Inland terminal location selection

Strengthening the position of the shipping line in the container port hinterland

K. Verhoeven

Master thesis report
February 6, 2020

TU Delft

MAERSK

Image on title page retrieved from APM Terminals (2020).

Inland terminal location selection

Strengthening the position of the shipping line in the container port hinterland

by

Kyle Verhoeven

to obtain the degree of Master of Science
at the Delft University of Technology,
to be defended publicly on February 20 at 03:00 PM.

Student number:	4503619	
Project duration:	June 3, 2019 – February 20, 2020	
Thesis committee:	Dr. J. Rezaei,	TU Delft, chairman
	Dr. B. Wiegmans,	TU Delft, supervisor
	F. Liang,	TU Delft, supervisor
	M. Vybiral,	Maersk, company supervisor

TU Delft

Preface

This report is the final product of the graduation project concluding the Master of Science Program of Transport, Infrastructure & Logistics. With this deliverable, I also put an end to my studies at TU Delft and to my life as a student in general. The report describes the location selection problem for inland intermodal terminals as occurring in the hinterland of container ports. The project was carried out for Maersk, for which I dove into the fascinating world of container transport and logistics.

I would therefore firstly like to thank Maersk for making the project possible. In particular, I would like to thank my company supervisor Matej Vybiral for giving me the chance to join the team and for being always available for questions regarding the content and for conversations regarding anything but content.

The result could not have been achieved without the assessment committee. Firstly, I would like to thank Bart Wiegmans, whose critical attitude towards the problem and research approach really helped me in facing and structuring the whole project as well as the deliverables. Next, I would like to thank Fuqi Liang, who has guided me a lot through the set-up and application of the methodology and processing the results. And lastly to Jafar Rezeai, for his never-ending interest in the research and the valuable feedback during the meetings.

I would like to thank my friends for making my time as a student so enjoyable. To my girlfriend who is always there to hear about my struggles during study and graduation and to help me out when needed. And of course to my family, who supported me throughout the thesis and throughout my studies in general no matter what.

Kyle Verhoeven
Delft, March 12, 2020

Summary

In the last decades, the importance of the hinterland transport leg as a component of the overall container transport chain has been recognized by both scholars and industry professionals, specifically from shipping lines. Shipping lines aim to gain market share in the container port hinterlands by means of offering inland transport chain services to their customers, which should be sufficiently attractive based on costs, operational efficiency and provided services. A particular way of improving the inland transport chain is by effectively making use of *inland terminals*. Inland terminals allow to transport containers through cost-efficient intermodal set-ups and can be used as local storage spaces for customers' containers. By setting up inland terminals dedicated to the needs of the shipping line and its customers, capacity can be sufficiently committed to import and export container flows and a unique selling point in the hinterland can be created which facilitates the provision of door-to-door services to customers. The location of such an inland terminal within the inland transport chain is essential; it determines the distances between the terminal and the seaport and shipper/consignee locations, and thus the (cost-)efficiency of the broader transport chain. However, selecting such a location is a complex task in which multiple stakeholders and multiple factors are involved. In that regard, the following research question is formulated:

"How can a shipping line select a location for setting up an own inland terminal in order to increase its control on the container port hinterland?"

To answer this question, firstly the research system being the *inland terminal location* and the context of the multi-layered structure of the container port hinterland is identified. This structure consists of four interconnected layers; the *logistical layer* in which transport services and chains are organized; a *transport layer* in which transport and transshipment operations take place; an *infrastructural layer* which contains the provision of transport and transshipment infrastructure; and a *locational layer* which contains the geographic locations of the infrastructure within the economic space of the hinterland. Each layer element contributes to and is dependent on the elements occurring in the layer(s) above/below. By reviewing the interrelated layer structure, key actors and their activities with regards to the inland transport chain are identified. First of all, these include the shipping lines themselves as organizers of the inland transport and transshipment services (logistical layer). Secondly, transport operators perform the designed transport services, while terminal operators perform the designed transshipment operations (transport layer). Thirdly, transshipment infrastructure is provided and owned by the same inland terminal operators. Lastly, particularly in the sense of this study, the transshipment infrastructure location is selected by the shipping line (as organizer) and the inland terminal operator (as operator/owner). As each of these stakeholders has its own objectives with regards to the inland terminal, the evaluation and consequent selection of the location based on these objectives differ. The study takes into account these different objectives as follows:

- The shipping line evaluates an inland terminal location and makes the decision to select it based on the objective to *incorporate the terminal in the designed inland transport chain.*
- The terminal operator evaluates an inland terminal location and makes the decision to select it based on the objective *to ensure profitability of transshipment operations at the site.*
- The transport operator does not actually select the inland terminal location, since it is only *using* the facility in its own transport operations. Nevertheless, as they and

their operations are influenced by the decision, the broader inland transport chain is as well. Therefore, the terminal user's evaluation of the location, based on the objective to *use the inland terminal to optimize their transport operation scheme*, is also taken into account.

To deal with these different objectives in the location selection problem, a *Multi-Actor Multi-Criteria Analysis* approach is proposed, in which the preferences of the different actors are taken into account equally. As the actors' objectives vary, the criteria taken into account in the study also vary per stakeholder. The first step of this research is to determine the specific criteria used to evaluate the inland terminal location for each stakeholder separately. By means of a criteria selection survey, criteria observed in the literature are presented to specific experts belonging to either one of the actor types in order to have them select the factors they find most important. The actor-specific criteria sets resulting from this survey are evaluated through a second survey, in which preference statements are gathered for set. These preference statements are used to determine the weights for each criterion within each actor-specific criteria set using the *Best Worst Method*. As multiple criteria per set are considered, multiple optimal solutions to the weight determination problems exist. Therefore, non-linear determination of the criteria weights is applied, which results in criteria *weight intervals* (instead of single solutions). These intervals are preferred in this study because they represent a comprehensive range of the decision-makers' possible optimal preferences resulting from the several criteria sets. By considering weight intervals, utilities for alternatives based on these intervals can be aggregated into final utility scores which take into account each actor's preferences in an equal manner.

The results of the study are twofold. First of all, determined criteria weight intervals reveal the individual preferences of the actors involved, which lead to certain utility contributions to each alternative based on its respective data scores. The weight determination model results show that container volume related factor of *Market volume potential* is overall considered to be a highly important factor by the majority of actors. Next to that, shipping line actors specifically evaluate *Intermodal market profitability* as an important criterion and terminal operator actors specifically evaluate *Anchor customer proximity* (which is also container volume related) as an important criterion. In this regard, most utility contributions to the alternatives are assigned based on the highly evaluated container volume related criteria. The utility aggregation model applied to the case study on the study region around the cities of A, B and C results in the highest aggregate utility scores for the two A locations considered, which are mainly based on the high amounts of container volume potentials forecasted in this area compared to B and C. Another finding is the importance of *expansion possibilities* around alternative locations, since it is noticed that locations with no/limited room for physical expansion have considerable deficits in final utility scores. Sensitivity analyses further stressed the importance of container volume related characteristics for the overall most preferable locations based on all stakeholders' preferences.

Apart from this study contributing to the contemporary MCDM literature by proposing the use of the MAMCA approach in combination with BWM in order to involve actor-specific criteria sets and a subsequent utility aggregation methodology, the research adds practical knowledge to the differently perceived factors relevant to several stakeholders in the inland terminal location selection process. Practical implications of the study lead to recommendations for shipping line professionals to ensure that an area specified for potential inland terminal development has substantial amounts of container volumes imported/exported. The results of this study indicate the importance of having customers which can provide such volumes to all stakeholders involved, so that inland terminal related businesses can be profitable for all. Next to that, it is advised to have sufficient room for (physical) expansion to safeguard potential future developments if needed/wanted. With regards to the specific research inputs, it is acknowledged that the multi-interpretability as well as lack of certain data can be questioned. It is suggested to further test the applicability and practicality of utility aggregation in future multi-actor MCDM problems.

Contents

List of Figures

List of Tables

1

Introduction

Since the introduction of the container in the 1950s, container transport practices and affiliated logistics services have been and are ever growing. Modern logistics markets and supply chain management uses have gone hand in hand with the increasingly globalizing world economy, which made it possible and necessary to have efficient flows of goods throughout all parts of the world (Rodrigue and Notteboom, 2013). The collection of transport and logistics related activities taking place in order to get these goods flowing from origin to destination is called the supply chain (De Langen et al., 2013). The supply chain requires sufficient transport networks, operations and infrastructure, especially since the separate chain legs are all connected and dependent on each others performances (Acciaro and McKinnon, 2015). A major component global supply chains are the inland transport chains, which connect seaports with the shippers' and consignees' locations in the hinterland.

