step in the transport chain is the delivering of the containers to the right destinations of the shippers by truck. After successfully transporting the right shipments to the right destinations these subsequent steps are repeated but now in the other direction.

2.3. Cooperative Game Theory

2.3.1. Horizontal cooperation

One can only speak of real cooperation if "there is a tailored relationship based on mutual trust, openness, shared risk and shared rewards that yields a competitive advantage, resulting in business performance greater than would be achieved by firms individually" (Lambert, Emmelhainz, & Gardner, 1996). Horizontal cooperation can be defined as an active cooperation between two or more firms that operate on the same level of the supply chain and perform a comparable logistics function on the landside (Cruijssen, Salomon, Bräysy, Dullaert, & Fleuren, 2007b). The literature on horizontal cooperation in transport and logistics is limited in contrast to the literature on vertical cooperation (Cruijssen, 2006). However, Cruijssen (2006) presented some motives for horizontal cooperation classified in four main categories: cost and productivity, customer service, market position and other. The CRS project is a horizontal cooperation because the involved firms are all shippers that perform activities by transporting products from Spain to Rotterdam or vice versa. The main driver for parties to join the CRS project are cost reductions and to secure future transport possibilities.

Almost all literature focuses on the benefits and opportunities of cooperation and neglects the possible impediments, Cruijssen, Cools, and Dullaert (2007a) however define four categories of impediments related to horizontal cooperation in transport and logistics. The first one is finding the right partner. The second one are difficulties related to the negotiation process about the level of cooperation and definition of the responsibilities, rights and obligations of the various participants. The third one is the need for coordination, information and communication technology. The fourth one is the determination and division of gains. The difficulties related to the negotiation process about the level of cooperation also occurs within the CRS project. It is depicted by the uncertainties and questions how to divide the responsibilities of all the different activities (e.g. drayage in Spain, drayage in Rotterdam) within the intermodal supply chain. The determination and division of gains and costs is another issue that requires attention within the CRS project. The distribution of expected as well as unexpected costs in a fair way among the participants of a cooperation is very important to maintain a cooperation (Cruijssen, 2006). Horst, Konings, and de Langen (2006) confirm this, by stating that if one wants to obtain the required cooperation, each participant must have an incentive to do so. So for creating a successful cooperation, the benefits should be shared in such a way that all parties see the advantage of the collaboration. The impediments as discussed by Cruijssen et al. (2007a) also underscores the importance of dividing the possible gains (in this case possible cost savings) in a right way. Via a survey among several LSPs the following two impediments were expected to receive the most difficulties under the assumption that the right partners were already chosen (or when excluding the impediments regarding the right partner selection). "A fair allocation of benefits to all the partners is essential for a successful cooperation" and "when benefits cannot be shared in a perceived fair way, the larger players will always benefit most". These impediments are especially in the CRS project important, and need to be taken into consideration, because the project committee wants the route to expand to a daily train connection. So it is important that parties are "in there" for the long run and this is only possible when no shippers in the project become frustrated because their true contribution to the cooperation are undervalued by receiving not enough cost savings.

2.3.2. The Cooperative Game

The cooperative part of game theory focuses on working together. Cooperative game theory focuses on coalitions with binding agreements and on issues which arise when coalitions are formed, such as: value allocation.

Cooperative game theory primarily deals with obtained profits by groups of players if they coordinate their actions or work together (Hoyer, 2010). There are two main types of cooperative games: cooperative games with non-transferable utility (NTU games) and cooperative games with transferable utility (TU games). Transferable utility refers to the fact that the total pay-off of the game can be measured by a single number that can be distributed among the players (e.g. money) (Leyton-Brown & Shoham, 2008). In this graduation

project and thus in the development of the models transferable utility is assumed, whereas the TU is money. Transferable utility (TU) games are games in which players can form groups among themselves and can transfer the utility within the group. Utility is a measure of a player's level of happiness in the given states and therefore it quantifies the preference among possible choices. For this project a players utility is completely determined by the amount of money it receives in certain situations.

This paragraph is focused on games with a finite set of players to get a basic understanding of how a cooperative game with a finite set of participants is expressed in a mathematical manner (Leyton-Brown & Shoham, 2008). Denote $N = \{1, 2, \dots, n\}$ as the finite set of participants. A subset of participants in N is called a coalition denoted by S whereas N resembles the grand coalition in which all participants are active. When a coalition S forms, the total cost $c(S)$ for that specific coalition is generated (Frisk, Göthe-Lundgren, Jörnsten, & Rönnqvist, 2010). This cost function is called the characteristic cost function and each participant is called a player.

2.3.3. Benefit allocation

Often cooperation's use simple rules to distribute savings that are proportionally to a single indicator of either size or contribution to the collaboration such as proportional to the total load shipped, logistics costs before the cooperation, distance travelled for each shipper's orders, or proportional to the number of orders (Cruijssen, 2006). These are traditional (simple) allocation rules, but there also exist allocation rules based on game theory. Game theory deals with the mathematical modeling of these situations of conflict and with the analysis of these models using mathematical techniques (Slikker, 2014). Game theory can roughly be divided into cooperative and non-cooperative game theory. The first deals with situations in which groups of players coordinate their actions. This coordination results in joint profits, which often exceed the sum of the individual profits. The reason shippers combine their cargo in the CRS project is also to obtain synergies with reference to the total costs per shipper that individually could not be obtained. Cooperative game theory subsequently deals with the question how to divide these joint profits.

When looking at dividing profits in a cooperation (or in game theory: a cooperative game) stability is the basis of the core concept. Stability means that there is no coalition whose members together receive less than this coalition of the same members could obtain by itself. Because if two members in a coalition could earn more (or have less costs) when only joining together compared to being in a bigger coalition with more members, the coalition would be unstable. A stable pay-off vector of the earnings between different members in a cooperative game means that no coalition has an incentive to leave the grand coalition and form a coalition on its own (Slikker, 2014). When a pay-off vector is stable, it is called to be in the core of a game. Much research on cooperative game theory follows a similar research structure. They start with defining the problem in formal game theoretic concepts. Thereafter the profits or costs of all possible coalitions in the specific context are determined, often by using operational research concepts.

When a way of allocating all the costs is not guaranteed to be a core-element, this might be troublesome. In intermodal cost-allocation games, companies are unlikely to agree upon a cost allocation outside the core (Theys, Notteboom, & Dullaert, 2000). Cruijssen, et al. (2007a) state that literature on the distribution of both costs and savings arising from horizontal cooperation is scarce, and cooperative game theory provides a promising direction of solving these issues.

3.   Methodology

3.1.   Introduction
In this chapter the research methodology is discussed. In the first section a background is given to the problem at hand. Using the background and the problem definition, research questions and associated project aims are formulated. The regulative cycle is used to explain the method of research and the chosen structure behind this report. Finally the research design used within this project is explained whereas the deliverables per research question are given. Last the rigor versus relevance debate is treated by explaining how there is strived to maintain an adequate balance between both factors in this project.

3.2.   Problem background
A high level market analysis labeled the corridor between Spain and the Benelux as interesting for intermodal cargo shipping. They labeled the northwards and southwards corridors as a difficult transport market with volatile pricing, imbalanced freight flows and lots of seasonality effects (Jacobs, Vercammen, & Verstrepen, 2013). These factors are widely recognized as big obstacles for the efficient and sustainable organization of transportation networks. Therefore road transport is often seen as the most adequate option for shippers.

One difference of transportation of cargo by train is that it transports a lot more cargo at one time. A truck usually carries one container at a time, while a train can transport up to 40 containers at one time. Therefore, in order to exploit a train efficient (cost wise) a lot more cargo at once is needed to reach prices per container that can compete with current truck prices. The train only runs for the companies that are involved in the project. This means that the train needs enough cargo when going to Rotterdam as well as when it returns back to Spain. The companies within the final cooperation together are responsible for making sure they combine enough cargo such that the capacity of the train is fully (or sufficiently) used. The CRS project develops a dedicated train route where the train is only running for these companies involved in the project. They dedicate/commit volume to the train. In the proposed concept schedule by the rail operators the transit time of the train per route (terminal to terminal) is between 40 and 48 hours and the train has a capacity of 40 containers. Due to the difference in rail gauge width between Spain and the rest of the route, freight traveling on rail wagons must be transshipped at the French/Spanish border. This results in time loss. This transshipment (by interchangeable axles or transshipment by lifting the complete train) on the different gauges can lead to an extra time spend of approximately four hours. So in the future this travel time could get significantly shorter once the Spanish gauge width has been replaced (planned in 2016). A train schedule of two trains per week is chosen because of cost reductions per train due to cost synergies that can be reached by rail operators when making the material/staff planning for two trains. At the beginning of the project, on four moments of the week enough cargo has to be delivered to the train terminals by truck to reach cargo quantities that are near, or as much as, the train's capacity to reach prices per containers that can compete with current truck prices. So twice per week enough cargo in Valencia is needed (on Tuesday and Friday) and twice per week enough cargo in Rotterdam is needed (on Friday and Monday). In the remainder of this report, the northbound route (NB route) will refer to the train route from Valencia to Rotterdam and the southbound route (SB route) will refer to the route starting in Rotterdam and ending in Valencia.

Looking at the expected cargo quantities of BB on the northbound route a shortage in the total expected amount of cargo exists. An important reason for the fact that BB does not have enough cargo to fill a complete train is because the products that need to be transported are perishables. This means that BB cannot build up stocks of perishables, because stocking the products too long (and therefore build up volumes) would endanger the freshness of the products. A continuous (daily) transportation of these perishables is necessary in order to receive them as fresh as possible at the distribution centers of BB. So one might argue to change the train schedule to only one train per week, but this will not make any difference in the total amount of cargo that can be transported per train because BB's products cannot be stocked before transportation. Because of the shortages at the northbound direction, other organizations' volumes are needed to reach sufficient volume north- and southwards on the two way train route.

6

3.3. Problem definition

Without any cost savings a shipper is not interested in joining the CRS project and will most probably prefer the current way of transportation by truck over an intermodal way of transporting its products. Even though the use of intermodal transportation will yield reductions in CO_2 emissions for organizations, cost aspects often have the highest priority. In accordance to Cruijssen et al. (2007), the most important motives for horizontal cooperation in transport are improving the costs, service and efficiencies. Since several other organizations are necessary to have sufficient cargo on the northbound route, the project becomes a collaboration. This emphasises the importance of insight in the cost aspects for the exploitation model of the CRS project. Without good cost insights and subsequently the dividing of these costs between the parties, the exploitation of the new route is not possible. Instead of focusing on the interests of one particular actor, the interests of all the shippers have to be taken into consideration.

In sum, BB (and the project committee) needs an exploitation model that advices them how to exploit the CRS route once it is operational. In order to have a viable exploitation, possible savings have to be divided among all the involved shippers in such a way that the interests of all the parties are taken into account. Possible savings in this context are caused by a reduction of costs and that is why detailed cost insights, in a stochastic environment, in the new intermodal supply chain situation are very important. So far these detailed cost insights in a stochastic environment are missing to a certain level by the project committee.

3.4. Problem scope

Based on the current situation at the time this thesis started and problem definition, the scope of the project is summarized in Figure 3.1 below. Due to time restrictions this graduation project will focus on the cost model and the allocation of these costs among the parties involved in the collaboration. The main objective of this graduation project is to give insights in the costs of the new situation compared to the old situation and the allocation of these joint costs among the various shippers involved in the CRS project. No other factors for BB will be explored or developed as there might be other important factors in the exploitation of the intermodal route. Note that the reflection of this exploitation model is used to indicate the scope of this graduation project and is not reflecting the complete exploitation model as it might need extra factors that are of use for BB in this intermodal collaborative setting.
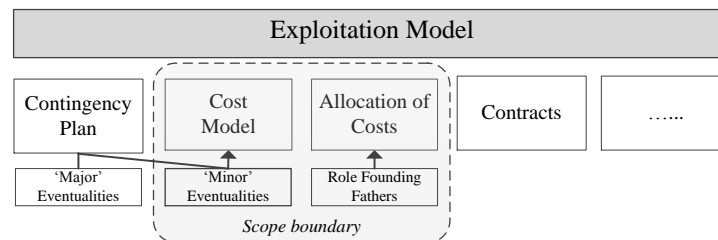
Figure 3.1 Representation of the scope

Cost Model

Cost insights are important because insights in the new cost of the intermodal supply chain are needed in order to make comparisons with the current situation where the transportation of products is almost completely carried out by trucks (separately by all shippers). A difference exists between major eventualities such as strikes or machine failure and minor eventualities. These minor eventualities can be shipments by truck arriving at the intermodal terminals too late that lead to situations in which containers miss the departure times of the train or emergency shipments by truck that are not suited for the train because the travel times of the intermodal route are too long. Both the major and minor eventualities can be considered as factors that are part of the contingency plan of the exploitation model. These 'smaller' eventualities however are considered within scope of this project and therefore are a factor that determine costs. Big eventualities such as strikes or machine failure do not fall within the scope of this research.

Allocation Model

The allocation of the possible savings (based on possible cost differences) is another important factor that needs to be included in the exploitation model. The allocation model tells the involved parties how the costs of the new route, and therefore the possible losses/savings are divided among the parties. The combination of the cost model and allocation model together form an important part for the exploitation model. The focus lies on the financial aspects caused by supply chain operations of the new exploitation of the intermodal route.

3.5.   Research Method

Based on the problem definition and the literature research, research questions are formulated that are of scientific as well as practical relevance. Before these research questions are presented the overall assignment is formulated in line with the main problem definition.

The goal of this master thesis is to:

Design a cost model and subsequently an allocation model (=the allocation of total costs) reflecting the intermodal logistical process in a cooperative setting with multiple shippers.

The research questions that were constructed during this graduation project are:

1. What are the costs when comparing the new intermodal situation to the old situation?

✓ Which processes need to be included in the cost models?

✓ What are the costs in a deterministic environment when comparing the new intermodal situation to the old situation in case the capacity of the train can be fully exploited by one shipper?

✓ What are the costs in a stochastic environment when comparing the new intermodal situation with several shippers to the old situation?

✓ What are the maximum distances/areas that can be served by the drayage activities in the intermodal rail road chain?

2. How to divide the collective costs among the various shippers involved in the cooperation?

✓ How to define the value of each possible subset of cooperating shippers in the intermodal route?

✓ What is an appropriate cost allocation rule?

For each main research question (1 and 2), the goal, the activities needed to fulfill this goal and the method of execution is described. Furthermore are the deliverables given to test the research questions on.

Main research question 1:
What are the costs when comparing the new intermodal situation to the old situation?

Goal:
Determining whether the intermodal route can compete on a cost basis compared to the traditional transportation of containers when delivering cargo between Spain and the Netherlands or vice versa, and subsequently the total savings that can be obtained by exploiting an intermodal route.

Method:
To compare the intermodal rail-road route with the old way of transporting cargo by truck, the relevant processes that need to be included in the cost model need to be determined first. These are found in literature in operations research and by attending meetings with the project committee that are currently developing the new intermodal road-rail route between Spain and The Netherlands (CRS project). After determining the relevant processes, the cost parameters forming the foundation of the cost model have to be valued using publicly available information in order to bypass confidentiality restrictions. The parameters are numbers such

as fuel costs per liter, driver wages, hourly cost and cost per traveled kilometer to operate a train or truck. With traditional road and intermodal road-rail transport processes and cost parameters known, a cost model is constructed to compare both situations. This cost model is partly based on existing calculation methods from literature.

Deliverables:
- The processes and associated cost functions for the cost model in both situations.
- A cost computation and evaluation model for the aforementioned transportation channels.
- Parameters and variables to serve as input to the model, attuned to the cooperative setting like the one in practice.
- Simulation results of the model, that show a cost comparison between both situations in a stochastic environment.

Main research question 2:
How to divide the collective costs among the various shippers involved in the cooperation?

Goal:
Since the exploitation of the intermodal route cannot be done by one shipper (due to volume shortages) this exploitation will involve a set of shippers that in the end will obtain joint savings. In a cooperative setting a fundamental question that often arises is: how will the players of coalitions apportion their joint benefit? The deliverables of research question 1 will give an answer to the amount of benefits / cost savings that can be obtained. The goal of the second research question is to come up with shipper specific container transportation prices for the shippers that join the cooperation in exploiting the intermodal route. These container tariffs in the end determine the final cost allocations as they are interrelated to each other.

Method:
The cost model has to be able to calculate the costs, for every possible sub coalition (given a final set of shippers that want to join the cooperation). Allocation techniques for allocating joint costs among shippers are drawn from scientific literature. Apart from this literature reviewing part, a qualitative research method is used to get insight in what shippers in practice think as being important for allocating costs among companies when involved in a collaboration. This is done by attending project meetings of the project committee that are developing the CRS route and by interviewing experts in the field of intermodal collaborations. These results are combined to determine the final cost allocation technique used in the constructed cost allocation model. Appendix I includes the interview technique that is used and a list of the interviewees.

Deliverables:
- A list of possible cost allocation techniques for cooperative settings. This information is drawn from scientific literature.
- A comparison between requirements for the allocation of costs deduced from practice and the techniques found in literature. Based on this comparison a choice is made for the allocation rule.
- The cost allocated per shipper and therefore prices per container per shipper, by aggregating the simulation results of the cost model with the chosen allocation rule.

The CRS route has not yet been implemented and the final set of shippers was uncertain during the execution of this research. Therefore to gain reliable results the cost model is tested in a stochastic environment by performing simulations in a Microsoft Excel plug in, called @Risk. The output of these simulations are used as input for the game that is constructed in this thesis. The research method used during this project is summarized in the graphical representation of Figure 3.2.
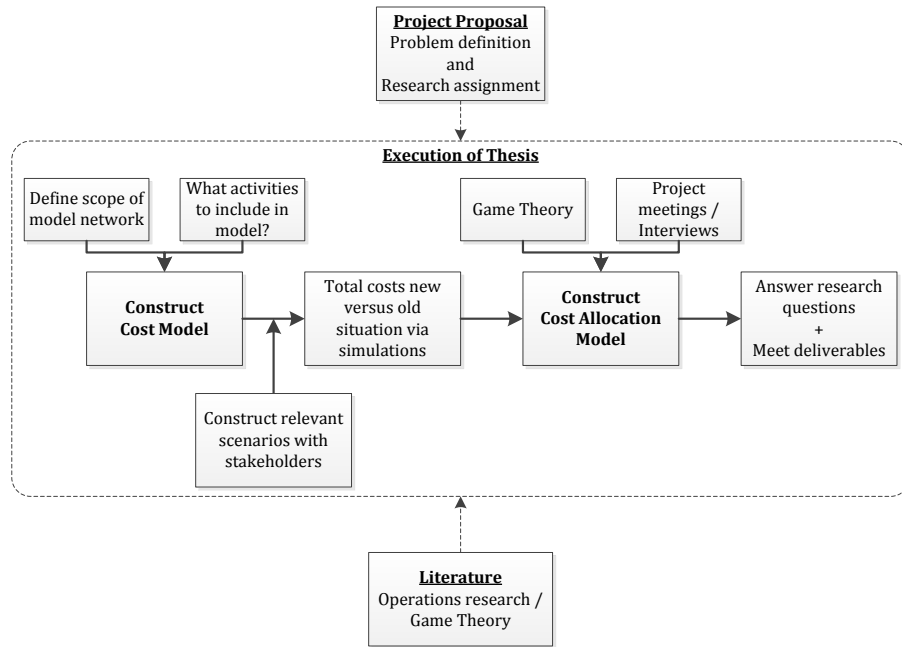
Figure 3.2 Research method

3.6. Methodology

The methodology of the regulative cycle is used as a guideline for the redesign (Strien, 1997). The list below displays the steps of the cycle used (J. E. van Aken, Berends, & van der Bij, 2007).

1. Problem definition 2. Analysis and diagnoses 3. Plan of action (design) 4. Intervention 5. Evaluation

This cycle ends with the evaluation step after which the cycle restarts to look for further improvements. In this project however, only the first three steps will be executed. Based on these three steps recommendations for further research are presented and ideas for implementation are given.

In scientific research an adequate balance between rigor and relevance should be strived for (J.E. Van Aken, 2005) (Bem, 2003). This means that on the one hand scientific research should be scientifically well grounded and an addition to the methods, models and knowledge of the current state of science. On the other hand the research should contribute to a relevant problem, should be meaningful and applicable. Rigor and relevance do not have to exclude each other, nonetheless is finding the right balance something which should be strived for.

A lot of scientific research exist about intermodal transportation and their potential benefits for shippers, LSP's and other stakeholders. Many articles discuss the level of importance of having enough volume and that a shortage of volumes could be an important reason for failing projects (Jacobs et al., 2013). Calculation methods to determine the costs of (parts of) intermodal supply chains are commonly described and used throughout operations research. A model to determine both the costs and a way to allocate these costs coping with the collaborative aspects, in a stochastic environment, that are often necessary for exploiting an intermodal route are less common. Aggregating both models into one application can therefore be seen as the contribution to scientific literature.

The relevance of this research lies in the application of the model to the CRS route. BB is curious how a collaboration such as the CRS project can be exploited. Subsequently they are interested in expected costs for all involved stakeholders in a dynamic environment and what exploitation options exist. Based on results and analyses of the constructed model insights are provided on the upper mentioned factors. To maintain reproducibility of the results no confidential information is featured in the model and throughout this thesis.

10

4. Analysis

4.1. Introduction

The development of a new intermodal door-to-door supply chain has different stakeholders. A stakeholder is an entity that is somehow affected by the new intermodal supply chain. Stakeholders have different priorities, goals and involvement. For this reason their interest in an intermodal cooperative supply chain differs among them. The stakeholders described in this chapter will partly become the player types of the TU game defined in chapter 6 of this report. This chapter contains a comparison between the current and intermodal supply chain. Next it is determined which activities in the cost models are taken into account. The chapter concludes with how costs are expressed in the models and by giving an overview of the exploitation finance structure for the cooperation.

4.2. Stakeholder responsibilities & priorities

The actors listed in the literature review display the multi partner setting of the way containers are transported from origin to destination in intermodal transportation. Figure 4.1 is a graphical representation of the actors discussed in chapter 2 for the case of the CRS project. It gives a better understanding of the interdependencies of the parties in the supply chain and is used for further discussions how the exploitation in this cooperative setting will look like. This paragraph is also used to explain why certain aspects, like the assignment of responsibilities to particular actors is not taken into consideration within this project.
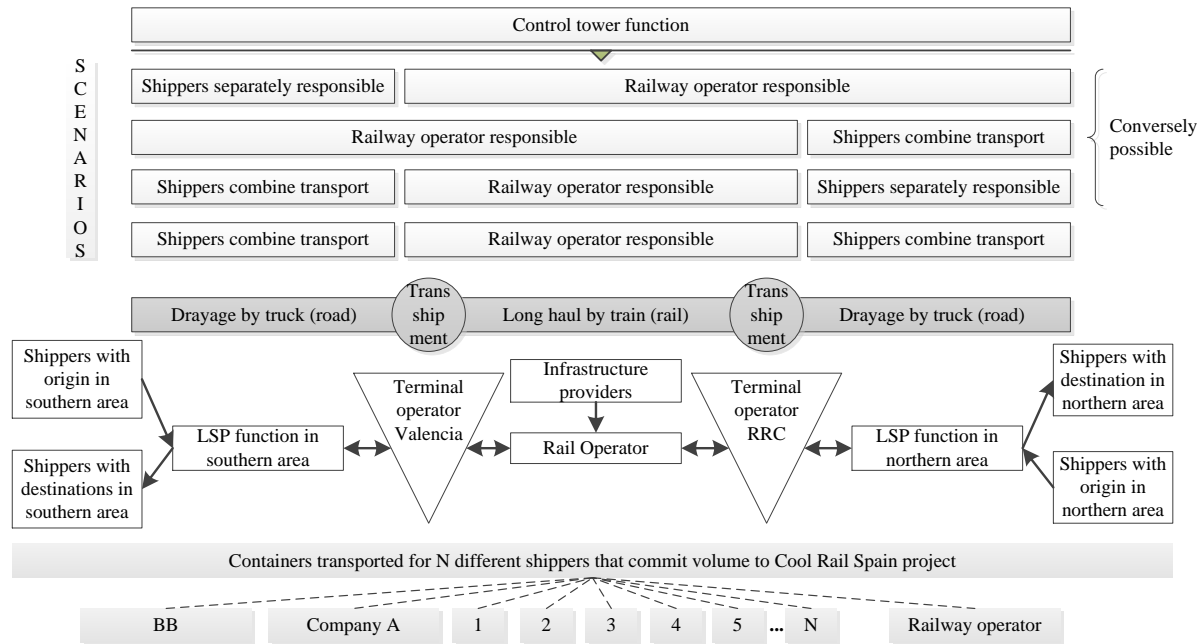
Figure 4.1 Intermodal overview

The operations that are executed within the complete supply chain, can be split up into three main classifications. The drayage operations by truck, the long haul by train, and the transshipments between the two modes of transportation. For the drayage part of the intermodal supply chain several different scenarios are possible on how to assign responsibilities among involved stakeholders. The first alternative is that the drayage of all the products in Valencia and Rotterdam respectively can be combined (=centrally planned) by all the involved shippers. A second alternative is that some shippers want to do this part of the intermodal chain separately from others. A third alternative is to execute the drayage part by making the railway operator responsible for this part of the chain as well. In this way the railway operator becomes responsible for the complete intermodal supply chain. This means that the rail operator will be responsible for both drayage

operations in Spain and the Netherlands, as well as the long haul. The railway operator then becomes responsible for the complete door-to-door delivery of the containers that includes all the planning and operational activities. Because the scope of this project is concentrated on the cost aspect of exploiting an intermodal supply chain in a cooperative setting, the exact sharing or distribution of responsibilities is irrelevant. Within this master thesis, the final set of shippers in the cooperation all make use of the same LSP who executes the drayage activities by road in both intermodal terminal areas and a rail operator for the long haul by rail.

4.3.   Current situation versus Cool Rail Spain

This paragraph explains the current situation where transport is carried out by a set of shippers that become involved in the CRS project. This is important because the current situation is used as the base situation to compare the new intermodal situation with in the final cost model of the intermodal supply chain with N number of shippers. A proper explanation of the current situation is also necessary to see if there are any important environmental properties to take into account when constructing the cost models and calculating the total costs in the intermodal cooperative setting. Besides a representation of the current situation and its processes also a representation of the new situation is given once the CRS route is operational.
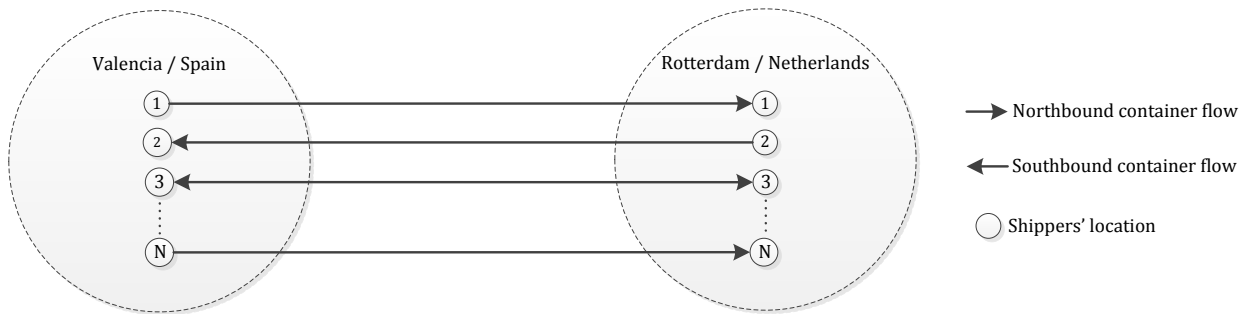
Figure 4.2 Current situation with multiple shippers containerized transportation

The set of shippers, in the figure represented by the shipper locations 1 up to N, indicate the unknown final number of organizations that in the end will commit volume to the CRS route in order to reach committed cargo quantities that are necessary for a viable exploitation. Because most of the cargo shortages exist on the northbound route, most of the shippers that will join the cooperation will transport products from Spain to the Netherlands as is indicated in the figure with the shippers' origin-destination combinations that have northbound route arrows. The organizations that are involved in the CRS project currently use external carriers to transport products from Spain to their destinations in the Netherlands or vice versa. So the cargo transportation from origin to destination (either north- or southbound) is performed by LSPs that are working for all the shippers separately. BB for example makes use of an external carrier that already transports some containers from the origins in Spain via an intermodal road-rail connection to BB's destination. Note that this intermodal route has other terminal destinations and origins than the locations that the project committee has in mind for the CRS project. This however doesn't affect the costs incurred by BB because they negotiated a predefined transport price for the transportation services offered by this external carrier from a specific origin-destination combination. The corridor between Spain and the Netherlands is characterized by a few market characteristics. Firstly the market is characterized by volatile pricing due to an imbalance in freight flows and high seasonality effects. For example, during the citrus season SB trucking is relatively cheap because of a high flow imbalance. Besides are SB shipments often without refrigerated conditions which leads to a further decrease of prices compared to cooled NB shipments. This difference in market prices of trucking NB or SB has to be included somehow in the constructed cost model. The differences in cost incurred by shippers that transport cargo NB or SB have big consequences for all shippers in the cooperation because the standalone cost can differ much for each of them.

In the intermodal situation the project committee (consisting of BB and one other shipper) again makes use of logistical service providers, but now to develop a new multi partner intermodal door – to – door containerized transportation chain. In the intermodal situation the supply chain is divided into more separate parts, like the drayage parts by truck and long haul by train. As a consequence more responsibilities have to be allocated among stakeholders, such as LSPs that perform the drayage activities, a rail operator and a 4PL/control tower. Figure 4.3 is an overall representation of the situation in which transport is carried out in the intermodal rail-road setting.
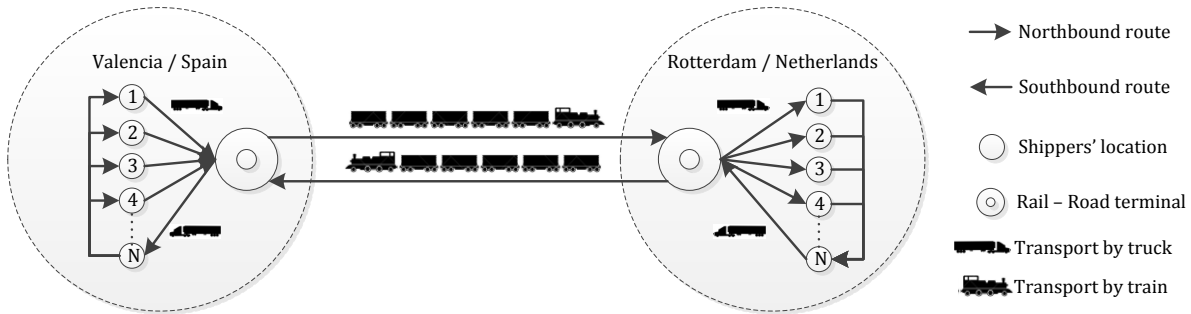
Figure 4.3 Abstract representation of intermodal CRS route

The CRS route will be a dedicated train route. This means that the rail operator operates the train specific for the parties that cooperate. The project committee wants to collaborate with other shippers that are able to commit volume to the train for a number of slots on a recurring basis. Each slot can be considered as one container spot on the train, whereas the trains' capacity equals the total number of available slots per train. The goal of the project committee is to complete a set of N shippers that in combination commit weekly cargo volume that is (near) sufficient to fill the complete train. In this way the risk of empty containers on the train is spread among all the parties that committed volume to the CRS route. If one party has less containers available for transportation than committed, that shipper still has to "pay" for the agreed committed volume as agreed upon at the start of a season, unless there is another party with more load than committed. The rail operator offers his service (train) in a roundtrip setting. For that reason, the combination of total volume transported via the SB and NB route is very important in order to let the CRS route be cost efficient. Upon arrival of the train on the terminal in Rotterdam the full containers are transported to the shippers' destination. Hereafter the empty container is transported to a location of a shipper that transports cargo southwards to Valencia. In this way, efficient trucking routes are being developed because the delivery and collection of cargo is combined in one roundtrip per truck. For the drayage activities, around 48 hours in Spain and 24 hours in the Netherlands is available to perform all the trucking necessary to unload and load the containers at the right delivery and pick-up locations of the shippers. In this way a transport trajectory between Spain and The Netherlands is set up in a closed loop supply chain corridor with synchronized and balanced northbound and southbound flows (Jacobs et al., 2013).

Morlok and Spasovic (1994) already mentioned this centralized drayage operations planning and its intrinsic benefits in cost savings and efficiency. They mention; "with coordination and information sharing, cases of two roundtrip movements, each loaded in only one direction, could be replaced with one roundtrip movement with loads in both directions. The cost of a roundtrip would then be assigned over the two loads, thus decreasing the cost per load by almost half compared to the independent operation" (Morlok & Spasovic, 1994). In appendix B an overview of this uncoordinated and centralized drayage planning is depicted as well as a proposed relationship design for the centralized situation in a closed loop roundtrip environment (Caris & Janssens, 2009). In this research only transportation off full truckloads are considered. In this way every drayage activity per truck maximally consists of two stops at locations of shippers. One stop to unload the container at a shippers' destination and one to load cargo at a shippers' origin. In chapter 5, a better understanding of these drayage activities and roundtrip structures of trucks is ensured by explaining in more detail what the possibilities of combined container trucking are and what the effects cost wise are.

In the intermodal cooperative setting, beside BB a lot of the other interested shippers are also active in the fresh produce sector. Therefore the northbound cargo mainly exists out of perishables, which implies that a lot of the northbound shipments need refrigerated conditions during transportation. This is why the project committee will use refrigerated containers (=reefers) for the transportation activities. These reefers will be hired from an organization who is specialized in renting containers suited for intermodal truck-train transportation. Hiring the reefers means that for one roundtrip the same containers will be used. So one container actually covers the complete roundtrip.

4.4. Quality restrictions on choice for transportation modes

Important reasons for using intermodal rail-road services are cost, availability and suitability of the service. This also holds for BB and other shippers that are active in the fresh produce sector. Their volume commitment is strongly dependent on which products are suitable, on a quality basis, for intermodal transportation. This quality, perceived by BB, is mainly driven and constrained on timeliness and therefore the maximum allowed time for transportation activities to maintain freshness of perishables. For example, some products of BB are always transported with two truck drivers in order to receive them on time at their distribution centers. Some products need such high quality standards (short transit times) that these products are not suitable for intermodal transportation (because of too long transit times).

Besides a group of products that is always transported with a second truck driver because of quality restrictions, another group of products normally receive only one truck driver. Within this group especially bulk products are suited for transportation activities by train. Specialty products with small stocks at distribution centres are not suited for intermodal transport because in case of delays, hardly any stock is left and delivering distribution centres of customers becomes problematic. Within these bulk products however, it may occur that due to supply / demand disruptions less time is available to transport these products from origin to destination. At the supply side it can happen that a supplier needs more production time for some perishables. For example if the weather wasn't favourable for the specific product type sometimes the products are hold longer in quarantine. This slows down the production process and leaves less time for transportation activities because these products still have a certain time constraint before they need to arrive at the DC of BB in order to preserve a desired freshness. In these situations a second truck driver is allocated to a truck. The demand side of the supply chain can also cause an emergency shipment. When customers of BB needs certain products earlier because stock levels decline (unexpectedly) below a desired level it may happen that they need products sooner than planned. In this situation again a second truck driver may be allocated to a truck. Figure 4.4 is a representation of the above mentioned quality discussion.
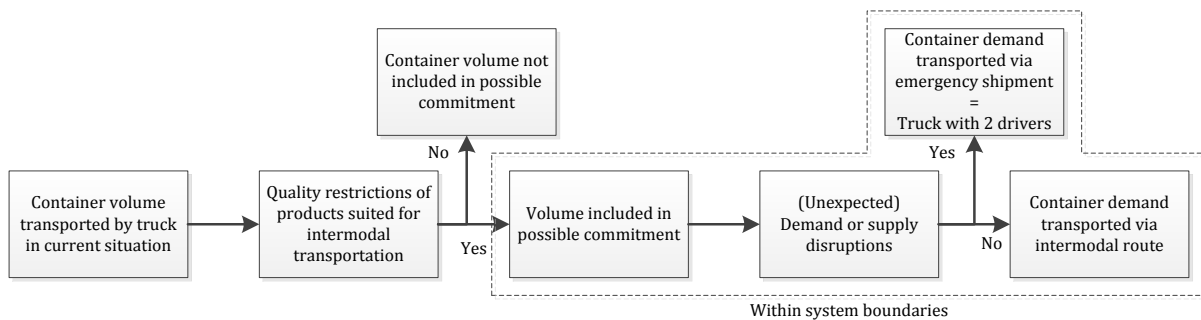
Figure 4.4 Quality on perception of mode choice and emergency shipments

The way the upper explained eventualities are included in the cost model, as a factor influencing the amounts of cargo available for intermodal transportation, is treated in chapter 5 of this report.

4.5. Cost structure

In order to make a comparison between the intermodal rail – road setting and the current situation, the costs of operating both concepts are determined. This is done based on which processes/activities are considered

within scope. The costs in the intermodal situation predominantly arise from two basic activities. These two activities are transportation and handling activities necessary for getting containers from predetermined origin-destination sets of several shippers. Besides these activities also some costs occur for renting materials and hiring a control tower. Finally also the reason why the cost of goods are not taken into account is explained in this chapter section.

4.5.1. Transportation activities

The movement of units in the current situation by truck only or a combination of truck and train determine the cost of transport. A distinction for internal costs of transportation is made between time related and distance related costs. Time related costs are caused by the passing of time and accumulate even when the vehicle is standing still. For example during loading or unloading at the shipper origins and destinations, or the trans-loading of containers at the intermodal terminals. Distance related costs arise only when the vehicle is moving (Vandwerwegen, 2008).

4.5.2. Handling activities

Several handling activities exist within both supply chains. First of all, products have to be loaded and unloaded in the container. The costs that occur with these activities are not taken into account while the assumption is made that the same amount of cargo is loaded into the units of transportation in both situations (i.e. trailer and reefer). That is why the costs of loading and unloading goods into trailers/containers are considered out of scope. This makes sure that the emphasis is on the transportation activities instead of the loading and unloading costs of materials that won't differ much in both situations. Shippers transport full truckloads (FTL) and therefore do not combine different products from different shippers in one trailer or reefer. Other handling activities are the intermodal terminal operating costs which will be included in the cost models. So the handling activities at the shippers origins and destinations only cause time related costs that are taken into account as transportation activities.

4.5.3. Renting materials

In the intermodal situation reefers are rented. These renting costs will be included in the cost models. The reefers that will be used, each have an own diesel tank that is used for cooling the containers. The diesel usage of the reefers will be included in the cost calculations as well.

4.5.4. Control tower

In the intermodal situation a party who serves as control tower is hired and performs activities as a control tower or 4PL in the cooperation. This organization makes sure that processes within the supply chain are aligned and coordinated. Costs that occur due to central coordination of the route are included as well.

4.5.5. Cost of goods

The holding costs of the goods within the transportation units were not taken into account in this research project. The cost calculations are based on the premise that the container is a black box. Based on the decision to consider the container as being a black box, holding costs of goods were not taken into the cost model developments and calculations. This is in line with excluding the loading and unloading of goods in the cost models since these activities mainly occur inside the containers and are the same in both situations so will not lead to cost differences.

4.6. Cost perspective and expression

This graduation project is executed from a shippers' perspective (BB is a shipper). This influences how costs are perceived and thus need to be expressed. It is an important aspect when looking at the cost functions that will be developed in the cost models representing the activities in scope within both situations. The shippers for whom cargo is transported are 'users' of services offered by third parties that are active within both supply chains. This means that when the costs of both the intermodal and current situation are calculated, these have to be depicted in such a way that they represent the prices the shippers have to pay for the services offered by

15

LSPs and other parties. The prices asked by these LSPs can be seen as the costs from the perspective of a shipper. So within this graduation project the costs calculated by the cost models are reflecting the costs incurred by the 'users' of the supply chain. These are equal to the prices asked by the external parties that perform activities within both supply chains. The users within the supply chain are the shippers and ultimately they are the participants within the constructed allocation game that commit volume to the intermodal route.

In all the models the costs will be based on transported number of containers. In this way all the scenarios and output of the models can be compared with each other. This makes sense because LSP's propose prices per transported container for a shipper. In this way the intermodal situation can easily be compared to the current way of transporting trailers. In the next section the stakeholder setting in the intermodal situation will be discussed to get a better understanding of how the cooperation in this setting will work (finance structure wise) and how this differs from the current situation. The detailed supply chain process descriptions that determines the cost structure of the cost model, however relevant, are discussed in the next chapter.

4.7. Supply Chain Exploitation/Financing

In the current situation in which containers are transported separately by all shippers, all entities pay for their own supply chain costs. Within this situation no difficult financing structure exist while every shipper has its own set of external carriers that execute transportation activities for them. In the new situation once the CRS route is operational, the project committee in the end wants one party who is responsible for the complete door-to-door intermodal supply chain. This party will function as the control tower within the exploitation of the route.

Within this project the horizontal collaboration and supply chain exploitation is modelled as follows. The grand coalition hires the control tower who gets paid a management fee for the upper explained responsibilities. This control tower will sign contracts with all the relevant entities that are needed in order to get a sustainable intermodal supply chain. In the model all relevant entities are determined by these entities that can execute the activities as explained in the cost structure section 4.4. of this chapter. The grand coalition together ensures that the control tower its cost will be fully reimbursed. Or in other words, all the cost that the control tower has to pay to all the LSP's that perform activities within the intermodal exploitation are ultimately being paid by all the participants in the grand coalition. No matter the amount of containers transported by the cooperation via the intermodal supply chain route. So the control tower can be seen as a central accountant, who is working for the coalition. Figure 4.5 is a graphical representation of the upper explained financing structure whereas the grand coalition is depicted as the horizontal cooperation.
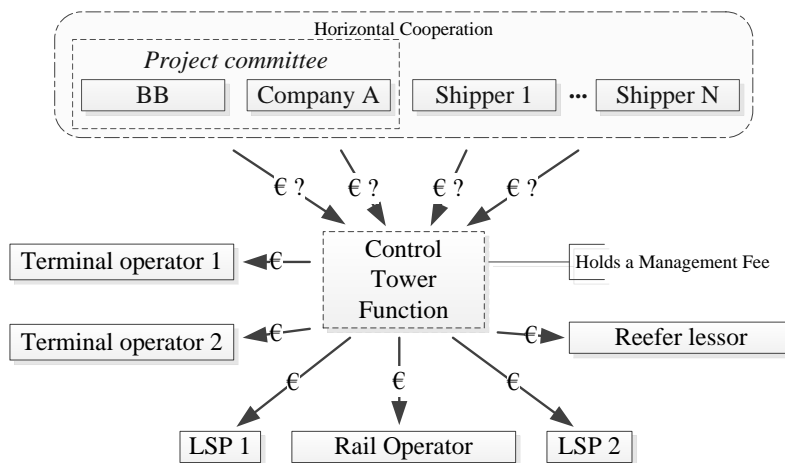
Figure 4.5 Exploitation financing structure

5.   Cost Model

5.1.   Introduction

Now that the activities within scope are determined, the cost model can be constructed. As discussed by Bertrand and Fransoo (2002) the first important step is to make a conceptualization of the system under study. Hereafter decisions about the variables that are included in the model are made, based on the scope determined in the previous chapter. For the intermodal cost model some important environmental properties are discussed. These environmental properties are translated in factors included in the intermodal cost model. After the intermodal cost model is developed, the cost model for the current situation is constructed as well.

5.2.   Conceptualization intermodal situation

In the final CRS setting more shippers will be active. So the costs for the drayage activities will be different for all combinations of shipper destinations and origin sets per terminal areas. As explained in the previous chapter transportation cost are dependent on time related and distance related cost. Both cost types are related to the distance covered. Therefore distances between the terminals and destinations / origins, as well as between locations must be known in order to compute the costs for these activities. The final set of shippers and locations is uncertain. Therefore, to construct a robust and generic model continuous approximation techniques of Erlenkotter (1989) and Donnelly (1978) are used to determine expected trip distances for the drayage activities in the intermodal supply chain. Different distances between shipper locations may be altered later. Although these scientific concepts are known for a long time, and maybe seem too old, they still are very useful for strategic problems where no detailed data is available. In transportation, these models have been used to estimate the (possible) benefits from transportation improvements, which corresponds to the aim of constructed model within this project (Langevin & Campbell, 1996). Models of this type assume, that demand is spread uniformly over a known area size. In the case of intermodal drayage operations, these demand points can be translated into pick-up and delivery locations of cargo for shippers which can be combined in one trucking trip. In this case these demand points are assumed to be uncertain and therefore stochastic in final position within both terminal areas. For both the southern area and northern area the distance between a delivery location of a container and a pick-up location and the distance between these locations and the intermodal terminal are approximated by continuous approximation techniques. For both the northern and southern areas expected average drayage trips per container are used in the cost model. Figure 5.1 is a graphical representation of the intermodal supply chain and the possible container flows that can occur. The numbers in the drayage areas represent the possible trucking trips in the drayage part of the intermodal chain. These are used to explain the dynamic trucking environment caused by the possible supplier demand properties. This is explained further in the next section of this chapter.
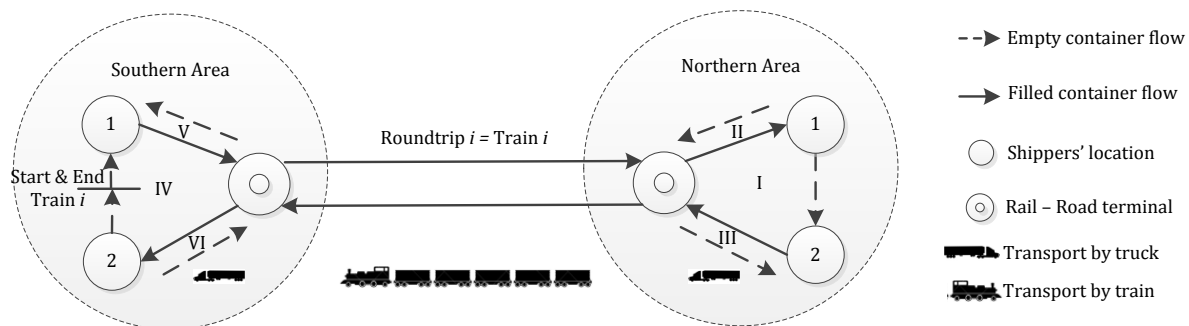
Figure 5.1 Conceptualization intermodal supply chain CRS route

The final number of shippers in the cooperation that transport products north- and/or southwards in this conceptualization figure are represented by only two locations. This is because all shippers' locations are

approximated and therefore "supposed" to be in those two areas. An average distance from the terminal to a pick-up or delivery location and between those locations is used in the cost model. When a roundtrip trucking trip is possible, no more than two locations per trip are visited. That is why only two (imaginable) locations per area are sufficient in the cost model in order to perform calculations on all possible trucking trips. The constructed cost model will calculate the cost of a specific roundtrip of train i. The intermodal CRS route is exploited in a continuous roundtrip environment. This means that the costs of the intermodal route depend on subsequent needs for transportation of the shippers at both the northern and southern area. Those needs for transportation of the set of N shippers within the cooperation at both the NB and SB direction together depend how the drayage trips will look like per roundtrip of train i. Therefore the "boundary" of one roundtrip needs to be determined (the start and end point of train i within the model).

The intermodal cost model is set up in such a way that the cost of one intermodal roundtrip is calculated. In Figure 5.1 the start and end point of every roundtrip is depicted in the southern area. The start and end point is in the middle of possible container flows in order to obtain good estimation for the cost per roundtrip. The drayage trips in the southern area between a cargo destination and cargo origin (that has to be delivered / picked up by a container) can be seen as the connection of subsequent roundtrips in order to get a closed loop supply chain corridor. Half of the drayage cost per roundtrip i depend on the number of delivery locations visited due to roundtrip $i - 1$, and half of the cost depend on the number of pick-up locations that need to be visited on roundtrip $i + 1$. A better explanation of how these drayage trip activities are related to the need for transportation per roundtrip is given in the next chapter section 5.3.1.1. The CRS route is exploited in a seasonal setting with a fixed number of roundtrip flows. For the first and last roundtrip the drayage activities to "connect" a delivery and pick-up location at the southern area are not needed. However, given the fact that a season during the first season consist of 44 trains, this will only have minor effects on the average roundtrip costs. Therefore in the cost model this effect is not taken into consideration.

5.3.   Modeling

5.3.1.   Intermodal Situation

Table 5.1 shows the notation of the parameters used in the cost model to calculate the cost in the intermodal situation.

Table 5.1 Parameter notation intermodal situation

Notation	
$q_{u,i}^{NB}$	# containers transported NB for shipper u on train i
$q_{u,i}^{SB}$	# containers transported SB for shipper u on train i
A	Surface of terminal areas in km^2
L	Average loading time in hours per container
U	Average unloading time in hours per container
W	Average waiting time per (un)loading activity per container
V_{ave}^t	Average speed in km/hour of a truck during drayage activities
T_{cap}	Capacity of the train in # containers
D_{lh}	Distance in kilometers of the long haul by train
V_{ave}^{lh}	Average speed in km/hour of the train
TT	Transfer time of train on different gauge width at Spanish border in hours
R	Renting costs per reefer per week in €'s
H	Average handling costs per intermodal terminal per reefer in €'s
VCT_d	Variable costs of truck transportation per kilometer in €'s
VCT_h	Variable costs of truck transportation per hour in €'s
VCL_d	Variable costs containerized transport per train per kilometer in €'s
VCL_h	Variable costs containerized transport per train per hour in €'s

CT	Yearly costs control tower in €'s
u	Diesel usage reefers in liter per hour
D_c	Liter price Diesel in €'s
γ_r	Delay factor in % for transportation by train
n	Total number of trains per year
O	Perimeter of areas
M	Number of origin and destination locations in both areas per time window
τ	Factor to change Euclidian distance into distance travelled by road
P_m	Assumed profit margin of LSPs in %
k_c	Distance factor given shape of area and location of terminal in the center of area
k_e	Distance factor given shape of area and location of terminal at the edge of area
d	Distance in # of km's between intermodal terminal and cargo origin / destination
d_{NN}	Nearest neighbor distance between a cargo delivery and pick-up location

5.3.1.1. Drayage trip possibilities

The future shippers that commit volume to the project and therefore become a member of the cooperation can have different commitment properties. A shipper for example may only have NB or SB container volume, or both NB and SB volume. These combinations of different types of shippers have an influence on the trucking trips that are needed during drayage activities. The fact that the project committee is developing a new train route, and the rail operator will run a dedicated train only for the shippers that are part of the cooperation, the combination of N shippers in the cooperation is responsible for delivering enough cargo in both route directions. When the CRS route is actual operational, the possible (im)balance on a roundtrip (because of stochastic demand / uncertainties) has an influence on the trucking trips. Note that the drayage activities in the northern and southern area depend on a combination of NB and SB container demands of the shippers. Another factor influencing the drayage trips is that some shippers can reach synergies because a specific location has both NB and SB need for transportation. Whenever this is the case, a truck can both unload and load the container at the same location and no trucking between two different destination and origin locations is necessary. However, this synergy possibility is not included in the cost model because it would increase the complexity disproportionately when looking at the influence on total costs. Therefore in Figure 5.2 when only a single location is visited, the trucking trip always exist of one filled container flow and one empty container flow by truck.

Before the different drayage trip possibilities can be explained further, one has to understand the demand properties of the intermodal supply chain setting per shipper. On every roundtrip of train i an accumulated NB demand in number of containers of a set of N shippers is transported, as well as an accumulated SB demand in number of containers of the same cooperating set of shippers. In Table 5.2 all the drayage trip possibilities are shown in relation with the possible causes. The numbers in the table refer to the same numbers in Figure 5.1.

Table 5.2 Drayage trip possibilities and causes

Container flows no imbalance	Reason	Drayage trip possibilities
I & IV	There is both NB need for transportation as well as SB need for transportation	Trucking trips with combined container location & destination
Container flows with imbalance		Allocation Intermodal cost
II & V	Accumulated NB need for transportation > Accumulated SB need for transportation	Trucking trips only serving a single location
III & VI	Accumulated SB need for transportation > Accumulated NB need for transportation	Trucking trips only serving a single location

The cost model that is constructed in this chapter will calculate the cost in the intermodal setting per train i. But because the intermodal CRS route is exploited in a continuous roundtrip environment the southern drayage trip possibilities depend on the accumulated demand of train i, train $i-1$ and train $i+1$.

As starting point for every intermodal roundtrip, train i starts its journey at the southern container pick-up locations. Before the train leaves, the containers with its origins in Spain have to be transported to the

intermodal terminal. However the exact drayage trips by road that have been executed in order to get the containers from their origins in Spain to the terminal depend on how many containers on train $i-1$ had to be delivered with destinations in Spain. If the accumulated NB need for transportation for a specific train i is higher than the accumulated SB need for transportation on train $i-1$, not only combined drayage trips can be executed. Subsequently, whenever the train arrives back at the intermodal terminal in the southern area, the containers need to be transported to the shippers destination in Spain and from here the trucks continue their trips to a location that has NB need for transportation in order to make efficient combined drayage trips. However the number of these trips depends on the NB need for transportation of train $i+1$. Figure 5.2 resembles the former explained relation between the accumulated needs for transportation and the drayage trip possibilities. For convenience in this section situations in which the accumulated need for transportation is higher than the trains' capacity of 40 containers is ignored and there is only looked at the actual # of containers that are being transported. How there is dealt with situations in which the actual need for transportation is higher than the trains' capacity will be explained in a later section of this chapter.

$$\sum_{\forall u} q_{u,i}^{NB} = 40 \ \& \ \sum_{\forall u} q_{u,i-1}^{SB} = 37 \qquad \sum_{\forall u} q_{u,i}^{SB} = 40 \ \& \ \sum_{\forall u} q_{u,i+1}^{NB} = 39$$
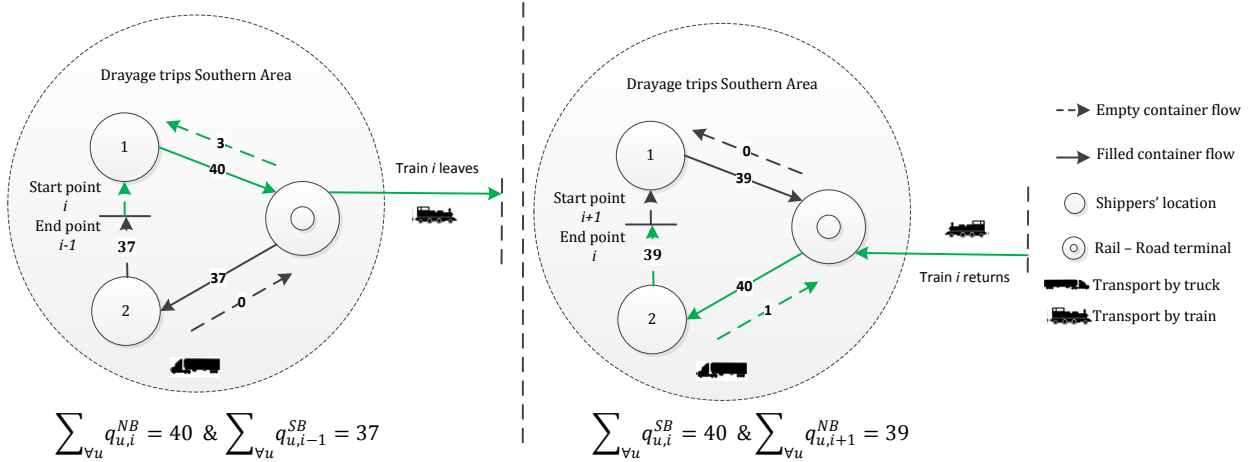
Figure 5.2 Example of relation between demands train $i, i-1, i+1$ and drayage trips

In order to determine the drayage trips in the southern area four different accumulated needs for transportation are necessary. As can be seen in the left example of Figure 5.2, the difference between the imbalance in container transportation result in three containers that directly are transported from the terminal to an origin location that is in need for transportation and only 37 combined drayage trips were possible. Therefore 3 containers are transported directly from the terminal to the origin location. To determine the number of containers that will be transported between destination and origin locations the SB demand of train i is compared with the expected northbound demand of train $i+1$ (right example). Because the northbound demand of the next roundtrip is lower than the southbound demand in the example, one container is directly transported back to the terminal instead of going via an origin location that has need for transportation. Therefore 39 containers are transported via an efficient double. Note that only 50% of the cost due to the flow of containers between a destination and origin that has need for transportation is allocated to train i because of the connection function of the southern area in order to get a continuous roundtrip corridor. The reason the containers are transported back to the terminal even when there is not sufficient need for transportation is because the cooperation hires a set of containers that are used throughout the intermodal supply chain at both terminal areas. So even though a container is empty (because not enough cargo) it still will be transported by train because there might be need for cargo transportation at the other terminal area and then the container is needed again.

5.3.1.2. Degree of Dynamism and Arrange Time
When looking at the possibility of combining a delivery and pick-up location within one drayage trip, the delivery time windows at the delivery locations and the availability of the cargo at the pick-up locations are

important conditions that determine the feasibility of such a combined roundtrip. In the intermodal situation the parties that perform the LSP function in both the northern and southern area know up front (before the train arrives at the terminal) what the destination addresses for the incoming containers are on every train. Parties commit cargo volumes before the start of the CRS route and therefore before the train is actual operational. Therefore are the pick- up locations known up front as well. It is reasonable to assume that almost all cargo transported NB are perishables and these products have certain limitations on availability. The availability and location of the cargo at locations can be translated as the arrange time of this cargo. The bigger this time window (arrange time) is, the bigger the possibility that all pick-up locations are known up front as well when the train arrives at a terminal or during a certain time window. The ratio of demand orders not know up front (static demand orders) and the total demand orders, in literature is described as the degree of dynamism (DoD) (Wong, Han, & Yuen, 2012). When all the delivery and pick-up locations of containers at a terminal area are known in advance, the planning of drayage trips turns into a deterministic static planning situation whereas the degree of dynamism equals 0 (no dynamic orders occur). In this case roundtrips can be planned according an algorithm. Caris and Janssens (2009) use an adjusted vehicle routing problem (VRP) algorithm to model the possibilities of a combined drayage trip. However, within this model the expected distances between locations is modeled according the approximation formula derived by Donnelly (1978). A bigger arrange time, leads to situations whereas more locations are known up front (or a lower DoD). In the constructed cost model a parameter is incorporated that resembles the upper explained concept. This is explained in the next chapter section.

5.3.1.3. Model
The following formulas are used to calculate the expected average drayage trip distances in both areas:

$$E(d) = (k \cdot \sqrt{A}) \cdot \tau \qquad\qquad \text{(Erlenkotter, 1989)}$$

$$E(d_{NN}) = (\frac{1}{2}\sqrt{\frac{A}{M}} + (0,051 + \frac{0,041}{\sqrt{M}}) \cdot \frac{O}{M}) \cdot \tau, \qquad \text{with } 5 \leq M \leq 64 \qquad \text{(Donnelly, 1978)}$$

The first formula is based on the expected distances in an area following the Euclidean norm for two arbitrarily placed points within an area. The formula reflects the distance between the terminal and the container delivery/pick-up location. For the northern area the factor $k = 0.376$ (referred to as k_c) is used because it is assumed that Rotterdam is located in the center of the area in which cargo is being delivered and picked up. For the southern area the factor $k = 0.639$ (referred to as k_e) because Valencia is located at the edge of the cargo demand area. In the case a combined drayage trip is executed, exactly two locations are visited (one delivery location and one container pick-up location). Whenever more cargo destination and origin locations are known M increases. In the average drayage distance for a combined trip, the total number of known pick-up locations per time window (M) is a parameter that reflects the degree of dynamism or the arrange time. The larger the arrange time window is, the higher this value M gets, and therefore an increased possibility that more pick-up locations are known in advance per time window. This leads to a reduction in the nearest neighbor distance (since there is more choice to combine origin and destination locations in one drayage trip and therefore an efficient nearest neighbor planning can be executed). The reason for this is that more locations spread across the same area leads to smaller nearest neighbor distances and therefore a smaller expected average distance between a destination and origin location. These formula assumes an Euclidean metric, which means that the distance between two points is a direct function of the coordinates and does not depend on the road network that lies between the points. The τ in both formulas is used to translate the Euclidean distance into an average distance that reflects the transportation via a road network instead. A value of 1.25 is used. Applying the two formulas to the drayage activities gives the set of formulas below. Formula (1) and (3) respectively represent the average expected distance from a drayage trip whereas a single location is visited. So the distance between the terminal to a shippers' location. Therefore the expected average distance calculated with the formula of Erlenkotter (1989) is multiplied by two. Formula (2) and (4) are representing the trip distances for a roundtrip drayage operation given a predetermined value M that reflects the arrange time window as discussed above. A roundtrip consists of a trucking flow from the terminal to a destination, a

flow between a cargo destination and pick-up location, and finally a trucking flow between the cargo destination and the terminal again. Therefore this distance is calculated by combining the formulas of Erlenkotter (1989) and Donnelly (1978).

$$D_s^{NB} = \tau \cdot 2 \cdot \left(\mathrm{k}_c \cdot \sqrt{A} \right) \tag{1}$$

$$D_d^{NB} = \tau \cdot \left(\left(2 \cdot \left(\mathrm{k}_c \cdot \sqrt{A} \right) \right) + \left(\frac{1}{2} \sqrt{\frac{A}{M}} + \left(0{,}051 + \frac{0{,}041}{\sqrt{M}} \right) \cdot \frac{O}{M} \right) \right) \tag{2}$$

$$D_s^{SB} = \tau \cdot 2 \cdot \left(\mathrm{k}_e \cdot \sqrt{A} \right) \tag{3}$$

$$D_d^{SB} = \tau \cdot \left(\left(2 \cdot \left(\mathrm{k}_e \cdot \sqrt{A} \right) \right) + \left(\frac{1}{2} \sqrt{\frac{A}{M}} + \left(0{,}051 + \frac{0{,}041}{\sqrt{M}} \right) \cdot \frac{O}{M} \right) \right) \tag{4}$$

The average costs per hour and kilometer travelled by truck are based on a report of the Dutch Ministry of Transportation and Water (Ministerie van Verkeer en Waterstaat, 2004). See appendix D for the specification of cost factors that are included. It is assumed that the hourly cost for transportation in Spain is 85% of the rate in the Netherlands. That is why for the SB drayage cost a factor of 0.85 is in front of the variable cost per hour. This assumption is made because the wages in Spain are lower compared to the Netherlands and wages are an important driver for the hourly cost factor for truck transportation (NEA, 2004). The average trucking speed is based on values reported by Black, Seaton, Rici, and Enei (2003). The trucking cost depend on a locations' demand setting (NB and/or SB demand), but also whether there is an imbalance on a specific roundtrip of a train. Whenever there is an imbalance, specific containers can skip the loading or unloading part at a shippers' origin or destination. Table 5.3 below represents all the possible container flows per train i and the cost functions for the drayage activities per container. When a combined drayage trip is executed both unloading activities and loading activities are executed. In order to load- or unload a container at a distribution center an average waiting time is included in the cost calculations.