1.1. The vertical integration of hinterland container transport: Shipping lines as designers of inland transport chains

The importance of the hinterland transport leg as a part of the total transport chain is increasingly noticed by shipping lines (Franc and Van der Horst, 2010; Van den Berg and De Langen, 2015). Traditionally, shipping lines were merely involved in the ocean transport of containers, using ocean vessels to move containers between seaports all over the world. The organization of the inland transport chains was taken care of by third parties such as freight forwarders and logistics service providers, making these parties the customers of the shipping lines (De Langen et al., 2013). However, shipping lines increasingly try to integrate their ocean transport set-ups with corresponding inland transport services in order to offer full door-to-door transport packages; they aim at vertically integrating into the container port hinterlands by taking control of organizing the inland transport services as well. In this sense, shipping lines position themselves as competitors of the original inland transport service providers.

This strategy builds on the importance of the inland transport chain in the broader supply chain, contributing to its total efficiency. Although such vertical integration developments have been recognized for over three decades, interest from academics and business professionals towards the inland transport services and operations is only recent (De Langen et al., 2013; Van den Berg and De Langen, 2015). Inland legs of global transport chains have not yet been subject to substantial efficiency improvements, in contrast to the maritime legs (Ducruet and Notteboom, 2012; Panayides and Wiedmer, 2011). For instance, costs for inland operations are considerably large compared to costs for ocean transport and port operations. Thus, the potential for improvements in hinterland transport (cost-)efficiency and integration within the global supply chain gets recognized more and more (Van den Berg and De Langen, 2015; Van Der Horst and De Langen, 2008). This is particularly interesting to shipping lines, since the attractiveness of an inland transport chain is highly dependent on its efficiency. In this regard, the ambition of the shipping line to integrate global supply chains by offering door-to-door services can be pursued by improving the efficiency of their inland transport chains, which increases their attractiveness to the shipping line's customers.

1.2. The role of the inland terminal within the inland transport chain

Inland transport chains exist in several set-ups, in which different kinds of transport operations and modalities are applied. Broadly, a division between *direct trucking* (consisting of one truck leg) and *intermodal transport* (consisting of at least one *main haulage* leg by intermodal vehicle such as train or barge and a *pre-* or *end-haulage* leg by truck) between seaport and customer location is recognized. With regards to cost-efficiency, direct trucking is regarded as flexible but expensive, whereas intermodal transport has significant economic advantages (especially with longer distances). This is mostly due to the bundling of containers by making use of larger vehicles compared to trucks, which lowers the costs per transported container unit (Simina et al., 2012). A major component of the intermodal inland transport chain is the inland terminal, at which containers get transshipped between truck and intermodal vehicle (or vice versa). Because of the necessity of the transshipment operations for intermodal transport, the inland terminal considerably influences the broader inland transport chain (Rodrigue and Notteboom, 2009). Next to intermodal transshipment, modern inland terminals are offering more services which add value to and increase the attractiveness of the inland transport chain (de Villiers, 2015). Accordingly, inland terminals have been progressively integrated within the chains, taking more active roles instead of being merely transshipment points. These developments are often directed from within the hinterland networks, e.g. in order to attract more freight flows towards a certain area. However, in a lot of cases, inland terminal development is initiated by companies traditionally operating in the seaport premises, such as *terminal operating companies* (Wilmsmeier et al., 2011). More recently, attention goes towards the shipping lines to engage in inland terminal practices (Van den Berg and De Langen, 2015). Active engagement with inland terminals gives shipping lines more control over these nodes in the network, which enables them to use the inland terminal in order to offer attractive inland transport chain services.