The first terms of the cost formulas (5 to 10) all represent the time dependent cost while the second terms always represent distance related costs. That is why in the first term the distance travelled by truck (determined by formulas 1 to 4) is divided by the average speed to get the duration for covering the trip distances. The loading, unloading and waiting times are added to the travel duration and multiplied with the variable costs of trucking per hour. The second term represents the distance related costs by multiplying the trip distance in kilometer with the variable cost of trucking per kilometer.

Table 5.3 Drayage trip possibilities and associated cost functions

Drayage trip possibilities	Southern area
Combined drayage trip	$\left(\dfrac{D_d^{SB}}{V_{ave}^t} + L + U + 2W \right) \cdot 0.85 VCT_h + \left(D_d^{SB} \cdot VCT_d \right)$ (5)
Single location	$\left(\dfrac{D_s^{SB}}{V_{ave}^t} + L + W \right) \cdot 0.85 VCT_h + \left(D_s^{SB} \cdot VCT_d \right)$ (6)
Single location	$\left(\dfrac{D_s^{SB}}{V_{ave}^t} + U + W \right) \cdot 0.85 VCT_h + \left(D_s^{SB} \cdot VCT_d \right)$ (7)
Drayage trip possibilities	Northern area
Combined drayage trip	$\left(\dfrac{D_d^{NB}}{V_{ave}^t} + L + U + 2W \right) \cdot VCT_h + \left(D_d^{NB} \cdot VCT_d \right)$ (8)

Single location	$$\left(\frac{D_s^{NB}}{V_{ave}^t} + U + W\right) \cdot VCT_h + (D_s^{NB} \cdot VCT_d)$$	(9)
Single location	$$\left(\frac{D_s^{NB}}{V_{ave}^t} + L + W\right) \cdot VCT_h + (D_s^{NB} \cdot VCT_d)$$	(10)

*The total southbound drayage cost per train **i** can be expressed as (11)*:*

$$DC_i^{SB} = \left(\min\left\{\sum_{\forall u} q_{u,i-1}^{SB}, \sum_{\forall u} q_{u,i}^{NB}\right\} + \min\left\{\sum_{\forall u} q_{u,i}^{SB}, \sum_{\forall u} q_{u,i+1}^{NB}\right\}\right) \cdot 0,5 \cdot (5)$$
$$+ \max\left\{\sum_{\forall u} q_{u,i}^{NB} - \sum_{\forall u} q_{u,i-1}^{SB}, 0\right\} \cdot (6) + \max\left\{\sum_{\forall u} q_{u,i}^{SB} - \sum_{\forall u} q_{u,i+1}^{NB}, 0\right\} \cdot (7)$$

*The total northbound drayage cost per train **i** can be expressed as (12)*:*

$$DC_i^{NB} = \min\left\{\sum_{\forall u} q_{u,i}^{SB}, \sum_{\forall u} q_{u,i}^{NB}\right\} \cdot (8) + \max\left\{\sum_{\forall u} q_{u,i}^{NB} - \sum_{\forall u} q_{u,i}^{SB}, 0\right\} \cdot (9)$$
$$+ \max\left\{\sum_{\forall u} q_{u,i}^{SB} - \sum_{\forall u} q_{u,i}^{NB}, 0\right\} \cdot (10)$$

* The numbers in the formulas for the total drayage cost on a roundtrip of a train are referring to the same numbers in the table above. This avoids very large and unreadable formulas.

The travelled distance via rail is based on information given by the rail operator. The average costs per hour and kilometer travelled by train are also based on the research of the Dutch Ministry of Transportation and Water (Vermeulen et al., 2004) (again see appendix D for specification of cost factors). It is assumed that repositioning the train on the other gauge width at the Spanish border is done at 20% of the normal hourly cost rate of a train during operational activities. The first term represent the time related cost by exploiting a train. The long haul distance is multiplied by 2 (roundtrip) and divided by the average speed of a train transporting cargo to come up with the total number of travel hours. These travel hours are multiplied with a delay factor (representing waiting times for shunting activities and other delays) and hereafter with the variable cost per hour to determine the time related cost. The second term represents the distance related cost and therefore the total roundtrip distance is multiplied by the variable cost per kilometer to operate a train. The last term represents the costs that occur with repositioning the train at the border and again is multiplied by two because during a roundtrip this is done twice.

Long haul cost

$$LH = \left(\frac{2D_{lh}}{V_{ave}^{lh}}\right) \cdot (1 + \gamma_t) \cdot VCL_h + (2D_{lh} \cdot VCL_d) + (2TT \cdot 0.2VCL_h) \tag{15}$$

Reefers are rented by the cooperation in order to exploit the intermodal route. Per train i the trains' container capacity is needed, so the same amount of reefers is being rent. Since the renting costs are depicted per container per week, the total renting cost per train can simply be calculated by the renting cost per container times the trains' capacity in number of containers.

Reefer renting cost

$$RC = R \cdot T_{cap} \tag{16}$$

For the control tower costs it is assumed that it would cost approximately €100,000 for a full year to outsource these kind of activities, based on a total of 66 operational trains per year. This number is based on meetings with rail operators. During the winter period the CRS route will be operational for 22 weeks whereas two trains per week will be running. During the summer only one train per week will be operational for again 22 weeks.

Control tower cost

$$\text{CTC} = \frac{CT}{n} \text{ , with } n = 66 \tag{17}$$

The fuel cost for the reefers only depend on the number of filled reefers transported on the NB route. The products that will be transported via the SB route will not need refrigerated conditions as is the case for the perishables that are transported via the NB route. That is why these costs are only influenced by the time it takes to travel from the shippers' origin in the southern area to the terminal, the long haul by train, and the travel time from the northern terminal to the shippers' destination. BB has a cooling system on its trailers that is similar to the one on the reefers that will be rented. Based on expert opinions within BB the average fuel usage of such a system is 2 liter diesel per hour. It is assumed that the reefer tanks will be refilled in Spain (because the diesel is cheaper in Spain). The following formula represents the total fuel cost per roundtrip. The first term displays the travel times needed for the drayage activities. The second term is the travel time by train and the third term the transfer time of the train to the other gauge width at the border. Fuel cost are only made whenever a container is filled with cargo. Therefore the cost per container are multiplied with the accumulated need for transportation NB (since it is assumed that only in the northern direction cooled conditions during transportation are needed).

Fuel cost reefer

$$FC_i = \left(\left(\left(\frac{\tau \cdot (0.376 \cdot \sqrt{A}) + \tau \cdot (0.639 \cdot \sqrt{A})}{V_{ave}^t}\right) + \frac{D_{lh}}{V_{ave}^{lh}} + TT\right) \cdot u \cdot D_c\right) \cdot \sum_{\forall u} q_{u,i}^{NB} \tag{18}$$

Since a combination of shippers are using the same set of containers on a train in both terminal area's for the drayage activities, the containers always have to be transported north- and southwards. If at the destination terminal area no demand occurs and there also was a transportation shortage towards that direction, it is assumed that the container can stay at the train and wait until the train leaves again to the other terminal. For the Northern area the terminal handling costs depend on a combination of the accumulated northbound and southbound need for transportation. For the southern area however, the terminal handling costs depend on a combination of needs for transportation of train i, train $i-1$ and train $i+1$, in the same way as the drayage trips. Therefore the handling at the intermodal terminals can be calculated with the following cost functions.

Handling costs northern terminal per train i

$$HC_i^{NB} = H \cdot \max(\sum_{\forall u} q_{u,i}^{SB}, \sum_{\forall u} q_{u,i}^{NB}) \cdot 2 \tag{19}$$

Handling costs southern terminal per train i

$$HC_i^{SB} = H \cdot \max\left(\sum_{\forall u} q_{u,i}^{NB}, \sum_{\forall u} q_{u,i-1}^{SB}\right) + H \cdot \max\left(\sum_{\forall u} q_{u,i}^{SB}, \sum_{\forall u} q_{u,i+1}^{NB}\right) \tag{20}$$

The total roundtrip costs to transport $\sum_{\forall u} q_{u,i}^{NB}$ containers per roundtrip i NB and $\sum_{\forall u} q_{u,i}^{SB}$ containers SB via the intermodal system are calculated by a combination of formula (1) to (20). Because the costs are perceived by users in the supply chain an assumed profit margin of 3% is added to the actual costs of the system. The only cost aspects that are multiplied with a profit margin factor are the drayage costs in both areas and the long haul costs. For the other cost the profit margin is somehow already included in the service offered by the entity.

Total roundtrip costs per train i

$$TC_i = \left(DC_i^{NB} + DC_i^{SB} + LH\right) \cdot (1 + P_m) + RC + CTC + FC_i + HC_i^{NB} + HC_i^{SB} \tag{21}$$

5.3.2. Current situation

In Table 5.4 the notation of the parameters that are used in the cost model are depicted for the current situation. This model is used to compare the current situation and the intermodal situation to determine the cost differences.

Table 5.4 Parameter notation current situation

Notation	
$q_{u,i}^{NB}$	# containers transported NB for shipper u on train i

$q_{u,i}^{SB}$	# containers transported SB for shipper u on train i
L	Average loading time in hours per container
U	Average unloading time in hours per container
W	Average waiting time per (un)loading activity per container
V_{ave}^{tl}	Average speed in km/hour of a truck during long haul activities
D_t	Distance in kilometers of long haul by truck
VCT_d	Variable costs of truck transportation per kilometer in €'s
VCT_h	Variable costs of truck transportation per hour in €'s
γ_t	Delay factor in % for transportation by truck
P_m	Assumed profit margin LSPs in %
φ	Imbalance factor ($1 < \varphi < 2$)

The cost calculation for the current situation is straight forward. The costs for transporting a container NB or SB are exactly the same since in the model an assumed average distance between locations in the northern and southern area is taken. This is done by using google maps and taking the average over the distances between Valencia – Rotterdam and Murcia – Rotterdam. For the long haul trucking a different average speed is taken than in the drayage situations whereas the trucks cover smaller distances and often travel through more densely populated areas with less highways (Vandwerwegen, 2008) (Vermeulen et al., 2004). Also a delay factor is included in the cost calculation to reflect delays incurred by waiting times at borders but also traffic jams and other factors that may lead to delays. This delay factor is taken over the calculated number of hours the long haul transportation by truck takes, because delays only influence the costs incurred by the passing of time. The actual cost for transporting a container NB or SB by truck is calculated by the following formula.
Long haul cost by truck per container NB and SB

$$r = \left(\left(\frac{D_t}{V_{ave}^{tl}} + L + U + 2W \right) \cdot (1 + \gamma) \cdot VCT_h + D_t \cdot VCT_h \right) \cdot (1 + P_m) \tag{22}$$

As already mentioned , SB trucking is relatively cheap because of a high flow imbalance in truck movements between Spain and The Netherlands. To get the cost for transporting a container in a specific direction the upper formula is multiplied with an imbalance factor that in the final cost calculations is valued in such a way that it resembles the difference in long haul trucking rates during the winter season as shippers in the current situation experience them. This leads to:

$$r^{NB} = \left(\left(\frac{D_t}{V_{ave}^{tl}} + L + U + 2W \right) \cdot (1 + \gamma_t) \cdot VCT_h + D_t \cdot VCT_h \right) \cdot (1 + P_m) \cdot \varphi \tag{23}$$

$$r^{SB} = \left(\left(\frac{D_t}{V_{ave}^{tl}} + L + U + 2W \right) \cdot (1 + \gamma_t) \cdot VCT_h + D_t \cdot VCT_h \right) \cdot (1 + P_m) \cdot \frac{1}{\varphi} \tag{24}$$

These cost functions resemble the cost for transporting one container. In the final cost calculations the current situation is compared with the intermodal situation and a fair comparison must be made between both situations. How this is done is explained in section 6.2.4. of this report.

5.4. Cost evaluation in stochastic environment

During the execution of this thesis the final set of cooperating shippers and their volume commitments were not known. Besides, is the CRS route a complete new implementation that has not been exploited before. In order to create reliable insights in the cost aspects of the complete route the model is tested in a stochastic environment. The logistics manager of BB formulated the goal of the stochastic cost model as determining the probability of the total costs for participants in the cooperation in relation to the risks of the entire operation. Therefore a stochastic environment is created and simulations are performed with @Risk, which is an Microsoft Excel plug in. With these simulations the likelihood of possible outcomes (roundtrip costs) can be determined given certain stochastic input parameters. This section discusses the assumptions made to test the

model in a stochastic environment and gives some further explanations of how stochasticity is incorporated in the cost model.

The assumptions made to perform simulations are listed below:

1. The stochastic need for containerized transportation per shipper is Poisson distributed.

2. At the start of a season the shipper specific commitments are determined, and stay the same during a season the intermodal route is operational.

$$\sum_{u \in N} Q_u^{NB} \leq V \text{ and } \sum_{u \in N} Q_u^{SB} \leq V \text{ (no overbooking possible).}$$

3. Whenever the shippers accumulated need for container transportation is higher than the accumulated commitments, the overcapacity is trucked at the shipper specific trucking rates t_u^{NB} and t_u^{SB}.

The first assumption is made because the Poisson distribution has some properties that correspond with the stochastic need for transportation per shipper. The Poisson distribution is discrete accommodating the fact that only discrete number of containers can be transported. A second property is that the Poisson distribution only has positive values corresponding to the fact that a negative need for containerized transportation is impossible. The Poisson distribution implies that the average number of occurrences of a particular event in a certain unit of time is μ and that the arrival times occur randomly in time and are uniformly distributed (the mean number of events in an interval is directly proportional to the length of the interval). Every train follows a fixed planned time schedule and starts its journey to the northern or southern direction at a fixed time that is known by the cooperation. By taking a fixed time period per shipper in the cooperation that ends a few hours before the departure times of a train, the total numbers of containers that are needed to transport their total cargo volumes per roundtrip can be determined. For example: BB is able to allocate available cargo volumes on the train that become available between 30 hours until 6 hours before the train leaves. This leads to a fixed time window per roundtrip for BB of 24 hours. The cargo quantities that become available within these 24 hours are depicted in number of containers. Considering the needed containers for transportation per shipper correspond to the above explanation of the Poisson distribution, the assumption that the total need for transportation in number of containers is Poisson distributed holds. The suitable time windows per shipper in the cooperation might differ because they might have other types of cargo (not perishables). However if this time window per shipper is constant during a season, the shipper specific mean need for transportation can still be reflected by a Poisson variable because the μ holds for that shipper specific time window.

The second assumption is made to keep the model tractable and to bypass situations in which some sort of rationing games have to be applied. Whenever commitment numbers are higher than the train's capacity, choices have to be made what portion of a shippers' initial committed container numbers per train are accepted. Because the intermodal route is a new route it is a viable assumption that the accumulated commitment numbers will not exceed the trains' capacity.

The third assumption has some effects on the cost calculations. Whenever the accumulated demand taken over all shippers for containerized transportation exceeds the trains' capacity V, it is assumed that this overcapacity is trucked against the same tariffs as in the current situation. The overcapacity in containers that are trucked will not affect the total cost savings (are the same in both situations) and therefore are not taken into account during the cost calculations. However in situations where the accumulated demands are less than the trains' capacity, the costs of the intermodal situation are compared to the costs of the current situation in which the amount of trucks is adjusted to the need for containerized transportation. So in order words, the fixed costs of the intermodal route (which is the complete long haul part by train, the reefer renting cost and the control tower cost) always have to be paid by the cooperation (independent of the need for transportation in # of containers). Less containers in the current situation simply means that less trucks of LSPs are hired to perform the transportation activities.

When increasing the number of iterations in a simulation, the sample mean approaches the expected value of the population. In order to get reliable results for the expected exploitation costs of the intermodal route, the number of iterations is set to 50,000 roundtrips. When results are reported the mean value over all 50,000 separate outcomes per simulation are taken. Appendix J gives a deeper explanation of why this amount of iterations is high enough.

5.5. Input parameter determination

This section explains how the input parameters that are needed to perform simulations are determined. More specifically is the relation between the need for transportation, the commitment numbers and the actual number of containers transported via the intermodal route discussed. Table 5.5 represents the parameters that are used to determine the input parameters that are needed to perform the simulations.

Table 5.5 Additional parameters cost model

Notation	
$x_{u,i}^{NB}$	Actual northbound need for transportation in # containers of shipper u on train i
$x_{u,i}^{SB}$	Actual southbound need for transportation in # containers of shipper u on train i
Q_u^{NB}	# northbound committed containers of shipper u per train i
Q_u^{SB}	# southbound committed containers of shipper u per train i

The needs for containerized transportation per shippers are modeled according to a Poisson distribution. Only one parameter is needed as input for the Poisson distribution which is the expected value of the distribution denoted by λ. The mean need for transportation numbers μ_u^{NB} and μ_u^{SB} of each shipper equals λ_u.

So: $\lambda_u^{NB} = \mu_u^{NB}$ and $\lambda_u^{SB} = \mu_u^{SB}$.

During a simulation, for every iteration i, input parameters are generated according to the shipper specific Poisson distributions characterized by λ_u^{NB} and λ_u^{SB}. Based on λ_u^{NB} and λ_u^{SB}, for every iteration i, the values $x_{u,i}^{NB}$ and $x_{u,i}^{SB}$ are generated per shipper u. Subsequently these values are compared with the commitment numbers of every shipper. How these commitment numbers per shippers are being determined is explained in the next chapter. From this comparison the number of containers suited for transportation per shipper are determined (only depicted for one direction and for roundtrip i):

$$q_{u,i}^{NB} = \begin{cases} Q_u^{NB}, & if\ \forall u\ x_{u,i}^{NB} \geq Q_u^{NB} & (situation\ 1) \\ x_{u,i}^{NB}, & if\ \forall u\ x_{u,i}^{NB} < Q_u^{NB} & (situation\ 2) \end{cases}$$

When some shippers have available overcapacity in number of containers and others shortages this is used to fill the possible container shortage of other shippers (*situation* 3). So if for train i $\exists u \in N: x_{u,i}^{NB} < Q_u^{NB}$ and $\exists u \in N: x_{u,i}^{NB} \geq Q_u^{NB}$ this placement of overcapacity per shipper is determined via the following model:

Step 1: Define set $\{A\} = \{u \in N | x_{u,i}^{NB} \leq Q_u^{NB}\}$ and define set $\{B\} = \{u \in N | x_{u,i}^{NB} > Q_u^{NB}\}$
Step 2: Fix shipments for set A: $\forall u \in A: q_{u,i}^{NB} = x_{u,i}^{NB}$ and in it shipment for set B: $\forall u \in B: q_{u,i}^{NB} = Q_{u,i}^{NB}$
Step 3: Committed shipments $V_c = \sum_{u \in N} q_{u,i}^{NB}$, whereas the overage $V_B = \sum_{u \in B} x_{u,i}^{NB} - Q_u^{NB}$
Step 4: Randomize elements in set B: $\forall u \in B$: rank(u)=random (from Uniform[0,1]).
          Sort Rank(u) non-decreasing
Step 5: Start with the lowest rank: $k := 1$ and
                Do while $V - V_c > 0$ and $V_B > 0$
                        Step 5.1.: $\sigma = Min\{x_{k,i}^{NB} - q_{k,i}^{NB}, V - V_c\}$
                        Step 5.2.: $q_{k,i}^{NB} = q_{k,i}^{NB} + \sigma$ and $V_c = V_c + \sigma$ and $V_B = V_B - \sigma$
                        Step 5.3.: $k := k + 1$
                Loop

6.   Cost Allocation Model

6.1.   Introduction

Now that the cost model is constructed to make a comparison between the new intermodal and current situation the question arises how the costs in the new setting should be shared. A group of shippers that join in exploiting an intermodal route together are responsible for the losses and gains of the supply chain system. To address this problem, a game theoretic approach is used which is further elaborated in this chapter.

6.2.   Definition of cooperative game

Cooperative game theory proposes a variety of concepts for the division of profits in a cooperative game with transferable utilities. A game with transferable utility only holds if there is no restriction on the division of joint benefits between players. A cooperative game with transferable utility is assumed within this thesis. In this project, instead of focusing on splitting the savings of the coalition among players, it focuses on how to allocate the cost of exploiting an intermodal supply chain route. Therefore a cost allocation game is constructed. Denote $N = \{1, 2, \ldots, n\}$ as the finite set of all participants. A subset of participants of N is a coalition denoted by S. When a coalition S forms, the total costs $c(S)$ for that specific coalition is generated (Frisk et al., 2010). This cost function is called the characteristic cost function. Each player within this project is referred to as a participant of the CRS project/the horizontal collaboration. When looking at all the cost allocated to each participant this vector is expressed as the cost allocation vector $\gamma \in \mathbb{R}^N$.

The assumption of a cooperative game has effects on the model that are discussed. Within a cooperative setting, participants in the cooperation commit to a long-term collaboration, based on openness. Under these conditions of cooperative game theory there is no interest for the shippers to give commitments that deviate from their average need for transportation. If everyone shares in proportion to the profit/loss of exploiting the intermodal route, then there is no reason to deviate from this average need for transportation μ_u^{NB} and or μ_u^{SB}. Strategic or speculative behavior of shippers does not belong in a cooperative setting. A very important implication of this first application assumption is that every shipper's commitment equals its mean need for transportation. Mathematically this is expressed by the following two equations:

$$Q_u^{NB} = \mu_u^{NB} \text{ and } Q_u^{SB} = \mu_u^{SB}.$$

This implication of cooperative behavior of organizations does not fully correspond to the way organizations within the CRS project behave. However it is needed to model the exploitation of the route. In the CRS project, interested shippers do not commit the same amount as their mean need for containerized transportation to the intermodal route. Some shippers that for example already committed volume to the route committed only one container per train. These shippers on average probably have a higher mean need for containerized transportation on the specific day in the week a train is leaving NB and/or SB. Clearly these shippers have some sort of strategic intentions to join the CRS route. Even though the assumption of openness does not reflect the CRS setting perfectly, the model is still of use and relevant for organizations. The commitment of the shippers in the model equals the mean need for transportation. That is why the actual weekly cargo volumes available for transportation (expressed in number of containers) are highly influenced by the standard deviation of the chosen distribution to model the stochastic need for transportation. Since the intermodal route is a new implementation, it is imaginable that even commitments of shippers that only committed one container (while having on average for example enough cargo to transport 20 containers) might be uncertain. The intermodal exploitation in a synchronized roundtrip environment like the CRS route needs a lot of synchronized planning and centralized control (executed by the control tower). During the first season of operation it is possible that the route has to deal with startup problems. In the analyses phase of this report, some minor supply disruptions are explained based on quality restrictions. For shippers that transport perishables, this leads to situations that some cargo unexpectedly is transported with a second truck driver. This cargo is no longer suited for intermodal transportation. These unexpected eventualities are represented

by the stochastic and uncertain need for containerized transportation per shipper in the cooperation. In this way the overestimation of uncertainty in commitment numbers per shipper are scaled back somewhat.

6.2.1. Allocation rule properties

The cost allocation of a game can be done in several ways, based on satisfying a number of properties, i.e. fairness criteria. In game theory, a cooperative game is characterized by the behavior that players in subgroups may enforce in a cooperative manner in order to maximize their utility (Tseng, Yan, & Cruijssen, 2013). Cooperative game theory, models the process of negotiation among participants. Besides simple rule of thumb methods for the allocation of cost synergies, there are solution methods derived from cooperative games, that often fit well to horizontal collaboration compensation problems (Tseng et al., 2013). The cost allocation of a game can be done in several ways, based on satisfying number of properties, i.e. fairness criteria. No unique correct allocation rule exists in general. The allocation rule can be agreed upon by the players in a cooperation by agreeing on the allocation characteristics. The cost allocation rule f for game v prescribes one suggested way of allocating the cost of the grand coalition $c(N)$ to each player. When a cost allocation rule splits the total cost, $c(N)$, among the participants $j \in N$ it can be done in such a way that this allocation is said to be efficient (Frisk et al., 2010). In mathematical notation the efficiency allocation rule property is expressed by: $\sum_{j \in N} y_j = c(N)$, where y_j is the cost allocated to each participant j. Individual rationality is another important property which means that no participant in the grand coalition pays more than its stand alone cost (i.e. the cost incurred by a participant in the situation before it entered the cooperation). Mathematically this property is expressed as $y_j \leq c(\{j\})$ (Frisk et al., 2010). The set of allocation vectors that satisfy these two conditions are said to be in the imputation set. So the imputation set consists of cost allocation vectors that satisfy the following two conditions:

$$y_j \leq c(\{j\}), \qquad \forall i \in N \qquad \text{(individual rationality)},$$
$$\sum_{j \in N} y_j = c(N) \qquad \text{(efficiency)}.$$

Secondly, there should be no participants or any coalition of participants in the grand coalition that together are allocated a cost that is higher than in case the individual or coalition acted alone. When a cost allocation is in the core, the formed grand coalition is stable. This stability property always should be kept in mind. Whenever a cost allocation among the participants in a cooperation is stable, it means that no participants or coalitions in the grand coalition have an incentive to leave the grand coalition and form an own coalition. The set of allocation vectors satisfying the efficiency and the stability condition is called the core and the corresponding properties are:

$$\sum_{j \in N} y_j = c(N) \qquad \text{(efficiency)},$$
$$\sum_{j \in S} y_j \leq c(S), \qquad S \subseteq N \qquad \text{(stability)}.$$

6.2.2. Player set and coalitions

As discussed in chapter 1, this project focuses on a cooperation between several shippers. The final number of shippers within the cooperation during the execution of this thesis was not yet known. A set of seven participants in the cooperation is assumed, because this resembles the amount of shippers that at the moment are interested in joining the project. Capacitating the model to a number of seven participants is also done because otherwise the possible set of sub coalitions would become very large. This would make the application of the model unnecessarily time-consuming without gaining much extra research possibilities. The analysis of sub coalitions is required to enable the application of allocation rules to the grand coalition (Soons, 2011). Based on the seven player setting in this cooperative game, the set of sub coalitions of this game can be defined as $2^N = 2^7 = 128$ coalitions. The number of sub coalitions increases exponentially. 128 coalitions was considered as acceptable for doing the simulations in the application of the model. A ten player game for example would already lead to 1024 sub coalitions.

6.2.3. Characteristic function of the cost allocation game

The constructed intermodal cost model is able to calculate the operational costs of an intermodal rail-road supply chain given input parameters for the need for transportation (in # of containers) of a (sub)set of cooperating shippers. In line with standard notation of game theory, the term coalitions is used to refer to a subset of cooperating shippers, given a grand coalition N of seven shippers. This means that $N = \{1,2,3,4,5,6,7\}$, whereas the numbers refer to six other shippers in the cooperation apart from BB. Because there is no data at hand due to the (yet) unknown final set of shippers in the cooperation, the cost per coalition are determined by simulating 50,000 roundtrips. For every sub coalition 50,000 iterations are repeated given the input parameters. The exact input parameters used for the simulations are given in chapter 7. By performing simulations, for every sub coalition, the expected values (cost wise) for exploiting the intermodal CRS route are approximated. This is done by taking the average cost per roundtrip i of all simulation results. The intermodal costs of a coalition ($S \subseteq N$) per roundtrip i is defined as $TC_i(S)$. The characteristic cost function of the game v for coalition $S \subseteq N$ is defined by:

$$C(S) = \frac{\sum_{i=1}^{50,000} TC_i(S)}{50,000}$$

$\emptyset$ is known as the empty set. The empty set is defined as the empty coalition where no participants are involved. In this case the intermodal route has not been implemented and no costs occur. By definition an empty set has zero costs and thus $C(\emptyset) = 0$.

6.2.4. Single player type coalitions / stand-alone costs

For individual players (also known as singleton coalitions), the transportation of cargo via a new implemented intermodal rail-road route is not possible. Reason for this is that some form of collaboration is necessary in order to implement the CRS route successfully. Otherwise BB would already have implemented the new CRS route by themselves (reason for this are the cargo shortages). Besides, even when a shipper would have enough volume into one direction, it is very unlikely that it also has the cargo quantities in the opposite direction. Balanced roundtrip cargo volumes are necessary for successfully exploiting an intermodal supply chain. In this case, whenever a single player type coalition occurs, one cannot speak of horizontal collaboration. Therefore the supply chain costs for a single player type coalition are equal to the current supply chain costs in which the containers are transported via long haul trucking. The singleton coalitions therefore represent the stand-alone cost that reflect the incurred cost per participant before it entered the cooperation. Within the constructed game, this is a very important value because these stand-alone costs are needed to reflect the individual rationality property. This is an important property within the cost allocation game because it will be one of the restrictions to ensure a stable cost allocation among the participants. The stand-alone cost of the single player type coalitions is again determined via simulations but now by simulating the setting in which the transportation of containers is performed via long distance truck haulage. An extra parameter that is included in the calculation of the stand alone cost is a shipper specific discount factor. During this project it became clear that even though there are market trucking rates (calculated by r^{NB} and r^{SB}) some shippers may be able to negotiate extra contract discounts because of negotiation power. This negotiation power is caused by a high need for containerized transportation numbers in the southern direction. This has consequences for the stand alone costs per shipper. Therefore an extra parameter is included in the calculation of the stand-alone costs, which is a shipper specific discount factor δ_u. This is important to include in the cost allocation model because if a shipper for example pays 10% less than the average market price of other shippers in the cooperation this will have consequences on the maximum amount a shipper is willing to pay per container when exploiting the intermodal CRS route (individual rationality / stability). This following formula holds:

$$C(u) = \frac{\sum_{i=1}^{50,000} q_{u,i}^{NB} \cdot (r^{NB} \cdot \delta_u^{NB}) + \sum_{i=1}^{50,000} q_{u,i}^{SB} \cdot (r^{SB} \cdot \delta_u^{SB})}{50,000}, for\ u = 1,2,3,4,5,6,7$$

The final stand alone cost per participant in the cooperation depends on the commitment properties. It is possible that a shipper only commits container volumes into one direction (NB or SB). It is also possible that a shipper commits volumes into both directions. The parameters used in the cost function represent the actual number of transported containers per roundtrip i. When a shipper commits no volume into one particular direction this parameter in the cost function automatically becomes 0 in every iteration of the simulation. As a consequence no trucking cost in that direction is included in the stand-alone cost. Based on the assumption that shippers behave in a cooperative manner and therefore are open, the shipper specific stand-alone costs are known throughout the cooperation.