In general, inland terminals facilities are owned and operated by *inland terminal operators*, which are individual companies or linked to intermodal transport operators by means of holding. These ownership configurations imply that the shipping line has limited control over the inland terminal, resulting in the need for negotiations and contracts between the shipping line and the inland terminal operator in order to secure the inland terminal services required by the shipping line for the organization of its inland transport chain. Since numerous actors are involved in offering inland transport services (e.g. freight forwarders and competing shipping lines), competitors have the same practices regarding inland terminal service assurance, which leads to (potential) capacity likely to get occupied. By setting up an own inland terminal which can be controlled by the shipping line, certain inland terminal capacity could be dedicated to the needs of its (potential) customers and a proposed transport chain can be enhanced (e.g. because volumes can be transported with acceptable costs instead of higher costs as a result of overcapacity issues). Moreover, securing terminal capacity also facilitates the shipping line's competitive position in the local hinterland market, since an own inland terminal serves as a unique selling point in the area; competing shipping lines do not have these dedicated hubs which allow them to offer attractive door-to-door transport services. All in all, an own inland terminal contributes to the shipping line's ambition of vertically integrating into the container port hinterland by facilitating the provision of efficient and attractive transport services between seaports and customers' locations. On a side note, it must be remarked that it is not assumed that the proposed inland terminal would only handle containers specifically belonging to the shipping line, since those amounts are supposedly insufficient to ensure a terminal's profitability.

The location of the inland facility is a crucial factor with regards to its ability to contribute to the effectiveness of the inland transport chain, mainly because the location of the terminal determines the distances for container movements in the main haulage and pre-/end-haulage legs (Pekin, 2010). Selecting the inland terminal location is thus an essential task for the shipping line designing the inland transport chain in which the terminal is required to contribute to its efficiency and effectiveness. However, as the inland terminal business is not left to only the shipping line but also to other companies operating in the inland transport chain, multiple stakeholders for the location selection problem are recognized (De Langen et al., 2013; Franc and Van der Horst, 2010; Frémont, 2009; Monios and Wilmsmeier, 2012; Rodrigue et al., 2010; Wilmsmeier et al., 2011). The problem definition for the shipping line is therefore approached by taking into account the different objectives belonging to the several stakeholders involved. Besides the objectives of the shipping line itself, these include the objectives of terminal operating companies and terminal using companies.

1.3. A multi-actor multi-objective inland terminal location selection problem

As indicated, there are multiple objectives which play a role in the decision-making process of the inland terminal investment problem. In this research, these objectives are evaluated in order to develop a decision-support framework for the inland terminal location selection problem of the shipping line, which takes into account the preferences of the relevant stakeholders involved. In that regard, the purpose of the framework is to result in an inland terminal location which is most desirable based on the preferences of all included actors. As this location is supposedly most beneficial to the preferences of the companies involved in the inland transport set-ups, it contributes most to the services and operations they provide and thus to the overall effectiveness of the inland transport chain. In turn, this enables the shipping line to attract customers and increase its control on the container port hinterland.

Basically, whereas the shipping line is mostly focused on penetrating into the hinterland transport market by guaranteeing and consolidating certain transport chain services in their hinterland network, terminal operators and terminal users are mostly concerned with fitting the inland terminal facilities best in their transport and transshipment operations so they can offer these and as such comply with the transport chain requirements (Notteboom and Rodrigue, 2017). Because of these differences in objectives, the several factors which are involved in the evaluation of inland terminal locations (to be selected) are expected to be perceived and evaluated differently. In this research, these differences in evaluations are studied by means of a decision-support framework incorporating *Multiple-Criteria Decision Making (MCDM)* modeling. An MCDM model is developed in which the criteria relevant to the stakeholders (which may partly overlap) are assessed in terms of weight and effect on the ultimate decision-making process. Eventually, alternatives get assigned certain utilities based on their characteristics and the corresponding weighted criteria. The analyses of the evaluated factors, weights and utilities result in recommendations which can contribute to the shipping line's decision-making practice with regards to setting up inland terminals in order to improve their inland transport chain propositions.

1.4. Research aim and question

The aim of this research is to provide insight in the influence of the different objectives of relevant decision-making actors with respect to making use of and investing in inland intermodal terminals. The focus of attention goes towards the position of the shipping line, which uses the inland terminals in its transport chain services offered to its customers. The decision-making processes assessed in this study thus address the several criteria evaluated differently by actors relevant to the inland terminal practices as well as the aim of the shipping line to successfully use the inland terminal in its offered inland services in order to increase its control on the container port hinterland. Accordingly, the outcomes of this study serve as a basis for vertical integration strategies of shipping lines with regards to the inland terminal location selection problem.

This research objective results in the following research question:

"How can a shipping line select a location for setting up an own inland terminal in order to increase its control on the container port hinterland?"