6.3.   Choice of an allocation rule

How the costs are distributed among the players is determined by the allocation rule. In this section the allocation rule will be selected by looking at three dimensions:

1.   Fairness
2.   Understandability
3.   Practical considerations

Fairness is an important factor in determining how to divide costs for a joint effort. Although individual entities may perceive fairness in different ways, Frisk et al. (2010) states that individual rationality is the most desirable property of a rule. Some other basic axioms exist that could ensure a cost allocation in a fair way. These are explained in this section. One is the _efficiency_ property mentioned before. It states that the sum of all allocated cost to the individual participants must be equal to the grand coalitions' cost. Another axiom is _additivity._ This means that the sum of the payoff in sub problems should be equal to the payoff in the original game. The axiom _zero-player property_ (or dummy property) states that if the participant does not incur costs or makes a contribution to any coalition it joins, it should be allocated zero cost (Tseng et al., 2013). _Symmetry_ entails that if participant i and j have an equal marginal cost with respect to all coalitions not containing i and j, the payoffs allocated to the two players will be equal. The last axiom _monotonicity_ means that if one new player is included in a coalition, the cost never decreases. (Audy, D'Amours, & Rousseau, 2011; Frisk et al., 2010; Slikker, 2014) In appendix A an overview of often used allocation rules in literature is put together and from this list one cost allocation rule is chosen. The main arguments for this decision are given keeping the upper explained fairness criteria/axioms and the two other dimensions (understandability & practical considerations) in mind.

When only taking the fairness dimension into consideration for determining the allocation rule one could argue that the Shapley value is the best choice. This allocation rule is the only rule that satisfies the efficiency, symmetry, dummy and additivity properties (Slikker, 2014). The Shapley value allocates the joint costs based on marginal contribution of each specific participant to the grand coalition. For the CRS collaboration this would mean that a shipper that commits more containers to the route will receive a higher saving per container when compared to a shipper that commits less volume in number of containers. Even though based on fairness criteria the Shapley value seems the best choice, in reality shippers probably will not accept different relative savings per container for each shipper.

The most simple understandable solution to allocate joint costs within cooperation's is to split the common costs equally, weighted with each participant's volume. Often companies see this as a preferred model. However, the fairness dimension is at stake with this allocation model. Frisk et al. (2010) showed in their research that this basic model leads to large differences in relative savings among participants which in reality will lead to unacceptable situations. Especially in the case of the CRS project this will lead to unfair cost allocations because the highly differentiated current market prices for trucking containers in opposite route directions (that determine the stand-alone cost). Based on attended meetings of the project committee that were still in the developing phase of the new intermodal route during the execution of this master thesis it proved to be important that the relative savings among participants in the cooperation are comparable. The reason for this is that at the start of the project wants the intermodal route must be as attractive as possible for

other shippers (cost wise). In this way the route has the highest potential for other shippers to join the cooperation. Other shippers obtain the same savings as the founding fathers in the cooperation. Enough volumes are needed, so that the intermodal route can compete with transportation by truck.

This minimal relative savings among participants to strive for in the cost allocation is further strengthened by interviews with people that were active in the intermodal sector. Interviews were held with a control tower who was responsible for the cargo bundling for clients in the barging sector, persons from the Port of Rotterdam and experts in horizontal cooperation projects from institutes like Bureau Binnenvaart and Lean and Green Connekt. The interviewees all mentioned that within a collaboration shippers want an equal cost saving per transported container because otherwise the cost allocation would be considered as unfair. The absolute savings herewith are determined with the number of containers that are being transported. Even though the relative savings per container are the same for all shippers, there is still an incentive to increase the number of transported containers because logically more transported containers yield more absolute savings. This Equal Profit Method (EPM) allocation rule is the only rule found in literature that has as objective to minimize the maximum difference in pairwise relative savings between players. Frisk et al. (2010) noticed the same allocation restrictions of participants in collaborations in practice. That is why they developed the EPM allocation rule. One might argue that with this rule the interest of the founding fathers (i.e. the project committee) are ignored as they might want higher cost savings because they invested effort, time and money in the project. However getting the required volumes as other shippers join the cooperation has the highest priority. Without other shippers, the investments made so far by the project committee might become worthless. Without other shippers the CRS route is not exploitable. Figure 6.1 shows a cost comparison between the intermodal and current situation in a deterministic setting where a fixed number of containers is transported in both route directions. This figure depicts the relation between vacant spots on the train and the fast increase in average cost per container. It emphasis the issue of having enough cargo volumes and that a shortage of volume leads to a fast decline of the possible savings.
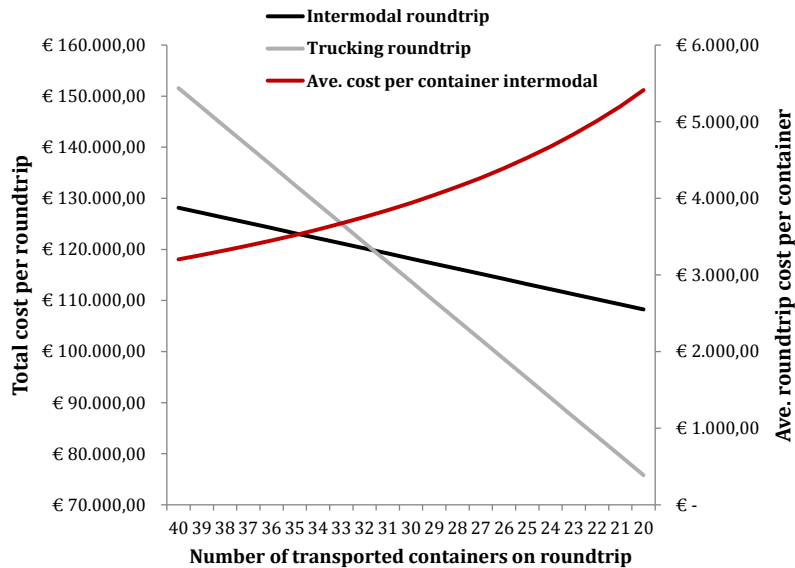
Figure 6.1 Total roundtrip cost and average cost per container given # of transported containers

Based on the discussed three dimensions there is chosen for the EPM cost allocation rule. The practical constraint of minimizing the relative savings among all the shippers in the cooperation is considered as the most important and the EPM rule satisfies this condition. When looking at the understandability dimension the EPM rule again scores very high as it is one of the easiest understandable rules of the list which can be found in appendix A. It is arguable that the cost weighted methods might be easier to understand but these rules do not ensure a stable cost allocation. Therefore the EPM is preferred over this allocation rule. Even though the Shapley value satisfies the most important fairness axioms, the EPM is preferred. This is done

based on the fact that the Shapley value will lead to different relative savings among participants which is considered as unacceptable.

6.4. Equal Profit Method Cost Allocation

The equal profit method is developed by (Frisk et al., 2010), and it aims to minimize the maximum difference in pairwise relative savings. These differences are calculated for each of the $N \cdot (N-1)$ distinct pairs of participants, and minimized by choosing the most suitable cost allocation, while satisfying the stability constrain if possible (Tseng et al., 2013). The final cost allocation per shipper $u \in N$ is represented by y_u. The relative savings of shipper u is expressed as:

$$\frac{c(\{u\}) - y_u}{c(\{u\})} = 1 - \frac{y_u}{c(\{u\})}$$

This is the difference in the incurred stand alone cost and the cost allocated in the grand coalition divided by the stand alone cost. This fraction expresses the relative savings of each shipper when comparing its stand alone cost to the cost incurred while collaborating all together. The equal profit allocation method is formulated by the following nonlinear program problem:

$$\text{minimize } f, \text{ subject to}$$
$$f \geq \left| \frac{y_u}{c(\{u\})} - \frac{y_j}{c(j)} \right|, \qquad \forall (u,j) \in N$$
$$\sum_{u \in S} y_u \leq c(S), \qquad P(S) \subset N$$
$$\sum_{u \in N} y_u = c(N)$$

The first constraint set is to measure the pairwise difference between the profits of the shippers. Absolute values are taken for the objective function to be able to minimize all relative savings with 0 as the optimum. The variable f is used in the objective to minimize the largest difference. The two other constraints define all stable allocations as they reflect the individual rationality and efficiency allocation rule properties. $P(S)$ means a power set of S which are all possible subsets of the set S that are a proper subset of grand coalition set N.

7. Results and analysis

7.1. Introduction

This chapter starts with the experimental design. The results of the model are presented by aggregating the constructed cost and allocation model. The chapter finishes with a sensitivity analyses to gain further insights in what important factors are on the expected cost savings and cost allocations per shipper in the cooperation. Throughout this chapter conclusions for the stakeholders (BB and the project committee) of this project are given per analysis type whenever possible.

7.2. Experimental design

By aggregating the cost and allocation model, the tariffs p_u for transporting one container via the intermodal route per shipper u in the cooperation are determined. The model consists of a grand coalition of seven shippers denoted by $N = \{1,2,3,4,5,6,7\}$. S is a sub coalition of N ($S \subset N$). Each shipper has a stochastic need for transportation in a single direction (northbound or southbound) or in both directions characterized by mean μ_u^{NB} and μ_u^{SB}. Therefore, either a shipper commits container volume northbound, southbound or in both directions. This leads to three types of "train tickets": a single directional ticket NB or SB, or a roundtrip ticket. The alternative for each shipper in the cooperation is trucking at a shipper specific trucking rate: $t_u^{NB} = \delta_u^{NB} \cdot r^{NB}$ NB and/or $t_u^{SB} = \delta_u^{SB} \cdot r^{SB}$ SB that are equal to the tariffs as in the current situation.

7.2.1. Grand coalition base composition

Because the final set of shippers is unknown and due to confidentiality restrictions a base composition for the shippers in the grand coalition is constructed. The values for the input parameters that are used for the base case are depicted in Table 7.1. This composition is made in accordance with BB and represents a possible exploitation scenario. Both in number of shippers as well as commitment quantities per shipper. All three type of shippers are represented by the base case, as there are shippers only transporting cargo into one direction (NB or SB) or in both directions (shipper 7). An overview of all the values that are used for the cost parameters in the cost model can be found in Appendix E. One value worth mentioning is the value for parameter M. This parameter gives the total number of locations that are known at the start of the drayage activities at a terminal area and therefore determines the distance between a cargo delivery and pick-up location. This value is set equal to the accumulated commitment numbers in particular directions. For the base case this leads to $M = 40$.

Table 7.1 Experimental design input parameters for base case

Shippers u	NB need for transportation		SB need for transportation		Commitments		Trucking discount factors	
	$\mu_u^{NB} = \lambda_u^{NB}$	$\sigma_u^{NB} = \sqrt{\lambda_u^{NB}}$	$\mu_u^{SB} = \lambda_u^{SB}$	$\sigma_u^{SB} = \sqrt{\lambda_u^{SB}}$	$\mu_u^{NB} = Q_u^{NB}$	$\mu_u^{SB} = Q_u^{SB}$	δ_u^{NB}	δ_u^{SB}
1	15	3.87	0	0	15	0	1	1
2	3	1.73	0	0	3	0	1	1
3	0	0	15	3.87	0	15	1	1
4	10	3.16	0	0	10	0	1	1
5	0	0	20	4.47	0	20	1	1
6	7	2.65	0	0	7	0	1	1
7	5	2.24	5	2.24	5	5	1	1

7.2.2. Cost allocation scenarios

Due to the structure of an intermodal rail-road supply chain, two natural boundaries exist of how to allocate costs in a cooperation. The corridor exist out of two modes per transported container which leads to two allocation options that broadly can be considered. These options also are considered by the project committee and that is why it is interesting to consider the relation between the chosen allocation/exploitation way and the effects on the actual cost allocations per shipper in the cooperation. One option is allocate all costs based

on the complete door-to-door delivery of containers which includes both modes. The other choice is to allocate the trucking aspect of the intermodal supply chain to each shipper separately. In the latter, boundaries are placed besides the intermodal terminals in both drayage areas. Therefore two allocation scenarios are constructed that both will be subject to analysis. For both the cost allocation scenarios that will be discussed in this section, the chosen EPM rule is applied for to the reasons as discussed in chapter 6 of this report. Note that the total cost for the cooperation will not change when using a different allocation scenario. Only the allocated cost per shipper given a total cost for the cooperation are influenced by the different allocation scenarios.

One possibility is that the complete route (so rail + road) and its costs are allocated such that the relative savings are minimized among the shippers taking the costs of the complete route into consideration. So everybody pays for everybody's cost. This first allocation scenario can be completely carried out by applying the EPM in the allocation model.

In the second allocation scenario, costs incurred by serving shippers with specific cargo drop and pick-up locations are allocated separately to these shippers. Besides are the different stand-alone costs of shippers taken into account differently when allocating the trucking costs directly to all shippers separately. For the second allocation scenario some small modifications to the EPM rule are necessary that are based on the modified EPM as reported by Audy et al. (2011). The second scenario includes an expansion of the EPM, which is the EPM combined with the Alternative Cost Avoided Method (ACAM). The ACAM method is necessary to be able to set the EPM allocation boundaries at both intermodal terminals. Figure 7.1 represents an overview of which activities create what costs in the second allocation scenario. Instead of minimizing the relative savings among shippers (based on their stand-alone costs) taking the complete door-to-door delivery into account, this relative saving is only minimized for the long haul part of the route. The stand-alone cost hereafter only serves as a restriction for the allocation of the absolute costs of serving a shippers' location by road.
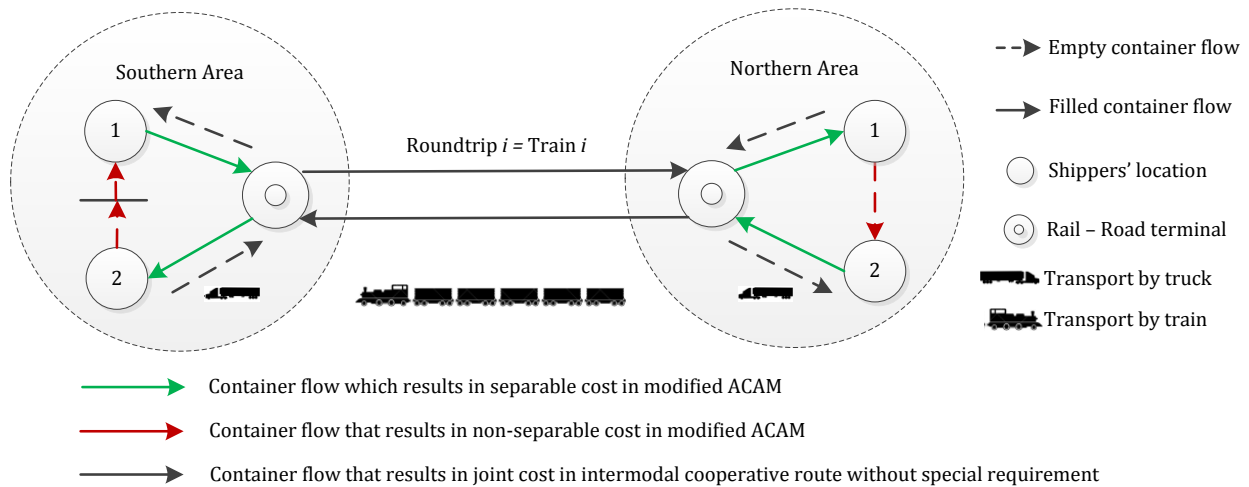
Figure 7.1 Container flows in relation to cost factors in modified ACAM and EPM cost allocation

The modified ACAM first allocates the separable costs to each shipper and next distributes the non-separable cost according to a weighted measure. The drayage trips that are covered by truck in order to get a container from the terminal to a shippers' location or vice versa (green arrows in the figure) can be seen as separable costs. These costs are "directly" allocated to the shipper where a container is destined to or is coming from. The non-separable costs can be seen as the drayage trips between a delivery location and a pick-up location (red arrows) in order to create an efficient double trip. A combination of these separable and non-separable cost can be seen as special requirements of all shippers in the cooperation. All shippers make use of the exact same long haul part by train. However the drayage activities are special and shipper specific based on certain requirements such as distance of the shippers' locations from and to the terminal. Since two shippers benefit

from these efficient doubles one cannot simply allocate the costs that occur with the trips between two shippers to one shipper and therefore these are allocated according a weighted measure. Before a step by step explanation is given of how the second allocation rule is applied in the model some extra definitions are given in the table below:

Table 7.2 Additional notations for allocation scenario 2

Notation	
$C_{acam}(N)^*$	The intermodal costs for the grand coalition without the drayage activities.
$C_{\{N\}}(N)$	Cost of intermodal route for grand coalition including the drayage cost for all shippers.
$C_{\{U\}}(N)$	Cost of intermodal route for grand coalition including the drayage cost for shipper u.
$C_{\{N\setminus\{u\}\}}(N)$	Cost of intermodal route for grand coalition including drayage cost for all shippers except u.

$$* \ C_{acam}(N) = \frac{\sum_{i=1}^{50,000} LH \cdot (1+P_m)+RC+CTC+FC_i+HC_i^{NB}+HC_i^{SB}}{50,000}$$

The following step by step description of the modified ACAM is based on Audy et al. (2011).

Step 1: The separable cost of each shipper $u \in N$ is calculated from:

$$y_u = C_{\{u\}}(N) - C_{acam}(N) \quad \forall u \in N$$

Step 2: The non-separable costs are calculated from:

$$t = C_{\{N\}}(N) - C(N) - \sum_{u \in N} y_u$$

Step 3: The relative weights to distribute the non-separable costs among the shippers are calculated from:

$$w_u = C_{\{N\}}(N) - C_{\{N\setminus\{u\}\}}(N) \quad \forall u \in N$$

Step 4: The non-transferable cost of each shipper $u \in N$ for its shipper specific drayage activities is calculated from: $\quad d_u = y_u + \frac{w_u}{\sum_{u \in N} w_u} t \quad \forall u \in N$

The calculated non-transferable costs are subsequently used in the modified EPM by adding the shipper specific d_u to the allocated costs y_u that are based on the costs without any drayage activities $C_{acam}(N)$. The cost model is constructed in such a way that it is able to calculate the separable cost for every shipper and non-separable cost of every roundtrip i (or iteration) during simulation. Hereafter the non-transferable cost are used in the modified EPM rule to calculate the cost allocations per shipper. The restrictions in the modified EPM have some small adjustments that look as follows:

$$\text{minimize } f, \qquad \text{subject to}$$
$$f \geq \left| \frac{y_u}{c(\{u\})} - \frac{y_j}{c(\{j\})} \right| \qquad \forall (u, j),$$
$$\sum_{j \in S} (y_u + d_u) \leq c(S), \quad P(S) \subset N,$$
$$\sum_{j \in N} y_u = C_{acam}(N)$$
$$\frac{C(\{u\}) - (y_u + w_u)}{C(\{u\})} \geq P_u, \forall u \in N$$

The second and third constraint set subsequently ensure stability and efficiency. The last constraint allows to set a minimum saving percentage to include the possibility to "protect" some shippers for having a too small cost saving relative to other shippers.

7.3. Results

This section reports the results of the simulations, with the base case as constructed in the experimental design in the previous chapter section, as input for the aggregated cost and allocation model. So note that these specific outputs only hold for a grand coalition composition similar to the base case. Later more general relationships will be reported based on the sensitivity analyses.

7.3.1. Cost evaluation base case

Figure 7.2 is a graphical representation of the simulation results and displays the cost outputs for the intermodal situation. In appendix F all outputs for the grand coalition and a sub coalition are depicted with a detailed explanation. In Figure 7.2 the cost boundaries per intermodal roundtrip can be seen. The graph shows a high relative frequency of a roundtrip cost around €125K. This is a consequence of the maximum capacity of 40 containers per train i. A more extensive explanation of this observation is also given in appendix F. No roundtrips were cheaper than €112K while the most expensive roundtrip was €130K. The cost interval in the current situation is much wider given that the lowest costs per trucking containers in a roundtrip setting is €84.4K and €151.6K the highest (see appendix F). The reason the costs interval of the intermodal situation is more narrow than in the current situation is discussed later in this chapter section. The mean accumulated stand-alone costs of the grand coalition are displayed together with the mean total costs of exploiting the intermodal route per roundtrip. Note that these mean costs approach the expected values of exploiting the intermodal supply chain since the average is taken over 50,000 iterations. The mean costs per intermodal roundtrip are €124K compared to an expected stand-alone costs of the grand coalition of €142K. This results in a total supply chain benefit of 12,59%.
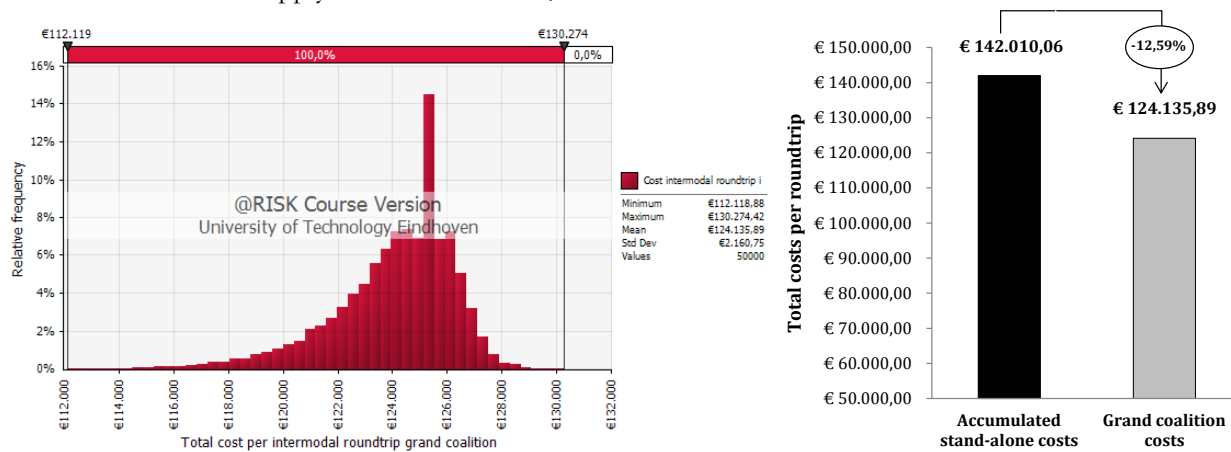
Figure 7.2 Simulation output intermodal situation and cost comparison trucking versus intermodal

With @Risk, filters can be added to the simulation outputs to analyze specific relations. The CRS project concerns the development of a complete new intermodal route. The project is at a development phase whereas the biggest concern is a shortage in cargo volume. Therefore it is interesting to see what cargo volumes in number of containers are necessary to yield benefits for the cooperation. In Figure 7.3 two outputs are displayed. The first is the actual transported number of containers on a roundtrip basis for all iterations (without a filter). The second is the output whereas all iterations that did not resulted in a supply chain benefit when comparing the current situation with the intermodal supply chain are filtered out.
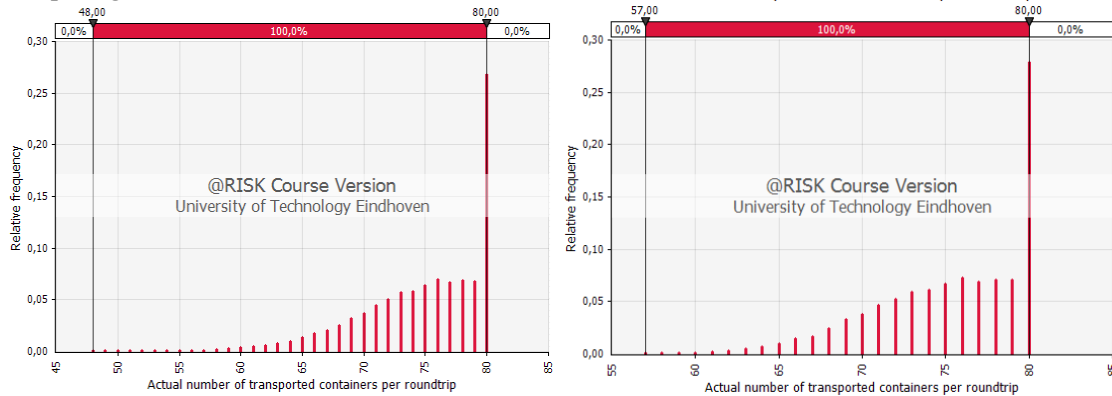
Figure 7.3 Actual number of transported containers with and without filter on iterations

In the intermodal setting 96,2% (or 48,121 out of 50,000 iterations) of all roundtrips yielded supply chain benefits. In Figure 7.3 can be seen that without filtering, between 48 and 80 containers were transported via the intermodal supply chain. When setting a filter on a minimal cost benefit of €0 the minimal transported number of containers increase to 57 (and 1,879 iterations are not displayed). This means that for the base case there was at least one roundtrip in which only 57 containers were transported on a roundtrip basis for which it was cheaper than transporting these containers by truck. However these situations are very rare since the relative frequency is almost 0. From the right graph it can be seen that from 65 containers and more the relative frequency increases to more likely values and so these situations occurred more often. If the cooperation is able to bundle at least 65 containers or more per roundtrip, there is a high possibility that the intermodal synchronized supply chain leads to cost savings. The high peek in relative frequency of 80 containers is because the train is capacitated on 80 containers on a roundtrip bases (40 per direction). Because the assumption is made that overcapacity of the cooperation is trucked against the same trucking tariffs as in the current situation they are not included in the cost comparison because they will not lead to extra savings. Therefore all situations in which more than 80 containers are being transported in the cost model results in situations in which exactly 80 containers are transported and compared to the trucking the same amount. Therefore a much higher relative frequency of 80 containers occur in the graphs.

To get a better understanding how the costs of exploiting the intermodal route relate to the costs in the current situation it is also interesting to look at the cost evaluation of all the sub coalitions. The sub coalitions are all coalitions S without the grand coalition N and the singleton coalitions in which no collaboration exists. The accumulated stand-alone costs and the costs in the intermodal setting per coalition per roundtrip for the base case composition are displayed in Figure 7.4. A coalition is only expected to form if the accumulated stand-alone costs exceed the intermodal cost. What can be seen in the figure is that nearly all sub coalitions are better off by staying in the current situation by trucking containers instead of exploiting an intermodal route. Only in the right part of the figure the accumulated stand-alone costs of a few bigger sub coalitions exceed the costs of the intermodal situation. Besides the grand coalition N, only the following four sub coalitions S were able to yield supply chain benefits. $S = \{1,2,3,4,5,6\}$, $S = \{1,2,3,4,5,7\}$, $S = \{1,2,4,5,6,7\}$ and $S = \{1,3,4,5,6,7\}$.
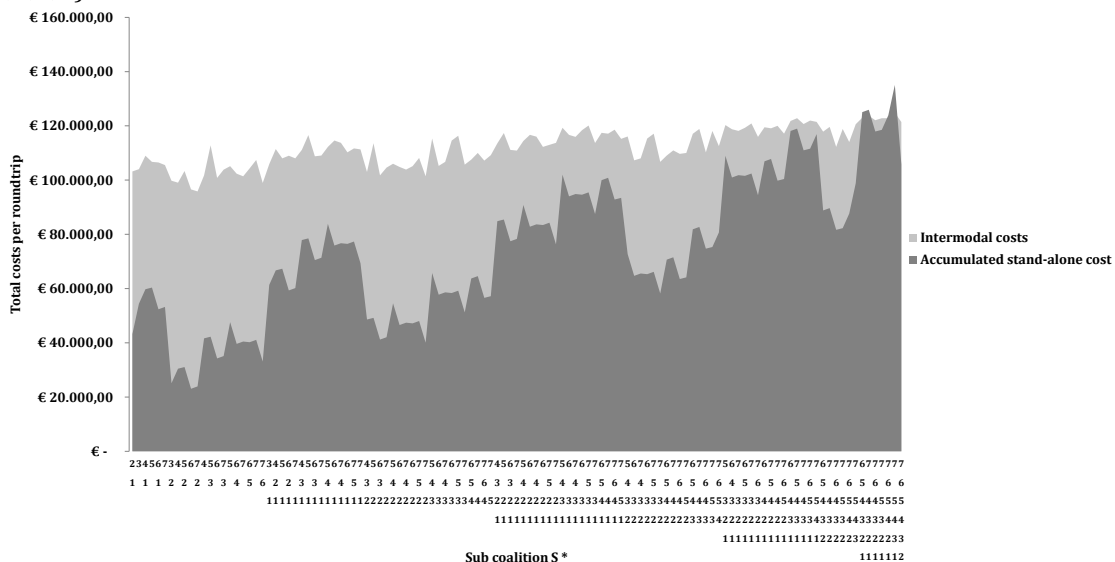
Figure 7.4 Simulation results mean costs trucking versus intermodal per coalition S, whereas $S \subset N$

(* at the horizontal axis, sometimes a member shipper of a sub coalition is not mentioned to maintain a concise description. In order to know what number is missing one should look at the first digit to the left of the empty spot.)

Small coalitions are not able to reach cost benefits because in the exploitation of the intermodal route many fixed costs are involved. Whenever a small coalition does not have accumulated need for containerized transportation close to the trains' capacity of 40 containers, the partners still have to pay for all the fixed costs

38

in the exploitation of the intermodal route. In the constructed game every shipper in every coalition commits its mean need for transportation to the CRS route. The commitment numbers per shipper in a smaller coalition do not differ from their commitments in bigger coalitions. Less accumulated need for transportation in the current situation simply means that less trucks are being deployed by the contracted LSP. There is no overcapacity to pay for. For this reason the stand-alone costs of the coalitions are very flexible (the bigger the coalition in number of shippers, the bigger the accumulated stand-alone costs. The intermodal costs only decrease a bit whenever the coalitions decrease in the number of shippers. This can be seen as the expected intermodal costs start around €100K and ends around €120K for the total cost per roundtrip i. This is caused by the high percentage of fixed costs which is depicted in Figure 7.5. The factors numbered with a 1 in the legend are fixed costs in the cost model, all other are variable.
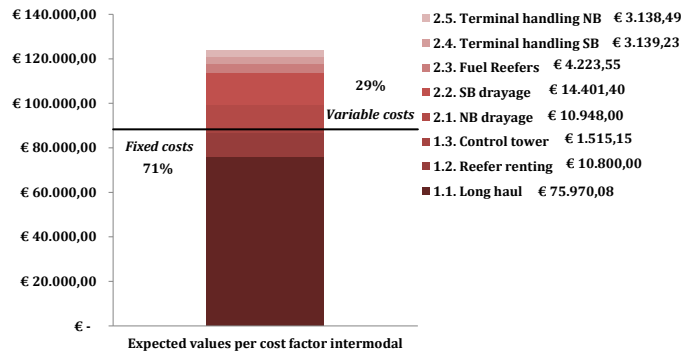
Figure 7.5 Fixed versus variable mean cost values per intermodal cost factors

7.3.2. Cost allocation

Now that the costs for the grand coalition are known, these have to be allocated among the shippers. Both cost allocation scenarios described in section 7.2.3. are discussed and the results are compared. The goal to determine the tariffs p_u^{NB} and p_u^{SB} per container per shipper u in the cooperation is pursued.

7.3.2.1. Allocation scenario 1

Within this scenario everybody pays for everybody's costs. This means that the complete intermodal roundtrip route (without making a distinction between the rail and road part within the supply chain) is allocated to each shipper in such a way that the relative savings among the shippers are minimized. Figure 7.6 displays the cost allocated per shipper. Shipper 1 in the cooperation is allocated the highest amount because this shipper has NB need for transportation in combination with a relatively high commitment number of 15 containers. Because the container market tariff for trucking containers NB is much higher than the SB tariffs (because of the imbalance in the total number of trucking flows) this shipper has relatively high stand-alone cost. That is why shipper 5 who has a higher commitment of 20 containers is allocated less costs. Its stand-alone costs are lower because of the lower trucking tariff for SB trucking.
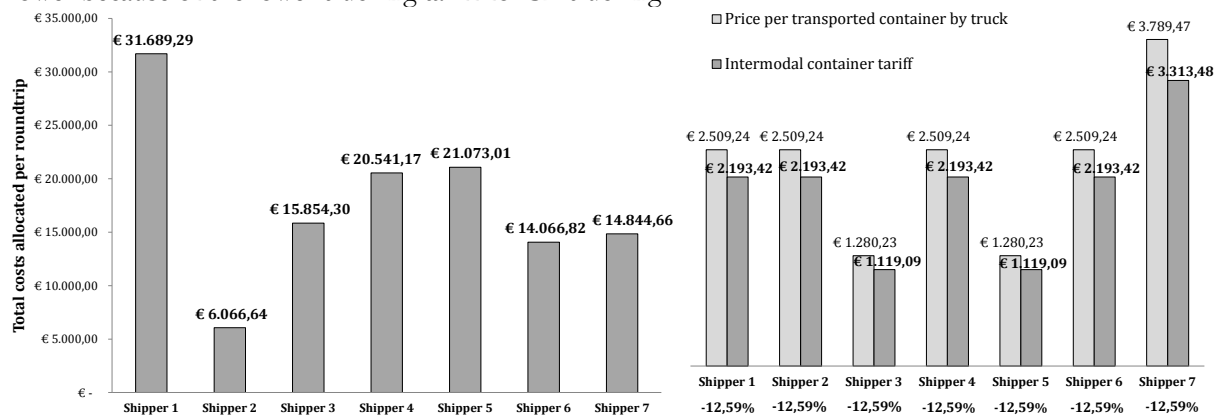
Figure 7.6 Cost allocation scenario 1 per roundtrip per shipper and container tariff p_u per shipper

The individual rationality property within the EPM allocation makes sure that the allocated costs will not exceed the stand alone cost. In Figure 7.6 the tariffs per container are depicted. These tariffs are calculated by dividing the absolute allocated costs per roundtrip i by the expected number of containers transported per roundtrip i per shipper. These again are based on simulation outputs. All shippers have an equal relative saving of 12,59% in comparison with the costs for trucking a container. Note that this saving is equal to the saving of the grand coalition relative to the accumulated stand-alone costs. The goal of the EPM method is to minimize the relative savings, which in this case apparently led to a relative saving of 0 between all shippers. Shipper 7 has a higher tariff per container because for this shipper the tariff resembles a "roundtrip ticket". Shipper 7 committed five containers in both directions. The price per transported container by truck are the same for shipper 1,2,4 and 6 and for shippers 3 and 5. This is because the specific trucking discount factor were all valued at 1 in the base case. Shippers 1,2,4 and 6 only have NB need for transportation and therefore pay an equal NB tariff per container in the coalition of €2.193. Shipper 3 and 5 have SB need for transportation and therefore have an equal SB trucking tariff per container of €1.119. The roundtrip container tariff for shipper 7 equals €3.313.

7.3.2.2. Allocation scenario 2

The second allocation scenario resembles the situation in which the project committee decides to split the total intermodal route into two parts. The rail part (long haulage) and the drayage part. It is arguable that shippers do not want to pay for activities needed for other shippers to get containers from terminals to destinations or vice versa. The details of this cost allocation rule were discussed in section 7.2.3. of this report. In Figure 7.7 the costs allocated per shipper are displayed and the tariffs per container while using the second exploitation scenario are displayed. Again these are calculated by dividing the absolute allocated cost values by the expected number of transported containers via the intermodal system per shipper.
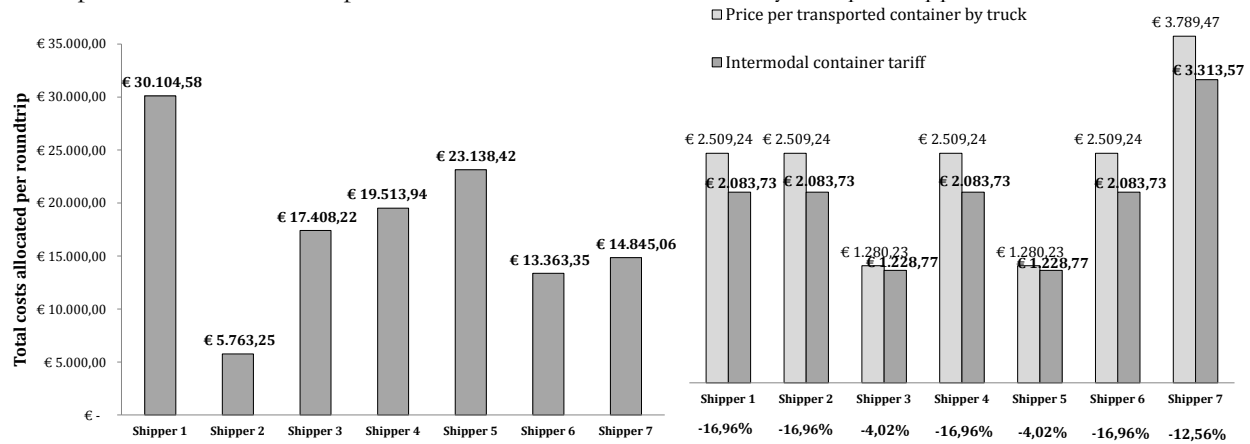
Figure 7.7 Cost allocation scenario 2 per roundtrip per shipper and container tariff p_u per shipper

The absolute cost figures allocated do not lead to any specific conclusions. Looking at the new tariffs per container the conclusion can be made that the relative savings between the shippers have changed. These changes are in favor for those shippers that transport containers NB. Their relative savings have increased to a total of 16.96%. The shippers that transport volume SB generate a total expected saving of 4.02% per transported container. Shipper 7, who commits slots on a roundtrip basis realizes a saving of 12.56% per container. This change in relative savings can be explained by the market specific characteristics of the current situation where containerized transportation is carried out by trucks. Again the imbalance in the total number of trucking flows between Spain and the Netherlands is important. The costs of the intermodal route without the drayage activities by road ($C_{acam}(N)$) are allocated relatively equally among the shippers. Since the stand-alone costs for SB shippers is lower than of NB shippers, shippers that transport cargo SB will get allocated less costs (absolute wise). Therefore the NB shippers "pay" a part of the long haulage for the SB shippers. If the cooperation chooses that all shippers have to pay for their drayage activities separately the differences in stand-alone costs (trucking costs) are not taken into consideration any longer. For that reason the savings of the shippers that commit volume SB see their savings decline much faster. The absolute trucking costs directly

allocated to SB shippers have a higher impact on their savings since their initial cost were much lower because of the lower trucking cost.

Table 7.3 shows the provisional and final (i.e. without and with the drayage costs, respectively) costs and savings per shipper. The provisional savings are equal for all shippers. The total cost of the drayage activities (non-transferable) do not take any shippers' complete provisional savings. Whenever this was the case the last restriction in the nonlinear problem formulation of the modified EPM could be changed to 1 (to get at least a saving of 1%). This would lead to different provisional savings between shippers. However as explained before have the non-transferable drayage cost (d_u) more impact on shippers that are transporting volume SB via the intermodal route. Therefore the final savings (4.02%) are much lower compared to provisional savings for SB shippers (30.44%).

Table 7.3 Provisional and final cost allocation EPM-ACAM

Shippers	$c(\{u\})$ Stand-Alone Cost (€)	Provisional (only y_u) Allocated cost (€)	Savings (%)	Final ($y_u + d_u$) Allocated cost (€)	Savings (%)
1	36,252.20	25.218,45	30.44	30,104.58	16.96
2	6,940.17	4.827,85	30.44	5,763.25	16.96
3	18,137.15	12.616,90	30.44	17,408.22	4.02
4	23,498.87	16.346,73	30.44	19,513.94	16.96
5	24,107.28	16.769,96	30.44	23,138.42	4.02
6	16.092,28	11.194,41	30.44	13,363.35	16.96
7	16.982,12	11.813,42	30.44	14,845.06	12.56
Sum	142.010,06	98.788,59	30.44	124,136.82	12.59

7.3.2.3. Allocation scenario comparison

In the constructed model all shippers are included in the cooperation with equal average distances to the terminal and between locations. In reality these distances will differ between shippers. Therefore the costs to load and unload containers at the shippers' locations in reality differ per shipper in the cooperation. When a SB shipper is located relatively far from the terminals (compared to other shippers in the cooperation), SB shippers will endure an even faster decrease of their savings when the second cost allocation scenario is used within the cooperation. When the second cost allocation scenario is used, the founding fathers can choose to set a minimum saving making sure each shipper gets at least the determined minimum saving. The last restriction in the modified EPM-ACAM allocation can be used to set a minimum saving per shipper in the cooperation. Figure 7.8 compares both allocation scenarios given the base case input parameters whereas the minimum saving is changed from 4% up to 12%.
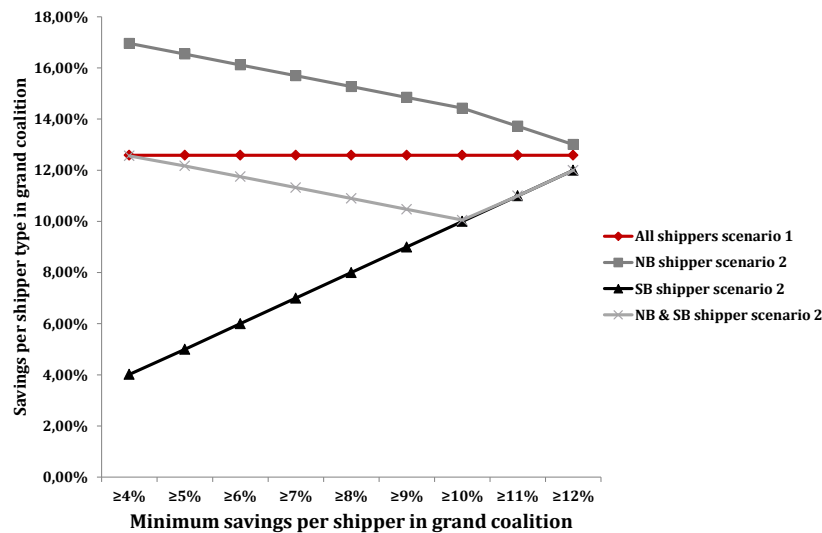

Figure 7.8 Savings per shipper type given a minimum saving for both allocation scenarios

A minimum of 4% is chosen because in the base case the SB shippers have a saving of 4.02%. Setting the minimum saving lower than 4% will not change the base case allocation among shippers. Setting the savings in the second allocation scenario higher than 12.59% is not possible as the efficiency property makes sure that the accumulated costs must be equal to the total exploitation cost. A minimum saving of 13% is not possible as the cost allocation according the first scenario leads to a relative similar saving among all shippers of 12.59%. Note that within allocation scenario 1 all shippers received a similar saving because the relative difference was minimized to 0. This allocation is represented by the flat red line in the graph.

This graph also indicates that NB shippers benefit the most when the second allocation scenario is applied as their relative saving increases compared to allocation scenario 1. More costs are transferred to SB shippers compared to allocation scenario 1. Up to a minimum saving of 9%, shippers that transport volume NB and in both directions cover the extra costs that are no longer covered by the SB shipper because of the saving restriction. When the minimum saving is set to 9% or higher, NB shippers also cover costs for the shippers that commit volume in both directions (and the savings of shippers that transport volume in both direction increases again).

Another conclusion is that marginal savings for SB shippers increase faster than savings for shippers transporting cargo NB decrease. If NB shippers agree to set a boundary on the minimum savings per shipper in the cooperation, a collaboration for SB shippers becomes disproportional more attractive. A combination of shippers transporting volume in both directions or only NB are able to make the route a lot more attractive for SB shippers. A small "investment" (accepting a lower saving) in the second allocation scenario for shippers transporting cargo NB, leads to a rapid rise in possible savings for SB shipper. When shippers transporting volume NB for example agree to hand in less than 1% of their original savings, the savings of SB shippers increase with a little more than 2%. This relations holds until a minimum saving of 9% in the base case.

7.3.3. Exploitation risks

From the results of the previous section, the cash flow between the shippers in the cooperation and the control tower can be determined. Considering a long horizon with a lot of roundtrips, the mean values determined by simulating 50,000 roundtrips can be seen as the expected costs of exploiting the intermodal route. If each shipper pays a container tariff per transported container based on the expected cost values, on the long run it can be expected that enough money is payed to the control tower to make sure this entity can pay all other stakeholders (the rail operator, the reefer lessor etc.).

An operational season only lasts 22 weeks whereas in the first season two roundtrips per week are executed. In total this gives 44 roundtrips. Within this project however, only uncertainty in the available cargo quantities and minor eventualities such as unexpected emergency deliveries are taken into account. Simulating 50,000 roundtrips will result in an average mean need for transportation per shipper close to its mean need for transportation. However, it is possible when considering a few dozen roundtrips significantly less containers are transported for some shippers in the cooperation. Instead of paying the expected cost values per transported container, every shipper could pay the tariffs based on the expected cost with an additional surplus to mitigate the risks that occur because of uncertainty in cargo quantities.

One of the interviewees at the Port of Rotterdam mentioned that it is very important to be transparent. This applies especially to costs expectations of participants. Expectation management is crucial for a collaboration to be successful. This can partly be done by calculating the worst case cost values of a project. Agreements on the maximum losses a participant is risking in a cooperation can be determined and agreed upon. By determining the "bottom line" of a project the interviewee mentioned that parties are less scared when a project has to cope with some setbacks. This increases the possibility of keeping all stakeholders and participants within the collaboration.

During simulations the cost evaluation (intermodal cost – trucking cost) per roundtrip is analyzed. Figure 7.9 depicts the output of the absolute cost saving per iteration or simulated roundtrip for the grand coalition. From this figure the upper and lower bound in total cost saving per roundtrip can be determined. From this output it can be seen that the "bottom line" of exploiting the intermodal route is a roundtrip that yielded a loss of €25.9*K* when compared to trucking the same amount of containers. Even though changes on such negative results are very low it can occur, as in reality it is unlikely that cargo availability is stable. Therefore the cooperation should take this into account to set the right expectations among participants.
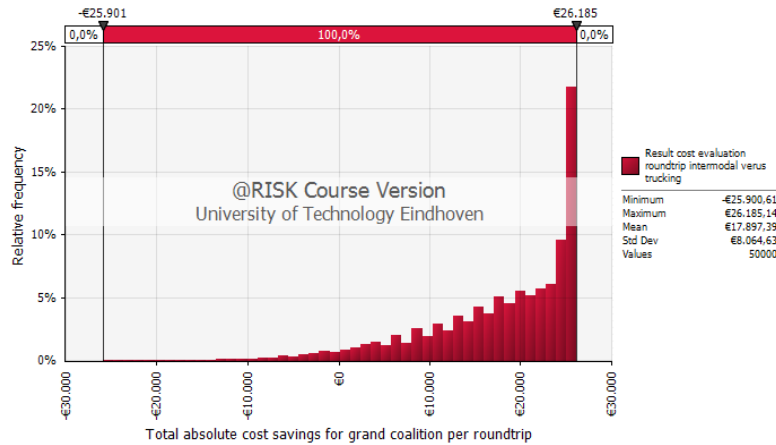

Figure 7.9 Simulation output cost evaluation intermodal versus trucking

Since the CRS route is a complete new implementation it is very plausible that the project has to cope with some unexpected setbacks and other operational problems that lead to extra costs. The real costs per roundtrip therefore could deviate substantially from the calculated expected values whenever such operational eventuality occurs, while in this model only risks caused by cargo availability are included. The rail operator mentioned that in order to let the exploitation of a synchronized intermodal supply chain succeed the ability to react quickly to operational challenges / problems in combination with situational awareness is a necessity. Operational challenges such as: trucks that are delayed caused by flat tires or because the cargo was not ready at a shippers' cargo pick-up location, snowy roads or traffic jams, and deviations on the expected time schedules of trains that inevitable will lead to an adjustment of the trucking schedules. All these unexpected eventualities will lead to an increase in cost for entities in the cooperation because they have to make adjustments in the initial plans. The initial offered contract prices to the cooperation are based on these initial plans. Even though the constructed cost model does not include costs that occur because of unexpected events, referred to as major eventualities, it can be included in the cost allocation determination by adding a surplus value per determined container tariff per shipper.

7.3.4. Empty container slot management

A big risk during exploiting the CRS route (especially in the first seasons) is having empty container slots on a roundtrip because the cooperation has less cargo volume available than committed. Two options to cope with these risks are tested and the results are given below:

The first option is letting the rail operator manage a fixed number of container slots per roundtrip. This solution is desirable if the cooperation has not sufficient average need for containerized transportation to come up with an expected 40 containers per roundtrip. The rail operator is responsible for that fraction of the total costs determined by its committed container slots. The number of slots which are managed by the rail operator can thus be considered as deterministic by the cooperation as these do not lead to any risks for the cooperation. In the model this can be resembled by a shipper type whereas the input parameter for the need for transportation is deterministic. The cost model has been tested whereas the need for transportation parameter of shipper 7 is changed into a deterministic variable. This leads to an increased total expected savings for the grand coalition of 12.92% (for the base case it was 12.59%). This is caused by the fact that a

portion of the fixed costs of the exploitation of the route is always covered by the rail operator. Whenever the cooperation has less containers available than committed, less fixed costs are covered by the amount of filled containers transported (marginal increase of fixed cost allocated to filled containers when transporting vacant slots is lower).

The second option is letting the control tower resell empty container slots of the cooperation to shippers outside the cooperation. The results for the second option are depicted in Figure 7.10 and hold for the base case. Two scenarios are tested. A scenario in which the control tower is able to resell up to 5 containers per roundtrip among its customer base. And a scenario whereas the control tower is able to resell a maximum of 10 containers. Within both scenarios the costs to source the cargo at an external shippers location is higher than the payed tariffs per container slot by these shippers. For the payed container tariffs the same tariffs were used as determined in the first allocation scenario for the base case. In this way it is tested until what amount the cooperation can "sponsor" the sourcing of external cargo before it is better to leave spots empty on a roundtrip. By letting the external shippers pay less than the actual costs, wider terminal areas for external shippers can be served. In situations the train leaves with empty container slots, the fixed costs are allocated to less containers which leads to an increase cost per filled container. By reselling slots the amount payed by external shippers is used to cover a part of the total costs for the cooperation. In situations in which the costs exceed the payed tariffs with €100, the cooperation yields extra benefits because the "extra costs" do not exceed the decrease in "rest costs" for the cooperation. This relation holds up to €700 in extra costs for picking up and delivering cargo per container for external shippers. Whenever less costs are made more resold containers to external shippers off course leads to lower total rest costs for the grand coalition.
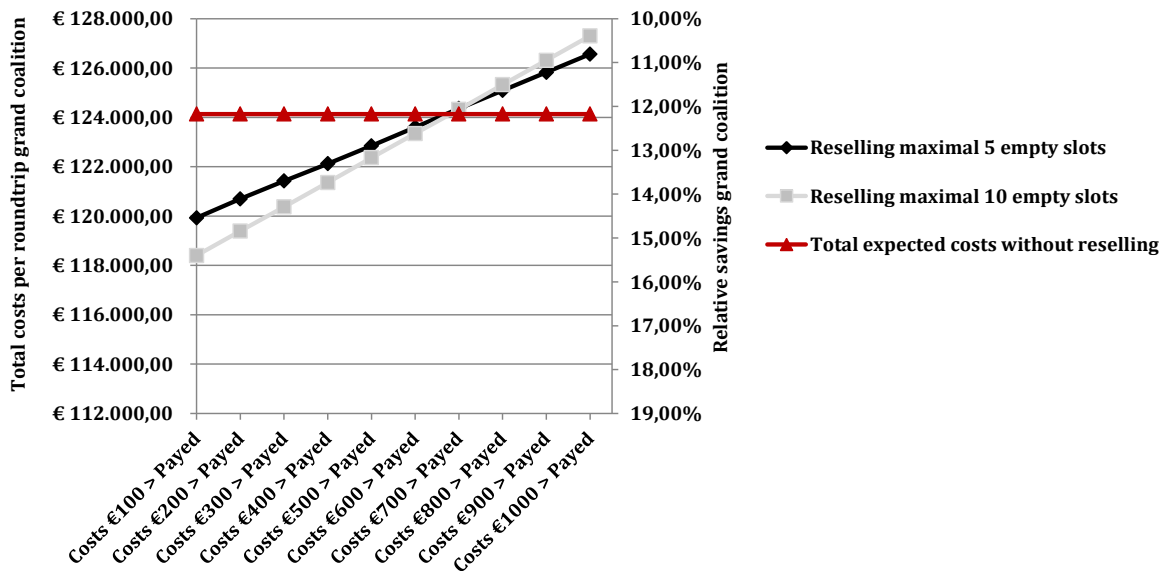
Costs for sourcing external shippers' cargo per container on roundtrip versus amount payed by shipper

Figure 7.10 Total costs for grand coalition with and without reselling of container slots

7.4. Analyses

In this section effects of some parameters on the expected total supply chain benefits and cost allocations are discussed. First the effect of changing the accumulated commitment quantities in the grand coalition is examined. Hereafter altering the drayage areas on the total expected cost savings for the grand coalition is researched. Next the effects of changing the efficiency levels during drayage activities on the total costs is examined. Fourthly the sensitivities of the trucking specific discount factors of shippers are explored. The analyses ends with checking the effects of correlated demands among shippers on the total costs expectations of exploiting the intermodal route. Two assumptions are subject to a sensitivity analyses as well. These contain the assumptions for the profit margins of LSP's and the delay factors for both transportation via rail and road.

The results for the latter two can be found in appendix G. These are included for integrity reasons. A part of the sensitivity analyses are executed by using the expected need for transportation values (extracted from the simulations) as input for the constructed cost functions. All variable costs in the intermodal setting are a function of the actual number of transported containers. When using the expected values of the input variables as fixed values in the cost functions, other parameters in the cost functions can be altered. This is how the graphs, representing the total expected cost savings per drayage area, are constructed.

7.4.1. Effects of grand coalition composition

Throughout this sensitivity analyses the same input parameters as the base case are used except the grand coalition setting is changed. Instead of setting the accumulated commitment number into both directions equal to the trains' capacity of 40 containers, the directional accumulated commitment numbers are changed and again 50,000 iterations are simulated per scenario. Three lines are depicted which depict three different types of grand coalition composition scenarios. In the first type both the NB and SB accumulated commitments are reduced. The other lines represent scenarios in which one directional accumulated commitment is held constant at 40 containers, whereas the other direction is reduced. In the case that the commitment numbers of the grand coalition are 40, a total expected cost saving of 12.59% is obtained which off course is the same as the results in section 7.3.1 as all the parameters are the same as the tested base case.

If the grand coalition has the same amount of accumulated commitments in both route directions there should be strived for a minimum commitment of approximately 32 containers. This can be considered as the break-even point for the intermodal route when comparing it to the current situation of trucking containers. The other conclusion that can be drawn from this graph is that vacant container slots NB lead to a faster decline of total cost savings than vacant slots SB. This is because SB shippers have lower trucking tariffs. Lower trucking tariffs lead to a lower impact on the accumulated stand-alone costs of the grand coalition which are directly related to the total cost savings. Break-even points of an intermodal route are very case specific and largely depend on the trucking tariffs per shipper in the cooperation. However if the cooperation is able to reach NB commitments close to the trains' capacity the SB commitment can drop significantly below the trains' capacity before the route is not cost efficient any more. When the stand-alone costs are higher more costs can be made for the exploitation of the intermodal route before the cooperation is not viable anymore and the break-even point (intersection of lines with horizontal axis) shifts to the right as can be seen in the graph.
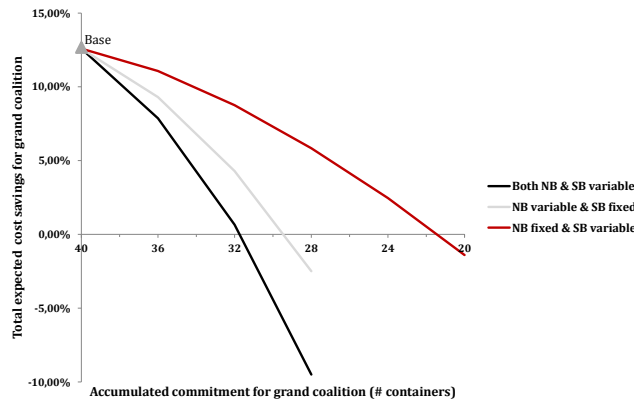
Figure 7.11 Effect of different grand coalition compositions on total expected cost savings

7.4.2. Effects of drayage areas

The line in Figure 7.12 gives the cost evaluation (cost intermodal – cost trucking) for an increase in both northern and southern drayage areas in both absolute as relative savings. Again all variables are held the same as in the base case whereas now the drayage areas are altered. A bigger drayage area leads to bigger average expected travelled trucking distances during drayage activities to transport containers from the terminals to shippers or vice versa. These average expected drayage distances (caused by the surface of the areas) have quite some impact on the total expected cost savings in absolute terms. Given the grand coalition composition of the base case the drayage areas in both terminal areas can increase to $150,000 km^2$ before obtaining 0

savings. An area of 150,000km^2 leads to an expected average combined drayage trip of 418km in the northern area and 673km in the southern area. For the final shipper setting these distances probably are too big because the shippers are located closer to the terminal but it does show what distances can be covered before the route is not cost efficient any longer. In appendix H an overview of average expected trucking distances per drayage areas can be found.
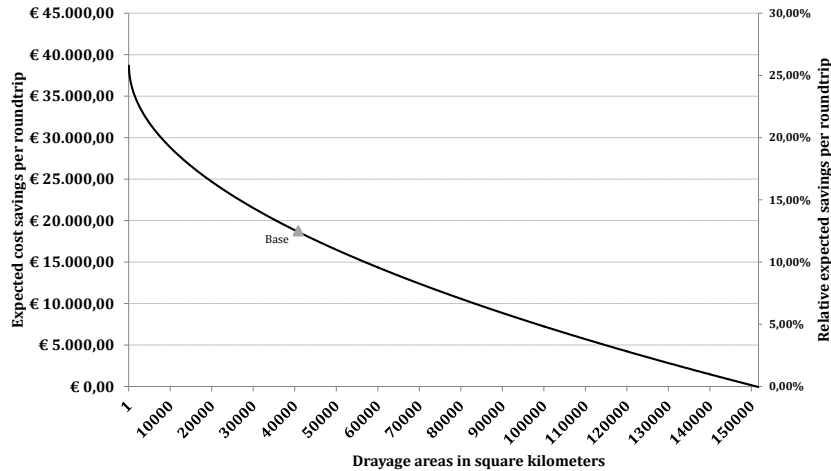
Figure 7.12 Effect of drayage areas on expected cost savings of intermodal situation versus trucking

The effects of a varying drayage area on the allocated cost per shipper in the grand coalition has also been considered. It is not surprising that the first cost allocation scenario leads to the exact same shape as the line in Figure 7.12. The efficiency property of the cost allocation makes sure that the total cost savings obtained by the grand coalition equals the accumulated cost allocated per shipper. Thus minimizing the relative savings among shippers leads to a relative saving per shipper that is equal to the total relative cost saving. That is why the cost allocation per shipper for the first scenario in Figure 7.13 on the left has the same shape as the line in the upper figure. Because there are no differences between the shipper specific allocations, all relative savings per drayage area of the seven shippers are expressed by the same bar.
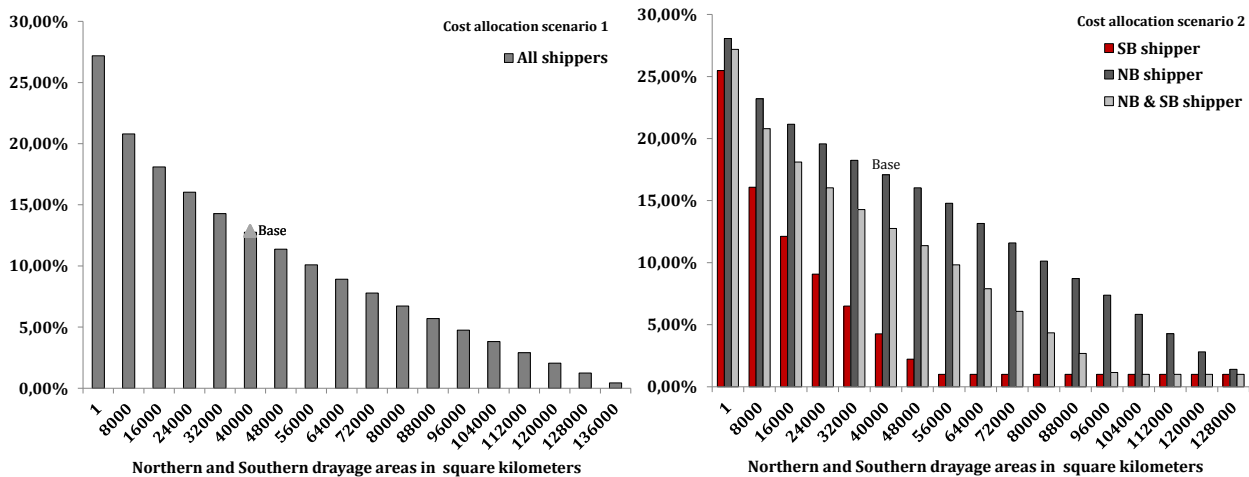
Figure 7.13 Effect of drayage areas on cost allocations per shippers according scenario 1 and 2.

The right graph displays the results of applying the second cost allocation scenario on the results depicted in Figure 7.12. Because the discount factors per shipper are held constant (still valued at 1) per area surface three different container tariffs are derived. One for shippers transporting containers NB, one for shippers transforming containers SB and one for roundtrip shipper 7. Even when the drayage area is "artificially" set

46

on 1 square kilometer, a relatively big difference per shipper type occurs. This is due to the time dependent cost factors in the cost model, such as unloading, loading and waiting time. They take place independent of the distance of a trip. These are also allocated separately as a non-transferable cost to each shipper. An increase in drayage areas leads to higher non-transferable shipper specific drayage costs. These costs have more impact on shippers transporting cargo SB caused by the low market trucking rate. If the drayage areas become larger than $48,000 km^2$ the SB shippers are allocated costs that lead to unstable cost allocations. For the roundtrip shipper this happens at an area of $96,000 km^2$. From these surfaces on, the last constraint in the modified EPM makes sure that these shippers hold a minimal saving of 1%. In these cases shippers that transport cargo NB cover the increase in drayage costs (that are not allocated to the other shippers because of the maximum cost restriction that ensures at least a saving of 1%) of the other shippers in the cooperation. That is why the savings of the NB shippers keep decreasing when the drayage areas increase above the surfaces when other shippers savings are held at 1%. If the drayage areas become larger than $128,000 km^2$ not enough supply chain benefits are obtained to get a stable cost allocation in the second scenario (given the other input parameters used in the base case).

7.4.3. Effects of efficiency during drayage activities

So far the parameter M is held constant at 40. The parameter M represents the number of locations known during a certain time window. More drop-off and pick-up locations of cargo during a certain time window per drayage area, leads to a lower nearest neighbor distance between locations because locations can be visited more efficiently (more locations in an area that will not get bigger decreases the average expected distances between these points). Lower average distances lead to lower costs and this section analyses the effect of changing this parameter that influences the nearest neighbor distances. The parameter represents two environmental properties during the operational execution of drayage activities that are listed below:

1. The shippers within the cooperation can deliberately choose for a centralized control of drayage activities after the train arrives at the intermodal terminals. This centralized control can be represented by a higher parameter M. A lower M resembles the situation when shippers independently execute their drayage activities and therefore loose the possibility on synergy possibilities that LSP's have when centrally planning the drayage trips.