Multiple sub-questions are developed in order to structurally and efficiently answer the research question:

1. What is the structure of the contemporary container port hinterland?
2. How do shipping lines exercise control over the container port hinterland?
3. How are inland terminals part of inland transport chains?
4. Which and how are the relevant actors linked to the inland terminal related activities within the inland transport chains?
5. What factors are involved in evaluating an inland terminal location within the inland transport chain?
6. How are these factors with regards to inland terminal location evaluation assessed by the different actors involved in the inland transport chain?
7. How can the differently assessed factors be used to select a suitable location for a shipping line's own inland terminal within the container port hinterland?

1.5. Research scope: The intermodal inland transport chain

The research scope of this study is defined by the container port hinterland. More specifically, it is focused on the intermodal transport chain between the container port and the demand and supply points (e.g. factories) within the container port hinterland, including (potential) terminals in the designated areas as components of these chains. This scope is graphically displayed in Figure 1.1.

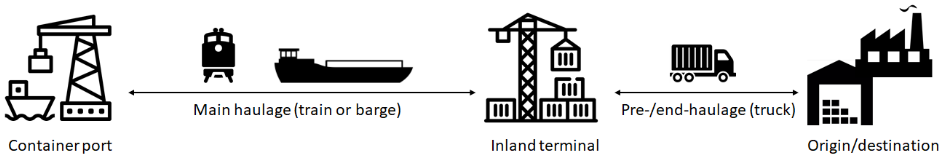


Figure 1.1: Scope of research: The inland transport chain

The scoped inland transport chain can go both ways:

- Import situation: The scope starts at the container port, followed by the main haulage part (via rail or barge transport), after which the inland terminal is reached. After the inland terminal, the end-haulage part (by truck) takes the goods to the final customers (consignees).
- Export situation: The scope starts at the shipper, followed by a pre-haulage part (via truck), after which the inland terminal is reached. After the inland terminal, the main-haulage part (via rail or barge) takes the goods to the container port.

In order to run and validate the inland terminal decision-support model, it is applied to the inland terminal location selection problem of shipping line Maersk. The geographical scope of this project is the hinterland region around the cities of A, B and C, which is denoted by Maersk as "future growth potential region". A map of these locations is displayed in Figure 1.2.

Figure 1.2: Figure is not available due to confidentiality reasons.

In the map, the seaports and the cities in the hinterland, being the demand and supply points, are indicated. Each of the three hinterland areas contains two discrete alternative locations for a potential new inland terminal, which are examined using the MCDM model. These alternative locations are further described in Chapter 4.

1.6. Academic relevance

Location studies are not new in operational optimization and management studies, also not for inland terminals. However, this research adds to the current literature on inland terminal location selection in particular and on Multi-Criteria Decision-Making in two ways.

1.6.1. The inland terminal location selection problem from the shipping line point of view

First of all, this study adds to the literature on inland terminals within the scope of the inland transport chain by viewing the specific inland terminal location selection problem from the shipping line point of view. Various scholars have studied the components, activities and dynamics of and in container port hinterlands. Multiple studies consider analyses on container transport markets (e.g. De Langen et al. (2013); Rodrigue and Notteboom (2013) and optimizing hinterland transport efficiency (e.g. Caris et al. (2012); Notteboom and Rodrigue (2017). However, few studies take the point of view from the shipping line being a main actor in such hinterland developments, mostly because it is a rather new development both in the professional sense as well as in academics. This is especially the case with regards to studies on inland terminals and inland terminal location selection, in which shipping lines originally are not the most common stakeholders being involved. Where Franc and Van der Horst (2010) and Van den Berg and De Langen (2015) touched upon the relationship between inland service integration and inland terminals, this study adds to the contemporary literature and follows up on their notions by focusing on the development and functioning of inland terminals from the perspective of the shipping line *as a key decision-maker*, with the main purpose of improving the shipping line's inland transport chain services offered to its customers. Next to that, this research contributes to the current literature on vertical integration in hinterland container transport markets by obtaining insights in the differently valued criteria involved in inland terminal location decisions by the shipping lines themselves as well as by supplier companies involved in the inland transport chains.