2. Another factor are the time windows in which the cargo has to be delivered or picked up at shipper locations. If all shippers set very small time windows in which cargo needs to be picked up or delivered, this decreases the possibility that a high number of locations can be served during the same time window. The rail operator also mentioned the upper relation between efficient planning possibilities and flexible arrival times of trucks at locations of shippers. The rail operator emphasized the importance that within an intermodal synchronized exploitation more flexibility is needed from shippers with respect to these time windows. The rail operator gave arguments from an operational perspective. He mentioned delays of the train that will occur which requires more flexibility in the arrival times of trucks at shipper locations and therefore more flexible time windows for their pick-up and delivery times of cargo. A high value of M reflects very wide time windows whereas a small value of M reflects the situation if shippers are demanding very specific pick-up and delivery times for their cargo. This makes an efficient drayage planning more difficult since small time windows lead to situations whereas the planning of drayage trips is restricted by a few number of locations per overlapping time windows. Less locations that can be visited during a certain time window leads to higher nearest neighbor distances and therefore higher costs.

Figure 7.14 represents the impact of altering the M parameter in the cost model. The upper bound in costs is determined by the lowest value of $M = 5$ (non-centralized drayage and/or a combination of very small time windows and non-flexible shippers) and resembles the lowest possible savings. The lower bound in costs is determined by setting the parameter M as high as possible, which is $M = 64$ (very efficient centralized drayage and/or a combination of very wide time windows and flexible shippers).
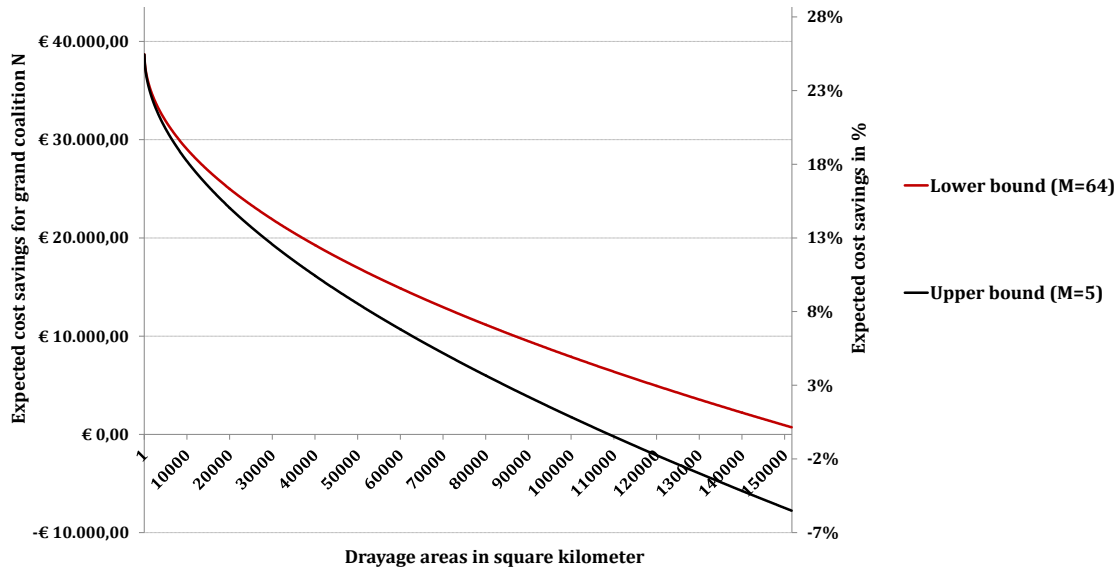
47

Figure 7.14 Upper and lower bound in costs due to efficiency of drayage activities

Comparing the lower and upper bound lines in the figure with each other indicates that efficiently planning the drayage activities has an significant impact on the expected cost savings. Besides it emphasis the level of importance for shippers to take a flexible attitude towards the cooperation. This leads to serious cost reductions for the road part that has a significant impact on the total exploitation costs as well. For a drayage area of $40,000km^2$ the difference in total cost savings for the cooperation between the lower and upper bound in costs is 2.18%. On average the difference between the upper and lower bound in expected cost calculations is €4.8K. Comparing this value with the expected savings of around €18K in the base case, emphasizes the level of importance of taking the upper two mentioned environmental properties into account when exploiting an intermodal route. The maximum drayage areas for both terminals decrease from above $150,000km^2$ to approximately $108,000km^2$. Translating these areas to expected distances for roundtrips leads to the following results. For the southern area the lower and upper bound in costs leads to a decrease of maximal distances for combined drayage trips from 682.04km to 571,17km. In the northern area this leads to a decrease of maximum drayage distances from 424,02km to 355,09km per efficient combined drayage trip.

7.4.4. Effects of shipper specific discount factors

In this section the effects of changing the shipper specific discount factors are researched. Again all parameters are held constant as determined in the base case except the parameters representing the discount factors. The trucking market is characterized by a high imbalance in freight flows. This leads to different directional trucking prices. The shipper specific trucking prices determine the stand-alone cost and subsequently the possible savings that can be obtained by collaborating. In reality the trucking tariffs NB are fairly equal among different shippers. Many trucking flows exist due to very high demands of shippers that hire LSP's to transport commodities, such as perishables, to the Netherlands. Therefore the discount factors for the shippers transporting cargo NB are not altered during the analyses. The SB specific trucking tariffs however might differ a lot between different shippers in the cooperation. This SB trucking market is not characterized by one market tariff per transported container. Especially during wintertime in the Netherlands a high surplus of import flows exist and Spanish LSP's are eager to find nearby volume that needs to be transported back to Spain. A party with high bargaining power might be able to negotiate a very favorable tariff for itself (even below cost price of the LSP). Shippers that do not transport high volumes SB are probably less capable to negotiate a very low trucking tariff.

Using @Risk, a sensitivity analyses is performed by varying the discount factors of the SB market trucking rates between 0,7 and 1,3. In this case 0,7 stands for a very low trucking rate and 1,3 represents a trucking

tariff that is relatively high compared to the average SB market price. In the tested base case only three shippers (3, 5 and 7) commit volume in the southern direction. The effect of altering the discount factors on the expected total cost savings for the grand coalition are determined. The results are depicted in Figure 7.15 and are based on the base case grand coalition setting.
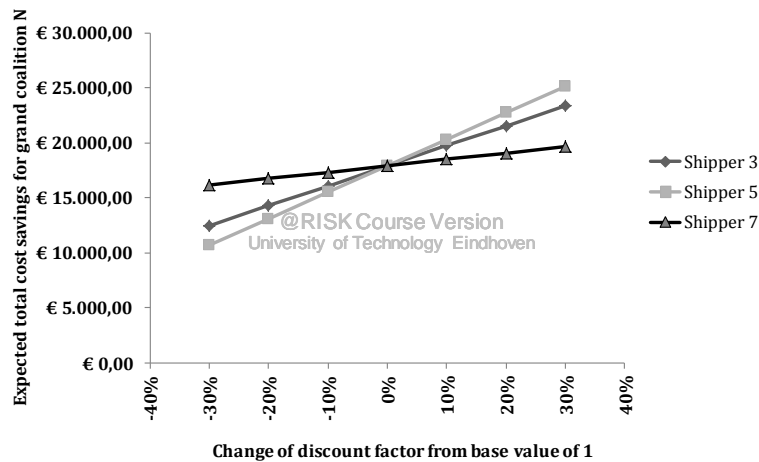

Figure 7.15 Sensitivity of changes in discount factors per shipper

A steeper line in the sensitivity report means a higher influence of a shippers' trucking rate on the total expected cost savings. This is not surprising as hipper 5 is the most influential. This is not surprising because shipper 5 has the highest commitment of 20 containers per roundtrip. This shipper approximately accounts for 15% of the total accumulated stand-alone costs. Therefore changing its SB trucking cost with -30% (discount factor 0.7) leads to a decrease of the expected savings per roundtrip of approximately €7K. In the other direction the same relation holds but it is less probable that a shipper with commitments reflecting such volumes has a SB trucking rate that is 30% higher than the average market price. However if it does, the expected total cost savings for the grand coalition will rise to an expected value of approximately €25K per roundtrip. This analyses depicts results of changing one value at a time, while holding all other discount values at the base values. Combining changes in the same direction of several discount factors at the same time would lead to more extreme changes in the expected cost. It would "smooth" the effects (i.e. less steep lines) when discount factors among different shippers are changed in opposite ways. Testing all these scenarios would lead to a lot of different combinations without leading to better insights. Therefore the remainder of this analyses focuses only on changing the discount factor of shipper 5. As concluded above, has this shipper the highest impact on the total expected savings.

In Figure 7.16 the expected cost savings of the grand coalition per SB discount factor of shipper 5 in relation with the drayage areas are presented. The shipper specific discount factor has a high influence on the expected cost savings. For the discount factor of 0.7 the maximum drayage areas decrease to a surface of around 105,000km^2. Given the market characteristics for trucking containers it is highly plausible that a shipper or a combination of shippers have SB trucking tariffs not meeting the standard market price but lower. Therefore the expected cost savings probably will be somewhere on the line representing the situation in which shipper 5 has a discount factor of 0.7. For the base case (with drayage areas of 40,000km^2) this would lead to an expected supply chain benefit of approximately 8%. A combination of shippers with less extreme discount factors and similar (accumulated) commitment values have the same effect as one extreme shipper that is active in the cooperation. For example if shipper 3, 5 and 7 all have a discount factor of 0.9, this could lead to similar results.

An important aspect of this new implementation and the collaborative aspects of the exploitation is creating the right expectations for other shippers that want to join the cooperation (as mentioned by the interviewee of the Port of Rotterdam). A shippers' trucking rate in combination with its container commitment is directly

related to the accumulated stand-alone costs and therefore the total cost savings of the cooperation. Therefore it is very important that these trucking rates are well estimated by the project committee in order to set the right expectations with reference to the maximum profitability of the intermodal route.
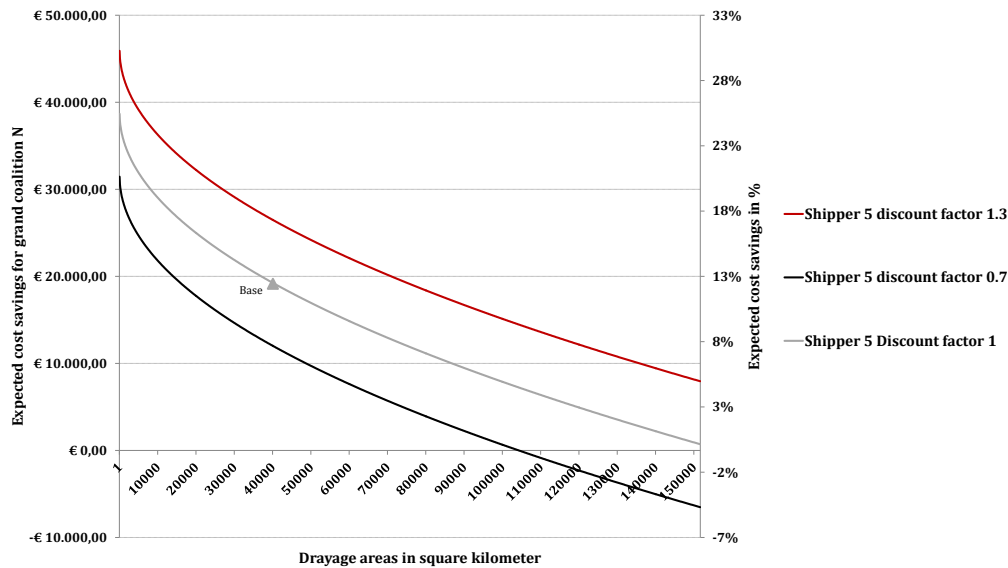
Figure 7.16 Sensitivity of changing shipper 5's discount factor on cost savings for grand coalition

Figure 7.17 depicts the second cost allocation scenario per NB and SB shipper in the grand coalition for all base case values with a varying drayage area. Cost allocations are calculated for a discount factor of 0.7 and 1.3 for shipper 5. When applying the first allocation scenario the relative savings per shipper will be equal as the total cost savings. That is why a second vertical axis representing the total cost savings in percentages in Figure 7.16 is given representing the relative savings per shipper when allocation scenario 1 is applied. When the second allocation scenario is applied the SB shippers' relative cost saving decreases faster due to a lower trucking cost. This effect is stronger for lower trucking cost (discount factor 0.7). If the drayage areas becomes too large, the individual rationality constraint of a minimum saving of 1% for every shipper makes sure that increasing part of the total cost is covered by the shippers that transport NB volume. This effect increases when the drayage areas increase. An increase of a SB shippers' SB trucking rate also leads to an increase of cost savings for all other shippers in the coalition. This also holds in the other cost allocation scenario and for all other shippers in the cooperation.

	1	8000	24000	40000	56000	72000	88000	104000	120000
■ NB shipper 0,7	24,37%	19,02%	13,78%	8,70%	3,77%				
▨ SB shipper 0,7	19,52%	4,78%	1,00%	1,00%	1,00%				
■ NB shipper 1,3	31,43%	26,10%	21,96%	19,04%	16,47%	13,75%	11,17%	7,81%	3,98%
▢ SB shipper 1,3	28,85%	18,51%	10,50%	4,84%	1,00%	1,00%	1,00%	1,00%	1,00%

Figure 7.17 Cost allocation scenario 2 and relative savings per shipper per drayage area

This graph indicates that SB shippers with high bargaining power (and a low trucking tariff) should be recognized by the project committee for two reasons:

1. The first is to create good estimations for the total possible cost savings.

2. The second is to consider what an agreeable minimum saving is for that specific shipper in the cooperation when the costs of the road aspect are allocated directly to shippers.

The earlier discussed effects of a fast decreasing relative saving gets stronger when a shipper has a low trucking tariff. What also can be seen in the graph is that a change in trucking tariffs for a big shipper in the cooperation has significant effects on the expected cost savings of the other shippers in the cooperation as well. At this stage of the project the cooperation has difficulties with finding sufficient volumes. If the CRS route successfully expands, situations may occur whereas too m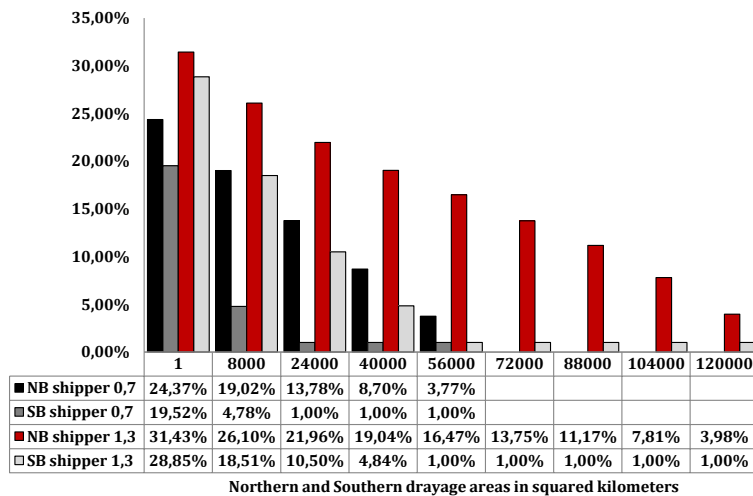uch cargo volume is available per train and not enough to start exploiting a second train. In these situations a rational reaction of other participants is to strive for the fact that shipper that have a low trucking tariff give low volume commitments as well. SB shippers with low trucking tariffs in the current situation should guard themselves against these developments.

7.4.5. Effects of correlated needs for transportation

It is very likely that all shippers within the cooperation that transport volume NB are transporting perishables. These products have strong seasonality characteristics and are very sensitive to weather conditions. Whenever bad weather occurs it may happen that there is less cargo available. These eventualities influence all shippers at the same time and therefore it is interesting to test the impact of correlated demand figures per shipper. In @Risk it is possible to construct correlation matrices. Because the SB shippers probably do not transport perishables via the CRS route these needs for transportation are not correlated when performing the simulation. An unexpected drop in need for transportation for NB shippers due to weather conditions would lead to a drop for all NB shippers in available cargo. Therefore the NB demand figures are positively correlated in @Risk to test the impacts on the cost expectations. A positive correlation means that if the need for transportation of one shipper is lower (or higher) than its mean, there is an increased probability that the same holds for the other shippers. For this sensitivity analyses the base values are used for all the input parameters. So all trucking discount factors are 1 and both drayage areas are 40,000km^2. The summary of the results of the base case and the correlated scenarios for both the upper and lower bound in cost is given in Table 7.4.

Table 7.4 Summary of simulation results with correlated demand for lower and upper bound in cost

	Total expected cost savings (€ & %)		% of roundtrips with supply chain benefit
No correlation upper bound cost	15.420,28	10.86%	94,50
Positively correlated upper bound cost	13.365,82	9.41%	87,90
No correlation lower bound cost	18.389,49	12.95%	96,40
Positively correlated lower bound cost	16.264,16	11.45%	90,40

Positively correlating the input parameters lead to lower expected cost savings per intermodal roundtrip. The number of roundtrips that yield supply chain benefits are (not surprisingly) lower as well for both the correlated scenarios. The reason for this is that the grand coalition has more difficulties with filling all the available slots per train. A drop in one shippers' need for transportation probably means that other shippers have less cargo as well. An increase in need for transportation however has less effect because of the trains' capacity of 40 slots. When all shippers have needs for transportation higher than their mean (increased probability because of correlation) only the maximum capacity of 40 containers can be transported by train. Because the overcapacity is trucked against the same trucking tariffs as in the current situation these will not affect the cost savings and therefore will not lead to higher savings. Positively correlating the need for transportation among the NB shippers seemingly has a higher impact on situations in which not sufficient containers can be filled and therefore lead to empty slots on a trains' roundtrip. This should be kept in mind to create the right expectations throughout the cooperation. In both cost bounds the environmental property that perishables are being transported and that these might be correlated among different shippers leads to a reduction of approximately €2K similar to 1.4% in relative saving for the grand coalition.

8.   Conclusions and recommendations

8.1.   Introduction

This chapter discusses the results and conclusions, the recommendations for BB, the limitations of this research and the recommendations for further research. The conclusions are structured in such a way that they provide answers on the research questions. The research questions with sub questions given and research assignment can be found in section 3.5 (page 8) of this report. Based on the conclusions generated with the cost and cost allocation model the recommendations how to set up the exploitation model are presented.

8.2.   Conclusions

In this section the main conclusions of this thesis are presented. The results from a cost perspective of a specific constructed cooperation composition are presented (base case). Moreover results that are applicable in general for a collaborative transportation corridor between Spain and The Netherlands are discussed.

8.2.1.   Conclusions regarding exploitation costs

The cost model led to a cost interval per intermodal roundtrip between €112K and €130K for the tested base case. The cost evaluation interval led to a range of roundtrips having a maximum loss and profit of respectively €25K and €26K, with an expected supply chain benefit per roundtrip of 12.6%. For scenarios in which the transported number of containers are equal in both route directions (such as the base case) the break-even point settles approximately at an accumulated container commitment of 32 containers in both directions. It is not likely that container quantities below the break-even points are transported in both roundtrip directions when having an accumulated commitment of 40 containers in both directions. Therefore the probabilities on these big roundtrip losses are small. Besides cargo uncertainty, other factors proved to have a significant influence on the total costs of exploiting an intermodal route. The main conclusions are listed below:

1.   Vacant container spots NB lead to a faster decline of expected cost savings than vacant spots SB.
2.   Efficiently managing the road aspect of the intermodal supply chain lead to lower costs by:
     o   a centralized control of the drayage activities by road within the intermodal route.
     o   implementing flexible/wide delivery and pick-up time windows for cargo at shipper locations.
3.   Other influential factors are:
     o   geographical locations of shippers with respect to the intermodal terminal.
     o   shipper specific trucking tariffs.
     o   correlated need for transportation.

These factors must be used to create reliable expectations regarding savings among participants in the cooperation. Besides exploitation losses due to cargo uncertainty, it is very important to quickly respond to operational challenges/problems. These quick responses to unexpected eventualities to maintain a synchronized roundtrip loop will probably lead to an increase in costs. It is very important to be transparent about these operational risks to other participants as well to create even more reliable cost expectations.

8.2.2.   Conclusions regarding allocation of costs

To determine viable and stable cost allocations among shippers in the cooperation, a choice was made for an allocation rule based on cooperative game theory. The decision for one specific rule is based on attended meetings of the project committee and held interviews. Based on this qualitative research the conclusion is made that intermodal collaborations are often perceived as fair if an equal relative saving per transported container among participants is used. The Equal Profit Method allocation rule, found in literature, satisfies this condition. Therefore the EPM rule is applied within the allocation model, as it strives for equal relative savings among participants when allocating joint costs. In appendix A, the composed list of allocation rules based on cooperative game theory literature can be found. To show the impacts on the cost allocations if the

cooperation decides on certain boundaries of the cost allocation, also a modification on the EPM is used. In this way two allocation scenarios are created and tested:

- Allocation scenario 1 in which all costs are considered as shared costs. In other words: everybody pays for everybody's costs.

- Allocation scenario 2 in which the shipper specific trucking costs are allocated to each shipper separately. In this scenario the shipper specific drayage costs are allocated directly to each shipper.

The goal of the aggregated cost and cost allocation model is to find stable cost allocations within the cooperation. Comparing both cost allocation scenarios leads to the following relative savings per shipper type in the cooperation:
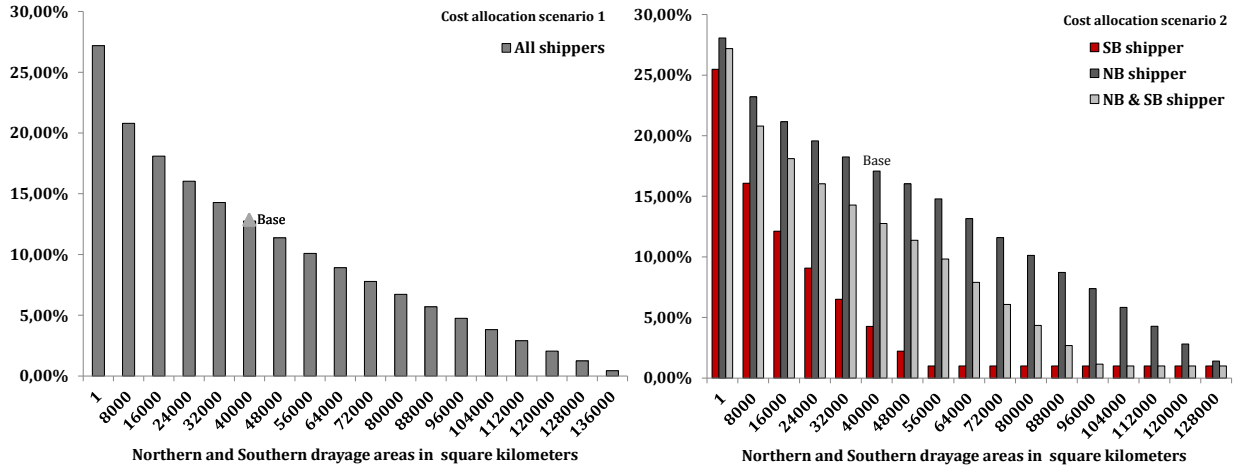
Figure 8.1 Relative savings per shipper for both scenarios with varying drayage areas

Figure 8.1 displays the expected savings per shipper type in the cooperation for both allocation scenarios given a terminal area size. If the cooperation applies allocation scenario 1 and wants a minimal saving of 5% per shipper, they should make sure that all delivery and pick-up shipper locations are located within a terminal area of $96{,}000 km^2$. The aggregated cost and allocation model proves that there exist viable ways to exploit an intermodal route in a collaborative environment reflecting an uncertain cargo environment. Special attention should be payed to the shippers that transport cargo SB to protect them for having not enough savings when allocation scenario 2 is applied. The absolute allocated trucking costs in the intermodal setting have an higher impact on shippers with lower costs in the current situation. Since SB shippers have lower trucking tariffs they see a fast decrease in relative savings if the distance to the intermodal terminals increase (increase in terminal area). Shippers that transport cargo NB benefit from the second cost allocation.
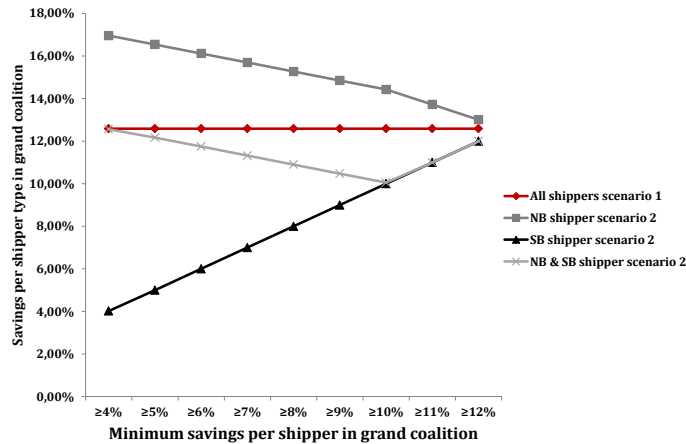
Figure 8.2 Savings per shipper type according minimum savings percentage in base case

Within the second allocation scenario a minimum saving restriction per shipper in the cooperation can be used. Figure 8.2 compares both allocation scenarios given the base case input parameters whereas the minimum saving is changed from 4% up to 12%. Marginal savings for SB shippers increase faster than savings for shippers transporting cargo NB decrease. A marginal decrease of 1% for shippers transporting cargo NB results in a marginal increase of more than 2% for SB shippers. This indicates that NB shippers are able to make the route more attractable for other shippers with just a small "investment" (accepting a lower saving). Besides, no risks are taken of losing possible participants because they feel they do not receive enough savings when setting the minimum saving per shipper high enough when applying allocation scenario 2.

8.2.3. Dealing with exploitation risks

To cope with the exploitation risks (besides cargo uncertainty), the cooperation could incorporate a surplus value paid by all participants per roundtrip. This surplus value can be added to the container tariffs as determined by the allocation model. Another important reason for working with a surplus value, is that it is believed that risks should be spread among all stakeholders in the cooperation. If one entity endures too much unexpected costs due to operational risks it will step out of the cooperation. Two important side benefits of creating an "open and shared cost exploitation culture" within the cooperation are the following:

1. It stimulates other shippers to be transparent about their current trucking tariffs. The analysis showed that these tariffs have a high impact on the expected supply chain benefits of all shippers in the cooperation. Therefore, knowing the tariffs is very important in creating the right expectations regarding savings among participants in the cooperation. Besides are these tariffs needed for a proper cost allocation per shipper, as they determine a shippers' stand-alone costs.

2. The second side benefit is that empty container slots can be managed collaboratively. The analysis showed that it is more beneficial for the cooperation as a whole to sell empty container slots with losses (actual costs > than tariffs paid) to external shippers than leaving container slots empty during a roundtrip. For the base case scenario it proved that it is beneficial to sell containers up to a loss per container of €700 before leaving slots empty yields better results from a cost perspective.

8.3.   Relevance and recommendations for Bakker Barendrecht B.V.

8.3.1.   Relevance of the constructed model

For BB this research should primarily be used as a quantitative analysis of an intermodal rail-road supply chain such as the CRS route. Within this thesis publicly available information is used to determine the cost parameter values. For internal use of the model, these can be changed into contract prices. When the final set of participating shippers are known, the approximation techniques used to determine the drayage trips can be changed into real distances between shipper locations. With small modifications, the model can be used as a tool that can support the evaluation of several exploitation scenarios such as the following:

1. The cost model can give approximations for the total supply chain cost given different shipper sets with specific locations in both Spain and the Netherlands.

2. By changing the cost allocation rule in the allocation model, the project committee can test a wide range of cost allocation scenarios and subsequently determine the shipper specific container tariffs.

If the project committee and the participating shippers agree on one of the allocation scenarios used in this research (see first recommendation), the constructed model can be used to determine what the expected container prices per shipper in the cooperation will be in reality.

8.3.2.   Recommendations

Use cost allocation scenario 1 (=EPM) because of the long-term goals of CRS.
The goal of the CRS project is to expand the train schedule to a daily train in three years. By applying an allocation rule that strives for similar relative cost savings among partners, the collaboration is made as attractive as possible for other shippers. The founding fathers in the project committee might find this unfair

because they already invested a lot of time and effort in the development of the route. However, other shippers are necessary to have sufficient transport volume (critical mass). For the tested base case a comparison between both allocation scenarios led to the following result. NB shippers saw an increase in savings, from 12.59% to 16.96%, while SB shippers a decrease in savings of 12.59% to 4.02%. For a NB shipper who commits 15 containers NB (shipper 1 in base case) this equals to an increase in absolute cost savings of approximately €1.5K per roundtrip. This value is negligible when put in perspective with the potential in extra benefits of an extra weekly train. When applying the first allocation scenario, shipper 1 has an absolute cost saving of approximately €5K per roundtrip. If the cooperation is able to exploit an extra train per week at least an extra €5K per roundtrip is saved by this shipper. Exploiting more trains leads to better offered prices of the rail operator due to an increased "bargaining power" so probably every extra train will result in extra marginal savings. Therefore it is recommended to apply long-term thinking (and chase the goal of having a daily train per week) when determining which allocation rule is applied throughout the cooperation. Setting an equal relative saving among partners leads to an increased potential of other parties joining the cooperation. The faster other shippers join the cooperation, the faster the cooperation can expand the weekly number of trains.

Use a central accountant to mitigate risks by sharing them between all stakeholders in the cooperation.

The exploitation of an intermodal rail-road supply chain in a synchronized roundtrip setting goes along with encountering operational challenges (Jacobs et al., 2013). The CRS route being a new implementation further emphasizes this fact. Besides uncertainties in available cargo quantities that could lead to unexpected losses, extra costs occur if operational challenges are encountered. These can range from a flat truck tire, damaged cargo, train and/or truck delays due to weather conditions etc. These eventualities will impact the smooth flow of the collaborative transport activities and disturb the synchronization. To tackle this it is very likely that extra costs are made. For example if trains are delayed it is likely that extra trucks are needed to deliver all cargo to the shipper locations and return back to the terminal with filled containers on time. It is too simple to assume that the LSP's and rail operator that are hired by the cooperation will cover all unexpected extra costs. Besides, shifting too many risks and costs to entities other than the shippers can lead to unviable situations for these entities which subsequently can lead to the withdrawal of key partners from the collaboration.

Using simulations (50,000 iterations/roundtrips) an average expected roundtrip costs in the intermodal setting is determined that yields supply chain benefits. However an operational season only lasts for 22 weeks with in the first year(s) either 44 or 22 roundtrips depending on the season. It is perfectly possible that instead of the expected cost values, a roundtrip is less profitable due to a shortage of cargo in combination with the upper mentioned reasons. Therefore it is recommended to work with a central accountant which keeps track of all the costs and payments the cooperation made so far. Instead of letting shippers pay amounts that are sufficient to cover the expected costs, each shipper should pay a surplus per roundtrip. In this way it is likely that at the end of a season shippers receive a refund and are not burdened with unexpected extra costs. Whenever unexpected events occurred during a season, the cooperation as a whole can determine how to cover the extra costs by using the surplus values that are already present at the central accountant or by designating a stakeholder who is responsible for the extra costs. For the determined container tariffs plus surplus values the cooperation could use the "old" trucking tariffs per shipper.