1.6.2. The inland terminal location selection study supported by MAMCA and BWM

Secondly, this study adds to the literature on multi-actor multi-criteria decision making problems by taking into account the varying preferences for individually relevant criteria stemming from the distinct objective(s) of each actor involved. In most primary literature on multi-actor MCDM, the views of the multiple actors involved in the research are generally taken into account by having them evaluate all criteria deemed relevant within one fixed criteria set (e.g. Kayikci (2010); Regmi and Hanaoka (2013); Roso et al. (2015), which are specifically focused on inland terminal location selection). Based on the evaluations of the involved actors, criteria weights are calculated which are used for further assessment of alternatives' utilities. The advantage of this approach is that the calculated criteria weights and the resulting utilities are directly comparable to each other, because they all stem from the same fixed set of decision criteria. However, it is argued that decision criteria (which are originally stored into one fixed set) are not necessarily relevant to the particular objectives of every actor involved in the process, as this implies that criteria *irrelevant* to certain actors are subject to their assessment while they actually are not the appropriate criteria to assess in order to properly reflect their preferences (Macharis et al., 2012). In fact, sets of decision criteria are likely to vary between the different actors in the study. Incorporating the multiple stakeholders' objectives into multi-criteria decision-making models is facilitated by the *Multi-Actor Multi-Criteria Analysis (MAMCA)* framework (Macharis, 2005). However, as the stakeholder-specific criteria sets consist of varying (amounts of) criteria for each actor, resulting criteria weights are not directly comparable to each other since they are based only on the other criteria in the set. Straightforward comparison between criteria weights of criteria from different stakeholder-specific sets is therefore troublesome. Nevertheless, the stakeholders' preferences can still be extracted to be used in the MCDM study. Accordingly, the inclusion of the *Best-Worst Method (BWM)* as weight determination approach into the MAMCA framework is proposed. The multi-optimality property of the non-linear BWM model allows to determine criteria weight *intervals*, in which the complete range of preferences of the respective stakeholders based on stakeholder-specific criteria sets are taken into account. In order to compare the final utility scores of the alternatives, a *utility aggregation* approach is proposed, by which it is made possible to equally include all actors' preferences with regards to the specific criteria they find relevant.

2
The inland terminal within the multi-layer structure of the container port hinterland

The aim of this chapter is to define the research system (i.e. the inland terminal location) and to define the context of the system by assessing the influences from/on the location. Since the inland terminal is located within the hinterland of the container port, the inland terminal location is viewed within the structure of this container port hinterland, which can be subdivided into multiple layers. Consequently, each layer is described separately in order to assess the features, activities and actors which (potentially) affect the inland terminal location. The end of this chapter includes an overview of the system inputs ought to be taken into account for the remainder of this research.

2.1. The multiple layers of the container port hinterland

The seaport hinterland can be defined as ”the area over which a port draws the majority of its business” (Notteboom and Rodrigue, 2017, p. 2). For the inland terminal, this hinterland definition implies the position of the inland terminal within the economical region around its location. As the location of the inland terminal is within this hinterland, it affects and is affected by the components and activities that take place in this area. This is also applicable to the selection of a *location* for the inland terminal, which thus gets influenced by these components and activities taking place in the hinterland context. In other words, the components and activities taking place in the container port hinterland are considered as input for the inland terminal location evaluation and selection process. Since the collection of hinterland components and activities is rather dynamic and complex, it is assessed by subdividing the complete structure of the container port hinterland into multiple layers, each containing corresponding components and activities. For this purpose, the four-layer model of Notteboom and Rodrigue (2017) is considered. This model allows to individually examine the several interrelated levels which compose the structure the hinterland. Since the original model focuses on the position of seaports in between their hinterlands and the ocean transport network (see Notteboom and Rodrigue (2017, p. 8) for details), it is applied in an adapted[1] form with a focus specifically on the hinterland in order to fit this study. This adapted model is displayed in Figure 2.1.

- The **logistical** layer involves the *organization* of transport and transshipment services in the container port hinterland, which together make up inland transport chains. The logistical layer thus involves the design of such inland transport chains by means of the organization of the transport, transshipment and affiliated logistical services offered by (inland) transport service providers to shippers/consignees between their facility locations and the corresponding seaports.

[1] In the original four-layer model, the focus is on the seaport as a node between ocean and hinterland transport. In the adapted model, this focal point is shifted from the seaport node (which is less relevant in this study) towards the inland terminal as a node between main haulage transport and pre-/end-haulage transport.