Use the control tower to "resell" empty container slots to (external) shippers outside the cooperation.

The analyses proved that it is better to "resell" containers with losses (for the base case up to €700 per container) than leaving a container slot empty. Therefore, larger areas can be served by road to fill containers that otherwise would be transported empty. It is still interesting (cost wise) for the cargo owner outside the coalition to use the CRS route because the cooperation partly covers the costs needed to "source" the cargo. In this way intermodal transportation can be cost efficient as well for these shippers. This recommendation moreover stimulates a faster growth of the route and therefore the long term goal of CRS, because of the following two reasons:

Firstly, higher commitment numbers among the same set of shippers within the cooperation are stimulated by reselling empty container slots. Shippers within the cooperation take fewer risks (an increase in costs per transported container when vacant container slots occur during a roundtrip) when increasing the accumulated commitment numbers.

Secondly, shippers outside the cooperation can use the CRS route as well. They can get used to the CRS route without taking any exploitation risks because they do not commit to the route. As a consequence they can experience the potential benefits of intermodal transportation, get acquainted and may get convinced by the concept and start using the route on a recurring basis in the future (seeing is believing).

Use a "trustee" within the cooperation.
The analysis showed that the shipper specific discount factors have a high influence on the total expected cost savings of all participants. Therefore it is recommended to use a trustee (Jacobs et al., 2013) in the cooperation that knows all the organizational trucking prices. The trustee can act as a reliable partner for all participants in the project by treating confidential information as such. For the CRS project this role could be executed by the consultants of Mercator Novus or the party who functions as the control tower/central accountant. A good estimation of the trucking prices (stand-alone costs) of each shipper is crucial to estimate the total cost savings of the project and subsequently manage the expectations of the involved shippers. This trustee could also be used to perform the central accountant role and to maintain an open cooperation.

8.4. Academic relevance

A lot scientific research exist about intermodal transportation and their potential benefits for shippers, LSP's and other stakeholders. Many articles discuss the level of importance of having enough volume and that cargo shortages often are the reason that intermodal road-rail projects fail, or can't succeed without supportive funding. This research validates the viability of this logistic concept by aggregating a cost model with a cooperative cost allocation model to cope with the collaborative aspects that are often necessary for exploiting an intermodal route. Collaborations often, only are viable whenever the pain and gain sharing is incorporated such that all participants agree. This research concentrates on this gain sharing mechanism by applying cooperative game theory in the cost allocation model. This research also yielded a cost model that is widely applicable because of its generic form. The constructed model during this project has proven its use by applying it to a real life project, and it may do so for other purposes in the future. Besides are some of the results listed in the conclusion applicable to intermodal supply chains in general.

8.5. Limitations to this research

The first limitation of this research is that it completely depends on publicly available information. Due to confidentiality restrictions it is difficult to use organization specific contract prices which would lead to better cost estimates and therefore more reliable conclusions. However, the transportation markets and its costs are transparent and the sources used reliable. The constructed contrasts in costs caused by valuing the parameters in a particular way therefore, do resemble the contrasts in reality. The overall conclusions regarding the expected cost estimations will probably hold. The boundaries on when an intermodal rail-road supply chain is beneficial given the parameters used throughout this thesis might change when using real company data.

A second limitation of this research is the assumption that the mean needs for transportation equals the commitment numbers of shippers in the cooperation.

$$Q_u^{NB} = \mu_u^{NB} \text{ and } Q_u^{SB} = \mu_u^{SB}$$

This assumption was necessary because need for transportation and commitment numbers are necessary to model the situation (to determine both costs and a way to allocate these costs). This section will give insights in the implications of the assumption and how these differ from reality.

1. In reality shippers commit volumes (far) beneath their average needs for containerized transportation. However if this was incorporated in the model, the stability of the grand coalition is at stake, the situation could not be modelled and no savings per shipper in the grand coalition could be determined. If a shippers' mean need for transportation is much higher than its commitment, they will yield more benefits when cooperating with less shippers. Shippers often will have available overcapacity to place on the train (actual need for transportation > commitments) and therefore they can ship more containers and receive higher savings when collaborating in sub coalitions with less shippers than collaborating all together in the grand coalition.

2. By assuming that the mean need for transportation equals the commitment numbers per shipper, the uncertainty in cargo availability directly affects the accumulated available containers per roundtrip. In reality a shipper for example might commit three containers while having an average need for transportation of 20 containers. The commitment numbers of this shipper can be considered as deterministic because the variance in need for transportation will never lead to a need for transportation that is less than three containers. These situations are not incorporated in this research. Therefore an overestimation of the cargo uncertainty is caused by the assumption.

8.6. Recommendations for further research

A number of objects has not been covered in this project, but deserve attention in the future. Some subjects could not be researched within the given time of a graduation project, others are neglected because certain assumptions were made. Other questions came up during the execution of this master thesis or are a consequence of this research.

Different perceptions of benefits

In this thesis, the cost allocation of the cooperation is modelled according to game theory. This assumes that stakeholders behave rational and on a transferable utility basis. This implies that the perception of the benefits of a strategy is the same as the actual calculated possible cost savings. This might not be the case as shippers in a collaboration like CRS can have different reasons to join a collaboration and therefore have different benefit perceptions (others than money). These are not included in this research. An interesting future research subject could be to investigate how shippers perceive benefits and what benefits should be included in an evaluation model to decide if intermodal transportation can "compete" with other forms of transportation.

Modeling behavior

During the execution of this thesis a choice had to be made whether shippers in the cooperation acted in a cooperative or non-cooperative way. Shippers in collaborations such as CRS have to give commitments before parties such as rail operators start to invest in developing an intermodal route. It was the determination of commitments that made it unclear whether shippers behaved cooperative or non-cooperative. Shippers commit volumes far beneath their average volumes. Questions arise why they do this and what the most important reason are for such decisions?

An interesting subject for further research is to investigate whether these kind of collaborations are non-cooperative or cooperative. It could be the case that shippers act strategically by giving commitments and wait what the move of other shippers are. It is interesting to research this kind of behavior and try to come up with different models that better reflect the behavior of shippers. For this research it is assumed that the mean needs for transportation are equal to the commitment number of shippers. Changing this assumption and construct a model reflecting the reality better (see limitations) would increase the accuracy of how viable an intermodal collaboration is.

Shortage gaming

Within the development and implementation of a new intermodal route exploited in a collaborative setting, three main phases can be distinguished. The first is the phase whereas the cooperation does not has sufficient

accumulated cargo volumes for the trains' capacity. The second phase resembles the situation whereas the trains' capacity is in balance with the total commitment numbers. The third phase represents the situations whereas the accumulated commitment numbers of a set of shippers exceed the trains' capacity. Given the assumption that shippers act cooperative the first two phases can be modelled in the same way as is done in this thesis.

If the cooperation expands because other shippers get acquainted with intermodal transportation, the accumulated commitment numbers can get larger than the trains' capacity but too small to exploit an extra train. In these situations the model will not yield stable cost allocations because shippers want to settle in smaller sub coalitions. In these situations the commitment numbers per shipper cannot be determined any longer via their average need for containerized transportation. Shortage gaming might occur which in this specific context means that shippers commit more than they need during an exploitation season, hoping that the partial commitment numbers that are granted will be sufficient. An interesting research subject would be to explore ways to cope with / model these situations, such that the cooperation remains stable.

Researches focusing on an operational level
This research focused on the development of a strategic model. A lot of factors which determine the costs of an intermodal operation were unknown during the execution of this project. Factors such as: the final set of shippers and their locations, time schedules of the train, pick-up and delivery time windows etc. If all these factors are known a wide possibility of researches that concentrate on an operational level are possible. A few examples are given:

- A first possibility is to concentrate on optimizing drayage operations.
- Another future research could focus on the optimal configuration between arrival and departure dynamics of trucks and trains and their relation to costs.
- Lastly an important subject for future research could be what the impact of using an intermodal supply chain is on important control parameters at shippers warehouses and other processes.

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Appendices

A.   Allocation Rules

(Audy et al., 2011; Frisk et al., 2010; Liu, Wu, & Xu, 2004; Slikker, 2014; Soons, 2011;)()

Volume or cost weighted method	Definition of variables	Explanation
$y_j = w_j \cdot c(N), \forall i \in N$ $w_j = \dfrac{c(\{j\})}{\sum_{i \in N} c(\{i\})}$	y_j: The costs allocated to player j. w_j: Participant $j's$ stand alone cost share of the total stand-alone costs. $c(N)$: The total costs of the grand coalition $c(\{j\})$: The stand-alone costs for player j.	This rule allocates the total cost of the grand coalition proportional to a participants' share of its stand-alone cost in the total stand-alone costs.
Shapley value	**Definition of Variables**	**Explanation**
$\emptyset_t(v) = \displaystyle\sum_{S \subseteq N\{t\}} \frac{|S|!\,(n-|S|-1)!}{n!} (v(S \cup \{t\}) - v(S))$	$|S|$: The number of collaborating participants in coalition S. $|N|$: The number of collaborating participants in grand coalition N. $v(S)$: The value of coalition S.	This method allocates the (marginal) contribution of each participant which can be described as the value of player i together with his predecessors minus the value of his predecessors, based on a random order of entering of participants.
Separable and Non-separable Costs	**Definition of Variables**	**Explanation**
$y_j = m_j + \dfrac{w_j}{\sum_{i \in N} w_i} g(N)$ $m_j = c(N) - c(N - \{j\})$ $g(N) = c(N) - \displaystyle\sum_{j \in N} m_j$ **Ways to calculate w_j:** *Equal Charge Method (ECM)* $w_j = \dfrac{Non - seperable\ costs}{\#\ of\ Participants}$ *Cost Gap Method (CGM)* $w_j = min_{S:j \in S} g(S), with\ g(S) = c(S) - \displaystyle\sum_{j \in S} m_j$ *Alternative Cost Avoided Method (ACAM)* $w_j = c(\{j\}) - m_j$	y_j: Cost allocated to participant j. m_j: Separable costs for participant j. w_j: Weighting factor to allocate non-separable cost to participant j. $g(N)$: Non-separable cost. $c(\{j\})$: The stand-alone costs for player j.	The idea behind these methods is to allocate to each participant its separable costs and then divide the non-separable costs based on a weighted measure to all participants.
Equal Profit Method (EPM)	**Definition of Variables**	**Explanation**
minimize f s.t. $\quad f \geq \frac{y_i}{c(\{i\})} - \frac{y_j}{c(\{j\})} \qquad \forall(i,j),$ $\quad \sum_{j \in S} y_j \leq c(S), \qquad S \subset N,$ $\quad \sum_{j \in N} y_j = c(N)$	y_j: Cost allocated to participant j. $C(\{i\})$: Stand-alone cost for player i. $c(S)$: Cost coalition S. $c(N)$: Cost grand coalition.	Minimizes the maximum difference in pairwise relative savings.

WRSM	Definition of Variables	Explanation
minimize f s.t. $f \geq \frac{w_i y_i}{c(\{i\})} - \frac{w_j y_j}{c(\{j\})} \qquad \forall (i,j),$ $\sum_{j \in S} y_j \leq c(S), \qquad S \subset N,$ $\sum_{j \in N} y_j = c(N)$	y_j: Cost allocated to participant j. w_i: Contribution ratio of player i. $C(\{i\})$: Stand-alone cost for player i. $c(S)$: Cost coalition S. $c(N)$: Cost grand coalition.	Minimizes the maximum difference in pairwise relative savings, by including contribution weighting factors.
Modified EPM	**Definition of Variables**	**Explanation**
minimize f s.t. $f \geq \frac{y_i}{c(\{i\})} - \frac{y_j}{c(\{j\})} \qquad \forall (i,j),$ $\sum_{j \in S}(y_j + w_j) \leq c(S), \;\; S \subset N,$ $\sum_{j \in N} y_j = c(N)$ $\frac{C(\{i\}) - (y_j + w_j)}{C(\{i\})} \geq P_i, \forall i \in N$	y_j: Cost allocated to participant j. $C(\{i\})$: Stand-alone cost for player i. $c(S)$: Cost coalition S. $c(N)$: Cost grand coalition. w_j: Non-transfarable costs calculated via ACAM P: minimum saving per player i.	Minimizes the maximum difference in pairwise relative savings over the transferable cost within a coalition and adding the non-transferable cost to it per participant. An extra modification is the inclusion of a participant specific minimal cost savings.

τ-Value	Explanation
Maximum amount is: $M_i(v) = v(N) - v(N\{i\})$ Minimal amount is: $m_i(v) = max_{i \in S}\big(v(S) - \sum_{j \in S, i \neq j} M_j(v)\big)$ $\tau(v) = \alpha M(v) + (1-\alpha)m(v)$	This rule compares a player's minimal rights pay-off with their utopia (ideal case). The value τ is an unique solution which is a compromise between these two values. The utopia amount (=maximum amount) of player i is the total value minus the value other players can achieve without player i. The minimal amount equals the amount which player i gets when all other players get their utopia value. For this solution the τ value lies between the minimal and the maximum value defined as indicated to the left. With $\alpha \in [0,1]$ and such that the sum of all allocations is the total value of the grand allocation.

Nucleolus
The Nucleolus identifies a cost allocation that minimizes the worst inequity, such that individual rationality is satisfied. For each coalition S it is determined how dissatisfied it is with the proposed allocation y and it aims at minimizing the maximum dissatisfaction of any coalition. The dissatisfaction of a cost allocation y for each coalition S is expressed by the excess. The excess value measures the amount by which coalition S falls short of its potential $c(S)$ in allocation y. The Nucleolus has the lexicographically greatest associated excess vector.

B. Merged drayage trips versus single drayage trips

The first figure represents the closed loop supply chain process as is the case within the CRS route. This is only possible if the cooperation executes the drayage trips such that it is synchronized with the departure times of the train.


Figure B.1 Representation of synchronized closed loop system

Whenever the train arrives at the terminal in the northern and southern area the activities that need to be performed can be summarized by two broad clusters.

1. Drayage trips to unload a container at a shippers' cargo destination
2. Drayage trips to load a container at a shippers' cargo origin location

Instead of performing two individual trips as indicated in the left figure below the cooperation is looking to make combined trips by merging a delivery and pick-up point in one drayage trip by truck. In this way the dead heading of a truck (travelled distance where the container is empty) is decreased. The proposed relational redesign on the right of the figure is taken from Morlok & Spasovic (1994).
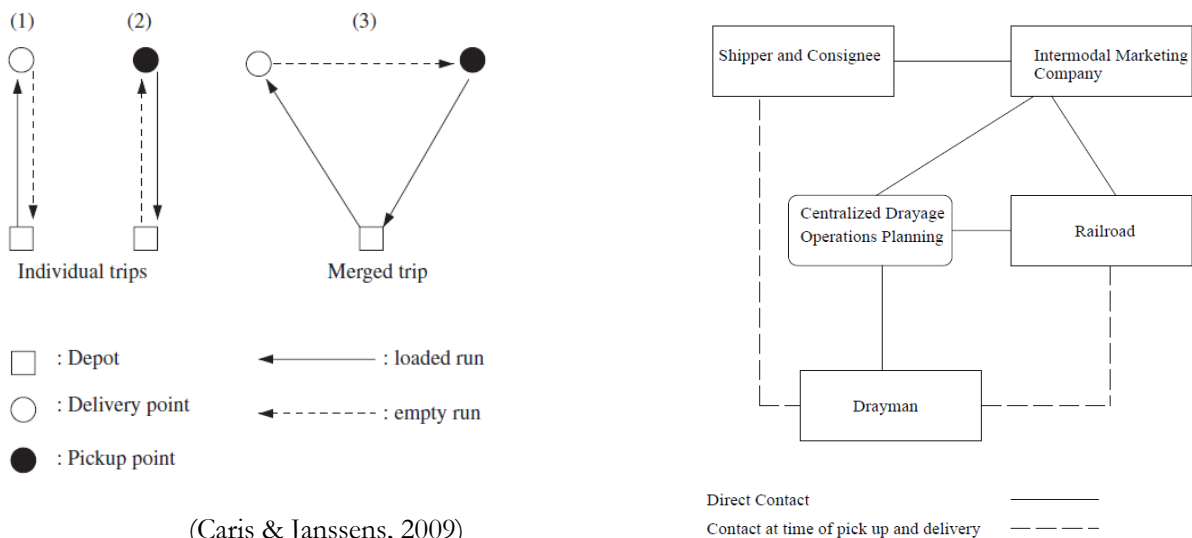
(Caris & Janssens, 2009)

Figure B.2 Single versus merged drayage trips and proposed redesign of relationships among parties

C. Continuous approximation

Table C.1. displays the configuration factors per area given both Euclidean and Manhattan norms. In this project the areas are considered circular. In the table the right configuration factor can be found behind the C and E, whereas the C indicates a circular area and the E gives the factor based on the Euclidean metric.

Table C.1 Configuration factors for areas given shape and distance metric

Market shape	Distance metric	Configuration factors		
		$\sigma(\beta, s, d)$	$\sigma(1, s, d)$	
C	E	$\left(\dfrac{2}{2+\beta}\right)\pi^{-\beta/2}$	$\dfrac{2}{3\sqrt{\pi}}$	$= 0.376$
	M	NA	$\dfrac{8}{3\pi\sqrt{\pi}}$	$= 0.479$
H	E	NA	$\left(\dfrac{1}{\sqrt{3}}\right)^{1/2}\left(\dfrac{4+3\ln 3}{6\sqrt{6}}\right)$	$= 0.377$
	M	see (3.11)	$\left(\dfrac{2}{3\sqrt{3}}\right)^{3/2}\left(1+\dfrac{7\sqrt{3}}{12}\right)$	$= 0.480$
D [a]	E	NA	$\dfrac{\sqrt{2}+\ln(1+\sqrt{2})}{6}$	$= 0.383$
	M	$\left(\dfrac{2}{2+\beta}\right)2^{-\beta/2}$	$\dfrac{\sqrt{2}}{3}$	$= 0.471$
S [a]	M	$\dfrac{2(2-2^{-\beta})}{(1+\beta)(2+\beta)}$	$\dfrac{1}{2}$	$= 0.500$

[a] For rectilinear distance, diamond-shaped market areas are squares rotated 45° with respect to the principal directions of travel, whereas square market areas are aligned with the travel directions.

Erlenkotter (1989)

Because the terminal in Spain is assumed to be at the edge of the drayage area another configuration factor, besides the given factors with a depot located in the center of the area, is needed. Table C.2 gives the configuration factors for different types of terminal locations. Note that situation b) reflects the situation in which the terminal is located at the edge of a circular area.
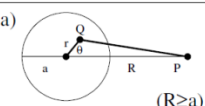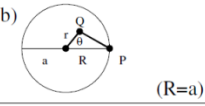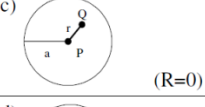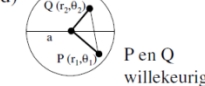
Situatie	Manhattan norm	Euclidische norm
a) (R≥a)	$E(d)\big|_{R\geq a} = R+\dfrac{4}{3\pi}a$ $\approx R+0{,}239\cdot\sqrt{A}$	$E(d)=$ $R\cdot F\left(-\dfrac{1}{2},-\dfrac{1}{2};2;a^2R^2\right)$
b) (R=a)	$E(d)\big|_{R=a} \approx 0{,}803\cdot\sqrt{A}$	$E(d)\big|_{R=a} = \dfrac{32}{9\pi}a$ $\approx 0{,}639\cdot\sqrt{A}$
c) (R=0)	$E(d)\big|_{R=0} = 0{,}477\cdot\sqrt{A}$	$E(d)\big|_{R=0} = \dfrac{2}{3}a = 0{,}376\cdot\sqrt{A}$
d) P en Q willekeurig	$E(d) = \dfrac{512}{45\pi^2}a$ $\approx 0{,}650\cdot\sqrt{A}$	$E(d) = \dfrac{128}{45\pi}a$ $\approx 0{,}511\cdot\sqrt{A}$

Figure C.1 Configuration factor for different situations for a circular area

A combination of the information mentioned in the table and figure is used to determine what values to use for the configuration factors in the cost model. For Rotterdam the factor 0.376 is used and for Valencia the factor 0.639 is used.

D. Overview of cost factors

Throughout this project costs for operating a truck and train are used to determine the cost of the intermodal route. The values of the cost parameters contain the following components:

1. Fixed costs (depreciations, MRB, interest, insurances)
2. Variable costs (repairs, maintenance, tires, fuel)
3. Staff costs (wages, social security costs, accommodation)
4. Specific transportation costs (materials used, inspections, permits, etc.)
5. Overhead (wages other staff, housing, ICT, etc.)

Besides these five cost components a distinction is made in direct and indirect costs. The direct cost are subsequently divided in direct distance dependent cost and direct time dependent cost. The relation between the cost components and the direct / indirect costs are depicted in Table D.1.

Table D.1 Relation between direct/indirect costs and components

Direct costs		Indirect costs
Distance dependent	**Time dependent**	*Fixed costs + Specific transportation costs + Overhead (per year)*
Variable costs (per kilometer)	*Staff costs (per hour)*	

(NEA, 2004)

In Table D.2 all the cost factors that are included in the used variable cost per hour and kilometer for cargo transportation by truck and train are given.

Table D.2 Cost factors included in values for cost parameters

Trucking costs	Train costs
1. Fixed costs	1. Fixed costs
Depreciation	*Fixed costs locomotives*
Interest rates	*Wagons*
Taxes	*Depreciation*
Insurances	*50% Maintenance*
General fixed costs	*50% Repairs*
2. Variable costs	2. Variable costs
Repairs	*50% Maintenance*
Maintenance	*50% Repairs*
Tires	*Fuel*
Fuel	*Other sources of energy*
3. Staff costs	3. Staff costs
Wages	*Wages*
4. Specific transportation costs	4. Specific transportation costs
Permits	*Shunting*
Chassis	*Train path charges*
5. Overhead	5. Overhead
ICT	*ICT*
Housing	

(Janic, 2007; NEA, 2004; Vermeulen et al., 2004)

The values per hour and kilometer for transportation by truck and rail used in the cost model represent the real total cost. So the used values are not corrected for the (average) load factors of both modes. This is done because in the CRS project a new route is implemented whereas FTL's are transported and LSP's offer tariffs based on this fact. Otherwise an overestimation of the cost is made. Even though only publically available information is used in order to bypass confidentiality restrictions throughout the cost functions, still a good representation of the costs in real life are calculated due to the inclusion of a broad range of cost factors in the cost parameter values as can be seen in the upper tables.

E.   Values of cost parameters

Table E.1 Values used per parameter in cost model for base case

Notation		Parameter value
A	= Surface of terminal areas in km^2	40,000
L	= Average loading time in hours per container	0.80
U	= Average unloading time in hours per container	0.70
W	= Average waiting time per (un)loading activity per container	0.25
V_{ave}^t	= Average speed in km/hour of a truck during drayage activities	50
V_{ave}^{tl}	= Average speed in km/hour of a truck during long haul activities	55
T_{cap}	= Capacity of the train in # containers	40
D_{lh}	= Distance in kilometers of the long haul by train	1,914
D_t	= Distance in kilometers of long haul by truck	1,932
V_{ave}^{lh}	= Average speed in km/hour of the train	60
TT	= Transfer time of train on different gauge width at Spanish border in hours	4
R	= Renting costs per reefer per week in €'s	270
H	= Average handling costs per intermodal terminal per reefer in €'s	40
VCT_d	= Variable costs of truck transportation per kilometer in €'s	0.27[1]
VCT_h	= Variable costs of truck transportation per hour in €'s	36.54[1]
VCL_d	= Variable costs containerized transport per train per kilometer in €'s	4.55[1]
VCL_h	= Variable costs containerized transport per train per hour €'s	751.50[1]
CT	= Yearly costs control tower in € 's	100,000
γ_r	= Delay factor in % for transportation by train	15
γ_t	= Delay factor in % for transportation by truck	5
u	= Diesel usage reefers in liter per hour	2
D_c	= Liter price Diesel in €'s	1.18
n	= Total number of trains per year	66
O	= Perimeter of areas in meters	708.98[2]
M	= Number of origin and destination locations in both areas per time window	40
τ	= Factor to change Euclidian distance into distance travelled by road	1.25
P_m	= Assumed profit margin in % of LSPs	3
k_c	= Distance factor given shape of area and location of terminal in the center of area	0.376[3]
k_e	= Distance factor given shape of area and location of terminal at the edge of area	0.639[3]
φ	= Imbalance factor $(1 < \varphi < 2)$	1.40

[1] See appendix D for a detailed overview of what factors are included in these values.

[2] The perimeter is calculated based on a circular area:

$$O = 2\pi r, \text{ and}$$
$$r = \sqrt{\frac{A}{\pi}} \quad \right\} \quad \text{thus: } O = 2\pi \sqrt{\frac{A}{\pi}}$$

[3] See appendix C for a detailed description of the values that are used.
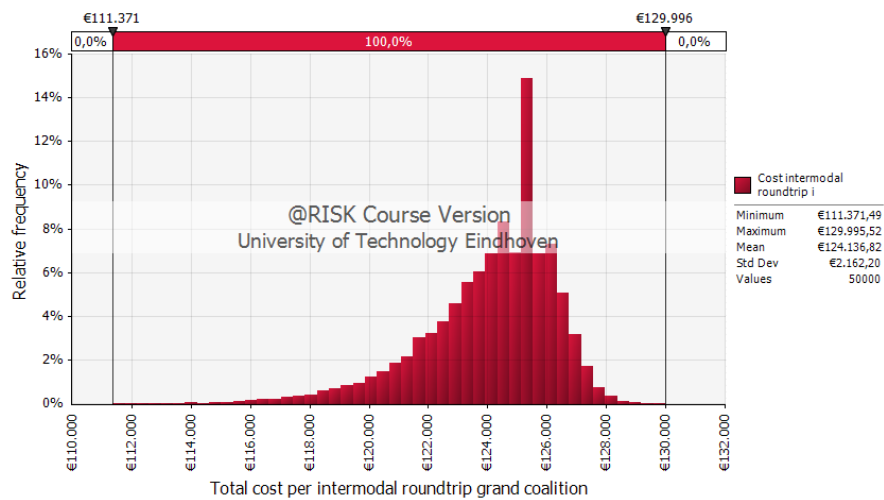
F.   Simulation outputs

First the simulation outputs of @Risk for the grand coalition are reported. Secondly the outputs for a sub coalition are given. Both outputs are listed in the same order:

1. Costs per intermodal roundtrip i
2. Costs evaluation when comparing intermodal situation with current situation in which containers are being trucked.
3. Accumulated NB need for transportation per roundtrip i
4. Accumulated SB need for transportation per roundtrip i
5. Total roundtrip need for transportation per roundtrip i (=acc. NB + acc. SB)
6. Actual transported number of containers per roundtrip given trains' capacity $V = 40$.
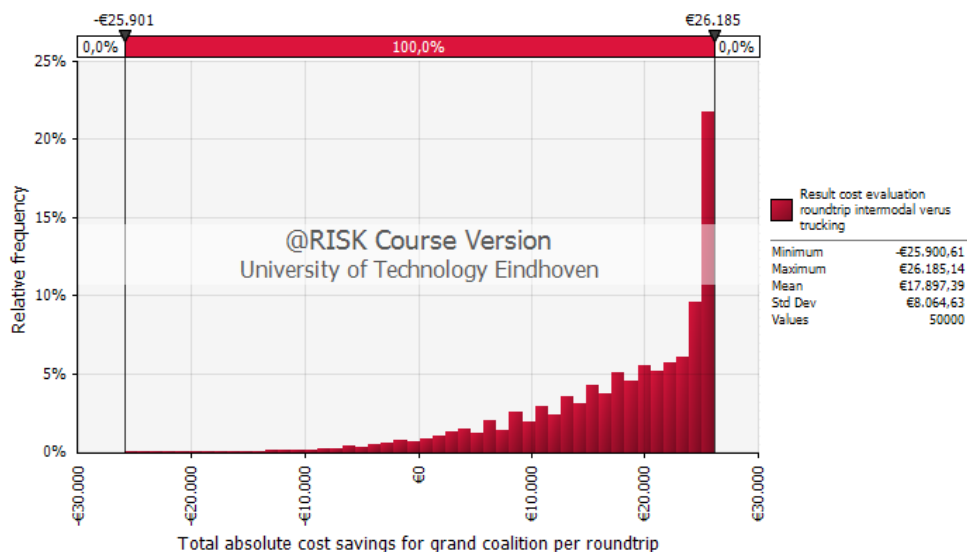
At the end of this appendix an explanation of the graphs and their differences is given.

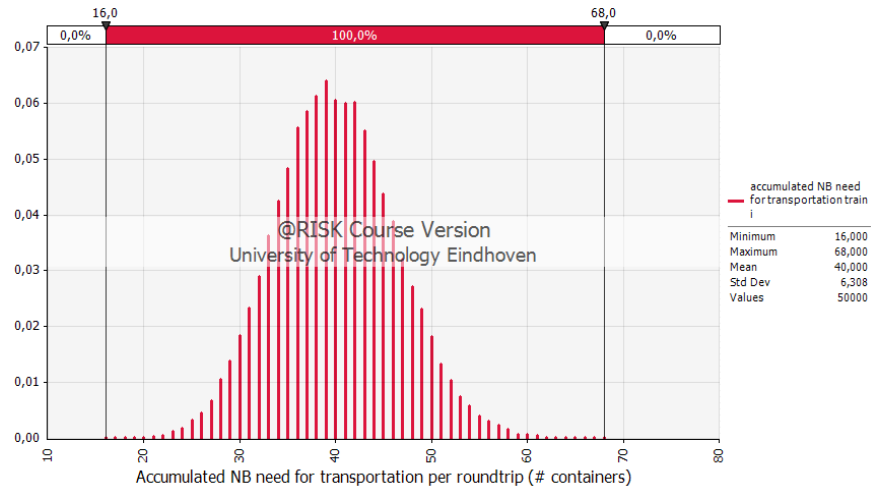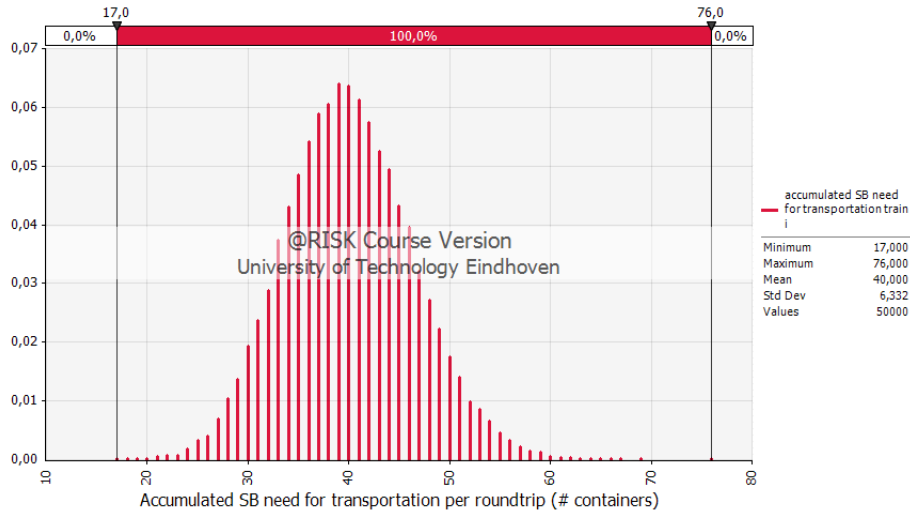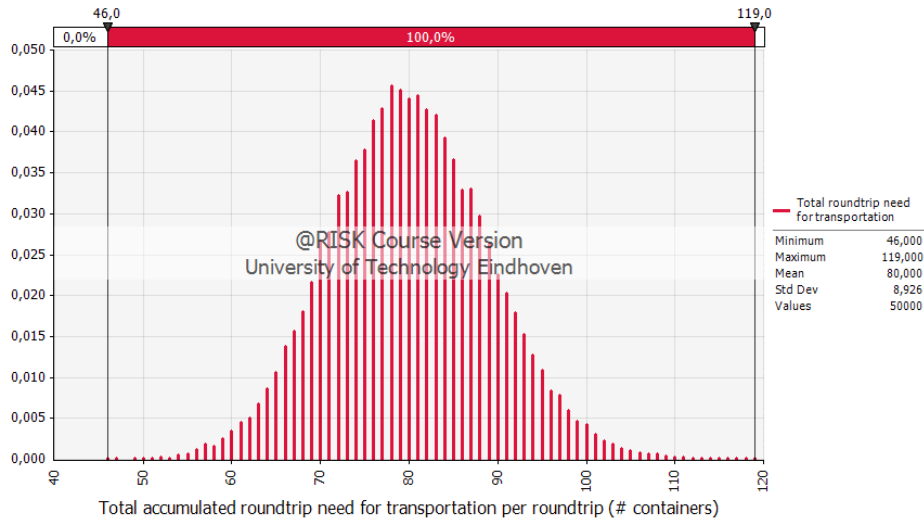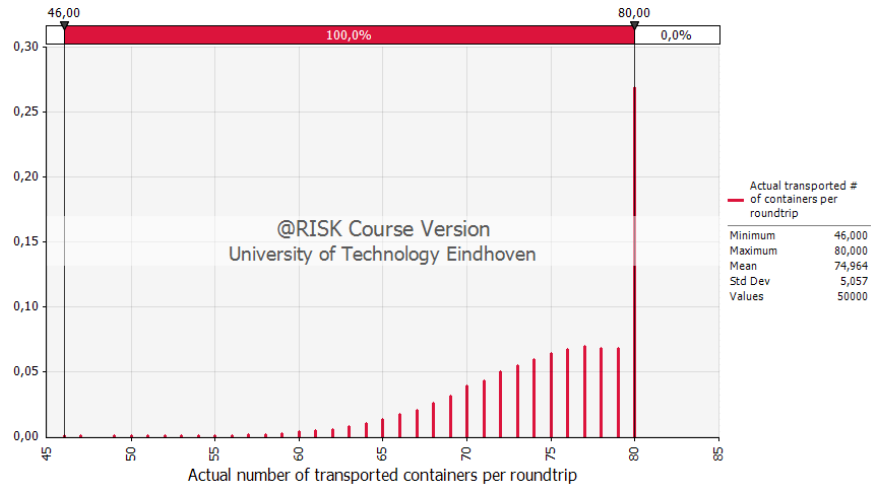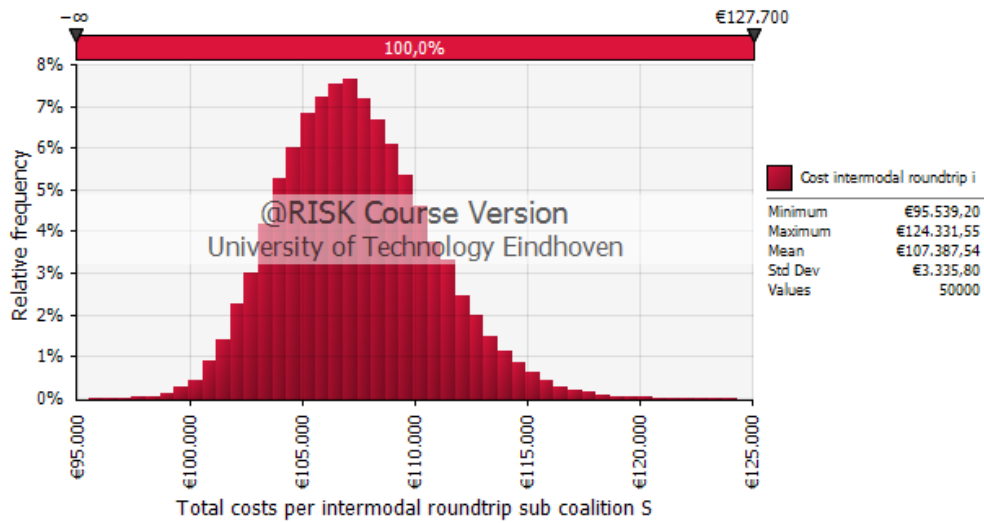**Simulation outputs for grand coalition N={1,2,3,4,5,6,7}**

1.

2.

68

3.

4.

5.

6.

Simulation outputs for sub coalition $S=\{1,2,5\}$

1.

2.
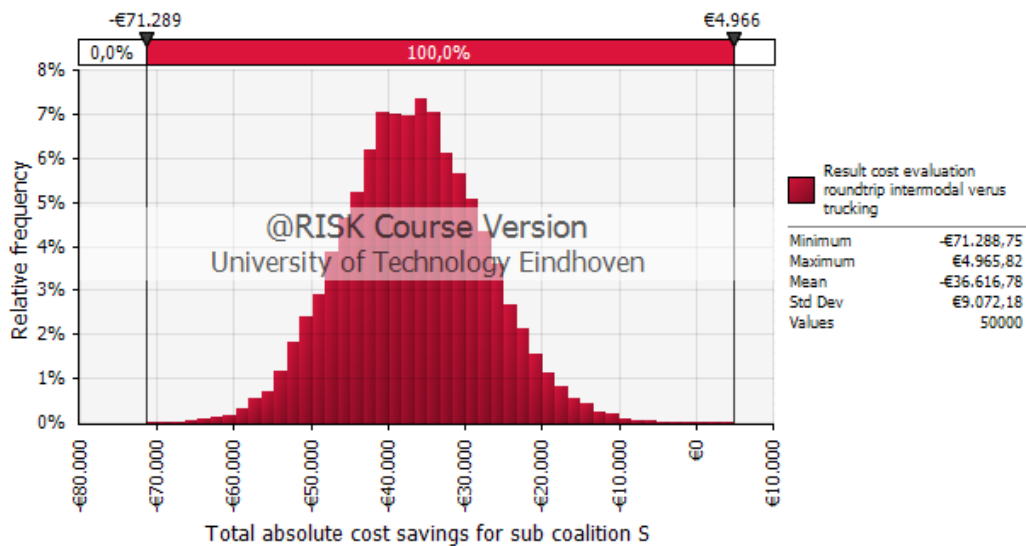
3.
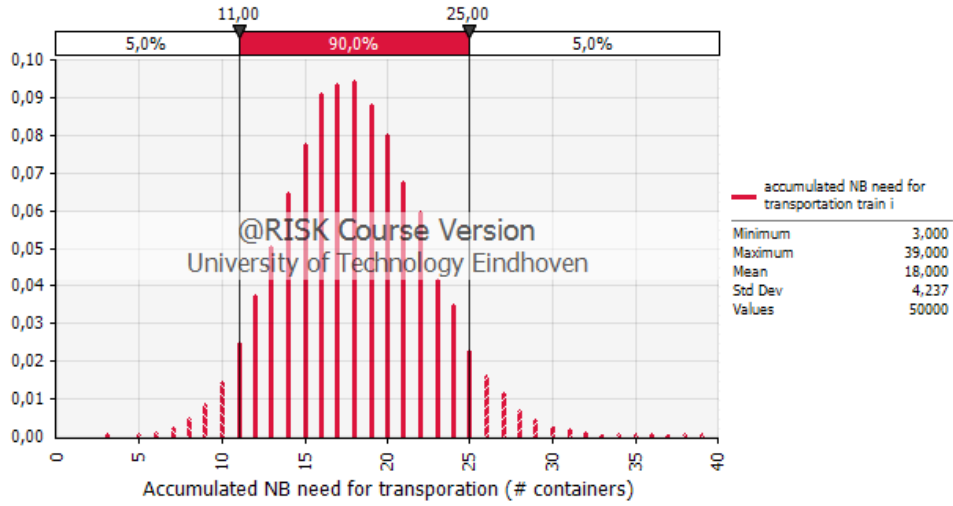
4.
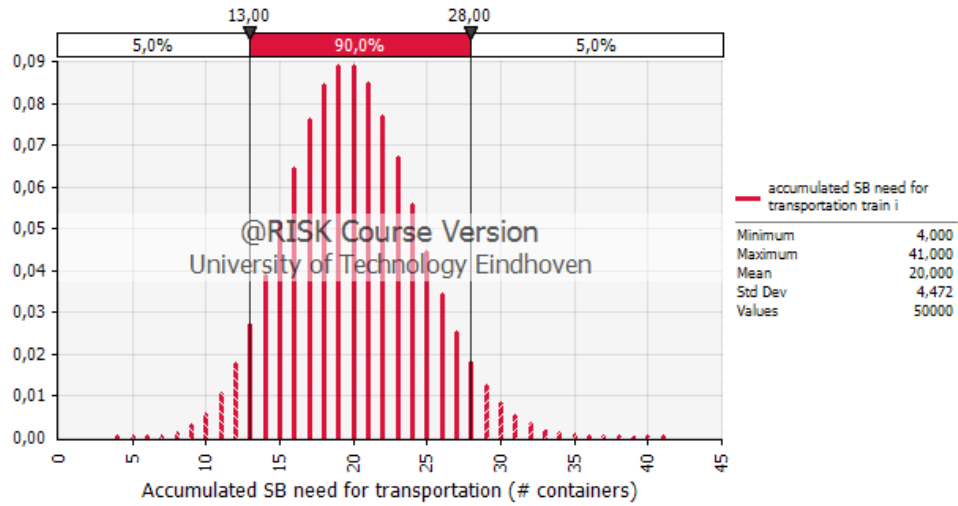
5.
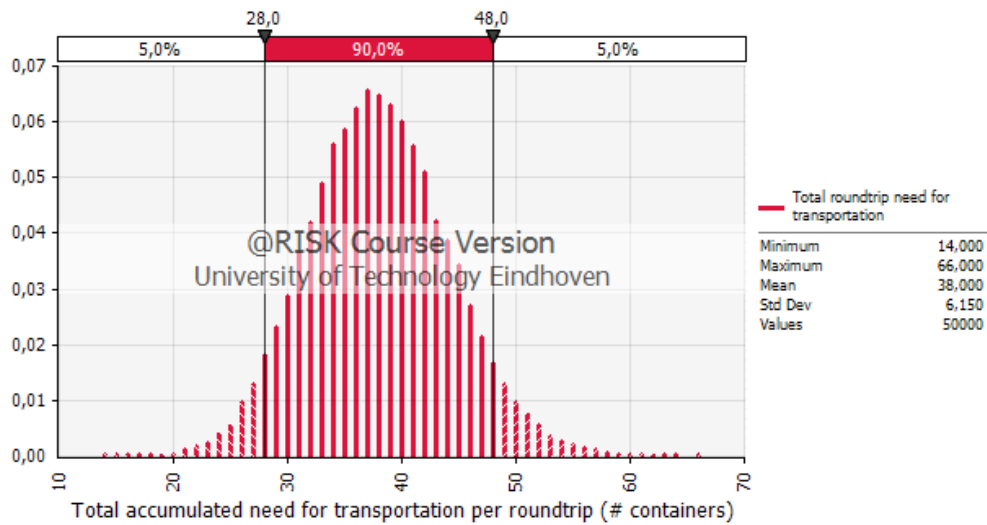
6.
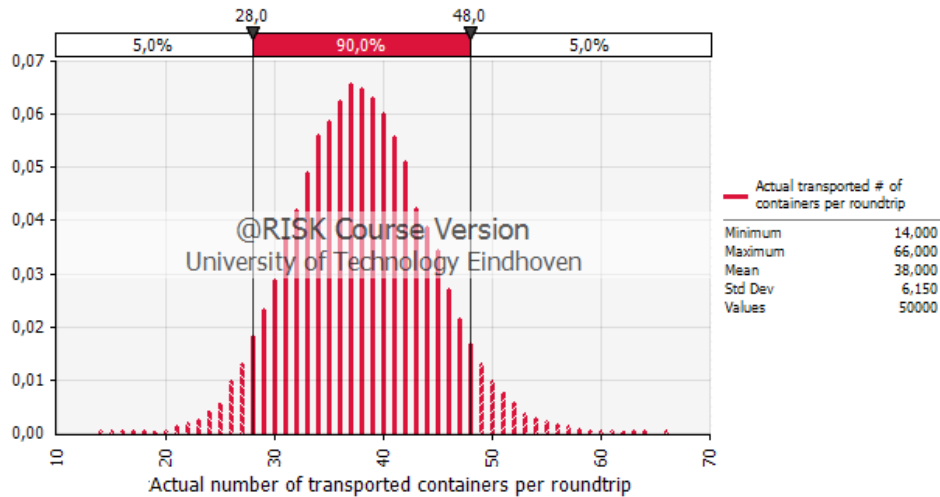
Explanation / comparison

For the grand coalition outputs the peaks in graph 5 and 6 are caused because the train is capacitated to 40 containers. All accumulated needs for transportation above 80 (40 NB and 40 SB) in graph 5 lead to an actual transportation of 80 containers on that specific roundtrip. All overcapacity of containers (>80) is transported by truck against the same trucking tariffs as in the current situation. These are not included in the costs calculations. The tail to the right from the peak in graph 1 is caused because the total roundtrip costs are determined in combination with needs for transportation in roundtrip $i-1$ and $i+1$ (because the route is exploited in a synchronized roundtrip setting). So even when both the NB and SB need for transportation on roundtrip i are at least 40 some situations with different costs per roundtrip occurred because there are a wide range of possibilities for the need for transportation on roundtrip $i-1$ and $i+1$ as well.

The output listed for the sub coalition looks different (no peaks) because this sub coalition is not large enough (commitment wise) to have needs for transportation bigger than the trains capacity. That is why these graphs do not have an irregular peak. That is also why graph 5 and 6 are almost exactly the same. The accumulated need for transportation per roundtrip can almost always (only one roundtrip had 41 containers NB which is the only deviation) be transported by train because the highest accumulated need is 66 containers (given the trains roundtrip capacity of 80 containers). That is also the reason why almost no roundtrips with cost savings occurred, because on average 38 containers were transported per roundtrip which is not sufficient to cover all extra fixed costs (graph 2).

G. Sensitivity analyses of assumed parameter values

Figure G.1 displays the outputs of a sensitivity analyses performed by @Risk. The base values of the assumed profit margin and delay factors in the used based case are as follows:

Profit margin   3%
Delay factor rail   15%
Delay factor road   5%

Within the sensitivity analyses these base values were altered (one at a time) between -100% and +100%, and the effects of these changes on the total average benefits per roundtrip for the grand coalition are tracked.
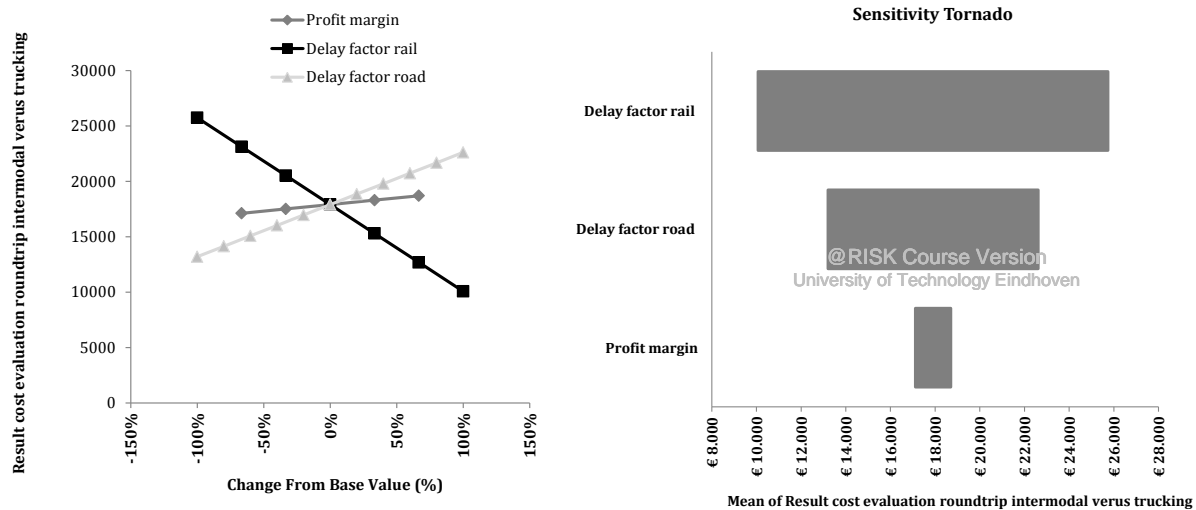
Figure G.1 @Risk output of sensitivity analyses on assumed parameter values

Changing the assumed profit margin only has minor effects because the margin already was very small. Besides, affects this assumption both situations that are compared in the cost model. Increasing the profit margin leads to slighter bigger benefits. Apparently this assumption has a little more impact on the trucking tariffs within the constructed cost model.

Lowering both delay factors have opposite effects on the total average benefits per intermodal roundtrip. The rail factor relates negatively to the expected cost savings. This makes sense because a lower delay by rail leads to less time related costs in the intermodal situation and therefore higher benefits when compared to the current situation. The road delay factor relates positively with expected benefits since increasing this delay factor leads to an increase in costs in the current situation (higher time related costs) whereas the intermodal costs will not change. This leads to an increase in total expected benefits.

Both delay factors have a significant impact on costs. However, the assumptions made are based on the average transit times of both modes in reality. Therefore keeping the assumptions at the base values probably lead to cost calculations reflecting reality best (since a good time related cost calculation).

H. Terminal areas and expected drayage trip distances

The direct distances reflect a single trip between a terminal and shipper location. The roundtrip distances therefore include twice the direct distances plus the expected nearest neighbor distance (given value for *M*). Note that all these distances are expected values based on the continuous approximation techniques as discussed in the report. Figure H.1. is a graphical representation of some area sizes displayed on a map with terminals in Rotterdam and Valencia. In the model the assumption is made that Rotterdam is located in the center and Valencia on the edge of the terminal area.

Table H.1 Drayage trip distances per terminal area

| Area | Northern | | Southern | | Northern | | | | Southern | | | |
| M | 40 | | 40 | | 5 | | 64 | | 5 | | 64 | |
A (km2)	Direct (km)	Roundtrip (km)	Direct (km)	Roundtrip (km)	Direct (km)	Roundtrip (km)	Direct (km)	Roundtrip (km)	Direct (km)	Roundtrip (km)	Direct (km)	Roundtrip (km)
1	0,47	1,08	0,80	1,74	0,47	1,23	0,47	1,01	0,80	1,88	0,80	1,66
2000	21,02	48,32	35,72	77,73	21,02	54,79	21,02	45,01	35,72	84,19	35,72	74,41
4000	29,73	68,34	50,52	109,92	29,73	77,48	29,73	63,65	50,52	119,06	50,52	105,23
6000	36,41	83,70	61,87	134,63	36,41	94,89	36,41	77,95	61,87	145,82	61,87	128,88
8000	42,04	96,64	71,44	155,45	42,04	109,57	42,04	90,01	71,44	168,38	71,44	148,82
10000	47,00	108,05	79,88	173,80	47,00	122,51	47,00	100,64	79,88	188,26	79,88	166,39
12000	51,49	118,36	87,50	190,39	51,49	134,20	51,49	110,24	87,50	206,22	87,50	182,27
14000	55,61	127,85	94,51	205,64	55,61	144,95	55,61	119,08	94,51	222,75	94,51	196,87
16000	59,45	136,67	101,03	219,84	59,45	154,96	59,45	127,30	101,03	238,13	101,03	210,47
18000	63,06	144,96	107,16	233,18	63,06	164,36	63,06	135,02	107,16	252,57	107,16	223,23
20000	66,47	152,81	112,96	245,79	66,47	173,25	66,47	142,32	112,96	266,23	112,96	235,31
22000	69,71	160,26	118,47	257,79	69,71	181,70	69,71	149,27	118,47	279,23	118,47	246,79
24000	72,81	167,39	123,74	269,25	72,81	189,78	72,81	155,91	123,74	291,64	123,74	257,77
26000	75,79	174,23	128,79	280,24	75,79	197,53	75,79	162,27	128,79	303,55	128,79	268,29
28000	78,65	180,80	133,66	290,82	78,65	204,99	78,65	168,40	133,66	315,01	133,66	278,42
30000	81,41	187,15	138,35	301,03	81,41	212,19	81,41	174,31	138,35	326,07	138,35	288,19
32000	84,08	193,29	142,88	310,90	84,08	219,14	84,08	180,03	142,88	336,76	142,88	297,64
34000	86,66	199,24	147,28	320,47	86,66	225,89	86,66	185,57	147,28	347,13	147,28	306,81
36000	89,18	205,01	151,55	329,76	89,18	232,44	89,18	190,95	151,55	357,19	151,55	315,70
38000	91,62	210,63	155,71	338,80	91,62	238,81	91,62	196,18	155,71	366,98	155,71	324,35
40000	94,00	216,10	159,75	347,60	94,00	245,01	94,00	201,28	159,75	376,51	159,75	332,78
42000	96,32	221,44	163,70	356,18	96,32	251,06	96,32	206,25	163,70	385,81	163,70	341,00
44000	98,59	226,65	167,55	364,57	98,59	256,97	98,59	211,10	167,55	394,89	167,55	349,02
46000	100,80	231,74	171,31	372,76	100,80	262,74	100,80	215,85	171,31	403,76	171,31	356,86
48000	102,97	236,73	175,00	380,78	102,97	268,40	102,97	220,49	175,00	412,45	175,00	364,54
50000	105,10	241,61	178,61	388,63	105,10	273,93	105,10	225,03	178,61	420,95	178,61	372,06
52000	107,18	246,39	182,14	396,33	107,18	279,36	107,18	229,49	182,14	429,29	182,14	379,42
54000	109,22	251,09	185,61	403,88	109,22	284,68	109,22	233,86	185,61	437,47	185,61	386,65
56000	111,22	255,69	189,02	411,29	111,22	289,90	111,22	238,15	189,02	445,49	189,02	393,75
58000	113,19	260,22	192,36	418,57	113,19	295,03	113,19	242,37	192,36	453,38	192,36	400,72
60000	115,13	264,67	195,65	425,72	115,13	300,08	115,13	246,51	195,65	461,13	195,65	407,57
62000	117,03	269,04	198,89	432,76	117,03	305,04	117,03	250,59	198,89	468,75	198,89	414,30
64000	118,90	273,35	202,07	439,68	118,90	309,92	118,90	254,60	202,07	476,25	202,07	420,93
66000	120,75	277,59	205,20	446,50	120,75	314,72	120,75	258,55	205,20	483,64	205,20	427,46
68000	122,56	281,76	208,29	453,22	122,56	319,46	122,56	262,43	208,29	490,91	208,29	433,89
70000	124,35	285,87	211,33	459,83	124,35	324,12	124,35	266,26	211,33	498,08	211,33	440,22
72000	126,11	289,93	214,33	466,36	126,11	328,72	126,11	270,04	214,33	505,14	214,33	446,47
74000	127,85	293,93	217,28	472,79	127,85	333,25	127,85	273,77	217,28	512,11	217,28	452,63
76000	129,57	297,87	220,20	479,13	129,57	337,72	129,57	277,44	220,20	518,98	220,20	458,70
78000	131,26	301,77	223,08	485,40	131,26	342,14	131,26	281,07	223,08	525,77	223,08	464,70
80000	132,94	305,61	225,92	491,58	132,94	346,50	132,94	284,65	225,92	532,47	225,92	470,62
82000	134,59	309,41	228,73	497,69	134,59	350,80	134,59	288,19	228,73	539,08	228,73	476,46
84000	136,22	313,16	231,50	503,72	136,22	355,05	136,22	291,68	231,50	545,62	231,50	482,24
86000	137,83	316,87	234,24	509,68	137,83	359,26	137,83	295,13	234,24	552,07	234,24	487,95
88000	139,42	320,53	236,95	515,58	139,42	363,41	139,42	298,54	236,95	558,46	236,95	493,59
90000	141,00	324,15	239,63	521,40	141,00	367,52	141,00	301,92	239,63	564,77	239,63	499,17
92000	142,56	327,73	242,27	527,16	142,56	371,58	142,56	305,25	242,27	571,01	242,27	504,68
94000	144,10	331,28	244,89	532,86	144,10	375,59	144,10	308,55	244,89	577,18	244,89	510,14
96000	145,62	334,78	247,48	538,50	145,62	379,57	145,62	311,82	247,48	583,29	247,48	515,54
98000	147,13	338,25	250,05	544,08	147,13	383,50	147,13	315,05	250,05	589,33	250,05	520,88
100000	148,63	341,69	252,59	549,61	148,63	387,40	148,63	318,25	252,59	595,32	252,59	526,17
102000	150,11	345,09	255,10	555,07	150,11	391,25	150,11	321,41	255,10	601,24	255,10	531,40
104000	151,57	348,45	257,59	560,49	151,57	395,07	151,57	324,55	257,59	607,11	257,59	536,59
106000	153,02	351,79	260,05	565,85	153,02	398,85	153,02	327,66	260,05	612,92	260,05	541,72
108000	154,46	355,09	262,50	571,17	154,46	402,59	154,46	330,73	262,50	618,67	262,50	546,81
110000	155,88	358,36	264,92	576,43	155,88	406,30	155,88	333,78	264,92	624,37	264,92	551,85
112000	157,29	361,61	267,31	581,65	157,29	409,98	157,29	336,80	267,31	630,02	267,31	556,84
114000	158,69	364,82	269,69	586,82	158,69	413,63	158,69	339,79	269,69	635,62	269,69	561,79
116000	160,08	368,01	272,04	591,94	160,08	417,24	160,08	342,76	272,04	641,17	272,04	566,70
118000	161,45	371,17	274,38	597,02	161,45	420,82	161,45	345,70	274,38	646,68	274,38	571,56
120000	162,81	374,30	276,70	602,06	162,81	424,37	162,81	348,62	276,70	652,14	276,70	576,39
122000	164,16	377,40	278,99	607,06	164,16	427,89	164,16	351,52	278,99	657,55	278,99	581,17
124000	165,50	380,48	281,27	612,01	165,50	431,39	165,50	354,39	281,27	662,92	281,27	585,91
126000	166,83	383,54	283,53	616,93	166,83	434,85	166,83	357,23	283,53	668,24	283,53	590,62
128000	168,15	386,57	285,77	621,81	168,15	438,29	168,15	360,06	285,77	673,52	285,77	595,29
130000	169,46	389,58	287,99	626,65	169,46	441,70	169,46	362,86	287,99	678,76	287,99	599,92
132000	170,76	392,57	290,20	631,45	170,76	445,08	170,76	365,64	290,20	683,97	290,20	604,52
134000	172,05	395,53	292,39	636,21	172,05	448,44	172,05	368,40	292,39	689,13	292,39	609,08
136000	173,33	398,47	294,56	640,94	173,33	451,78	173,33	371,14	294,56	694,25	294,56	613,61
138000	174,60	401,39	296,72	645,64	174,60	455,09	174,60	373,86	296,72	699,34	296,72	618,11
140000	175,86	404,29	298,86	650,30	175,86	458,37	175,86	376,56	298,86	704,39	298,86	622,57
142000	177,11	407,17	300,99	654,93	177,11	461,64	177,11	379,24	300,99	709,40	300,99	627,00
144000	178,35	410,02	303,10	659,53	178,35	464,88	178,35	381,90	303,10	714,38	303,10	631,40
146000	179,59	412,86	305,20	664,09	179,59	468,09	179,59	384,54	305,20	719,32	305,20	635,77
148000	180,81	415,68	307,29	668,62	180,81	471,29	180,81	387,16	307,29	724,23	307,29	640,11
150000	182,03	418,48	309,35	673,13	182,03	474,46	182,03	389,77	309,35	729,11	309,35	644,42

Figure H.1 Area surfaces with terminals in Rotterdam and Valencia

I. Interview methodology

The interviewing method used during the project was based on the long interview as mentioned by Mullins (2007). In a long interview, only a few open-ended questions are asked to let the respondent go where he or she wants to go, but control the direction of the conversation by using prompts. Prompts are very short questions used to encourage the respondent to say more about a theme just mentioned, or to address (again, in an open and non-directed way) another topic that is on the interviewer's mind but has gone unmentioned so far. The long interview technique differs from other guided interviews by not using lengthy checklists of predetermined focused questions and seek answers on questions that the interviewer knows the interviewee has answers on. This technique was used during the interviews for the following reason.

Each interviewee is an expert in his field of operation. Letting them freely elaborate on their business, experiences and knowledge. When using this technique it was prevented that my own ideas about possible solutions led the conversation. Mullins (2007) mentions that doing so can hinder learning objectives about alternative solutions or answers to existing problems or questions.

Each interview was prepared according the same way. Several questions were prepared whereas the first question always was a "interview-driver" (Mullins, 2007). This is a broad-ended question that encourages the interviewee to elaborate, about the subject asked, from their own perspective. These questions were concerned with what the interviewees experiences where with intermodal collaborations. A list of interviews held with interviewees for this project can be found in Table I.1.

Table I.1 List of interviewees

Company	Name
Bakker Barendrecht B.V.	R. Haesakkers
Mercator Novus	M. Biemond
Bureau Voorlichting Binnenvaart	M. Huijsman
Port of Rotterdam	S. Tolk
Port of Rotterdam	P. ten Broek
Wayz	A. van Velzen
Lean and Green	C. Koiter

J.   Confidence interval of simulation outputs

Based on Law (2007) the following method can be used to obtain confidence intervals for simulation outputs given the number of iterations during simulation. In this case 50,000 iterations are chosen and it is checked whether this number of iterations is high enough to obtain an acceptable cost range when a 99,5% confidence interval is applied.

If one would like to obtain a point estimate and confidence interval for the mean $\mu = E(X)$, where X is a random variable. Make n independent replications of the simulation (iterations) and let X_1, X_2, X_n be the resulting independent and identically distributed random variables (Law, 2007). By substituting the $X_i's$ into (1), $\bar{X}(n)$ is an unbiased point estimator for μ, and an approximate $100(1-\alpha)$ percent $(0 < \alpha < 1)$ confidence interval for μ is given by (2):

$$\bar{X}(n) = \frac{\sum_{i=1}^{n} X_i}{n} \qquad\qquad (1)$$

$$\bar{X}(n) \mp t_{n-1,1-\frac{\alpha}{2}} \sqrt{\frac{S^2(n)}{n}} \qquad\qquad (2)$$

$S^2(n)$ is the sample variance that can be extracted from the simulation output results in @Risk. For the base case grand coalition composition:

$$\bar{X}(n) = €124135,89$$
$$S^2(n) = €4675108.84$$
$$t_{n-1,1-\frac{\alpha}{2}} = t_{49999,0.9975} = 2.807$$
$$n = 50000$$

Thus, based on the upper formula (2) it can be claimed that with approximately 99,5% confidence $\mu = E(X)$, the expected cost per intermodal roundtrip, is contained in the interval of:

$$[€124108.75 , €124163.03]$$

Since this interval is very narrow (only €55 on €124K) it can be concluded that the number of 50,000 iterations is sufficiently high to get reliable results.