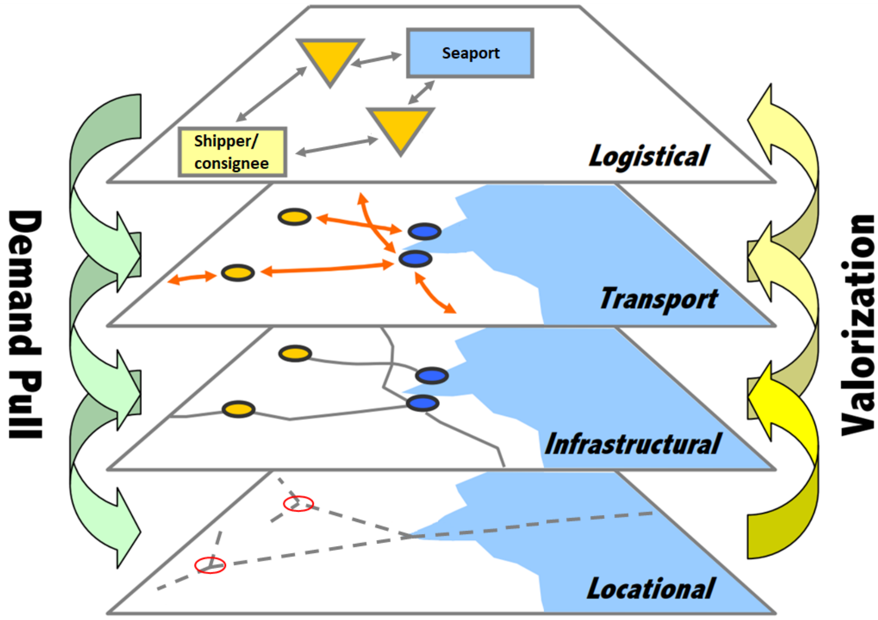


Figure 2.1: Four-layer model expanding the structure of the container port hinterland (edited from Notteboom and Rodrigue, 2017)

- The **transport** layer involves the actual *transport and transshipment operations* conducted within the hinterland, thus realizing the above mentioned designed services. With regards to intermodal transport, it involves the main haulage transport legs between seaports and inland terminals as well as the pre- and end-haulage parts between the inland terminals and the shippers/consignees. The transshipment operations take place in between such legs.
- The **infrastructural** layer involves the *transportation and transshipment infrastructure* available for the above mentioned transport and transshipment operations in the hinterland region. It includes the networks of highways, railways and inland waterways as well as the physical inland facilities including equipment such as inland terminals.
- The **locational** layer involves the *geographical locations* of the above mentioned infrastructure in the container port hinterland. As these locations are concerned with the positions in the economic space, it defines measures such as its centrality and intermediacy with respect to other geographical locations. As the infrastructure location encompass the *inland terminal locations*, selection of the inland terminal location is represented in the locational layer as well.

Certain downward effects (*demand pulls*) and upward effects (*valorization*) between the layers exist. The demand pulls indicate demand effects generated by an activity/feature in an upper layer imposed on the lower layer, e.g. transport operations (in the transport layer) require transport infrastructure (in the infrastructure layer). The valorization effects indicate the value added by activities/features in a layer to its lower layer, e.g. the existence of infrastructure (in the infrastructure layer) near a certain location (in the locational layer) makes sure that the location is actually accessible, which adds value based on this accessibility to the location. These effects imply the interrelatedness between the components from different layers with each other. More specifically with regards to this study, the effects imply the influences between the inland terminal location and the components of the logistical, transport and infrastructural layers.

2.2. Inputs from the multi-layer container port hinterland for inland terminal location evaluation and selection

According to the analogy of the four-layer model, the remainder of this chapter involves describing the system inputs stemming from the logistical, transport, infrastructural and locational layers. The purpose of this review is to define the context of each layer, consisting of components, actors and related activities deemed relevant to the inland terminal location evaluation and selection process.

2.2.1. Logistical layer contents

The logistical layer of the four-layer model comprises the organization of transport and transshipment operations in the container port hinterland, which linked together form the inland transport chains. The highest levels of these organization practices involve the design and the management of complete supply chains for customers (De Langen et al., 2013), in which strategies are developed which support optimizing companies' logistics configurations (e.g. the number and location of warehouses). In lower levels, the actual transport chains from origin to destination are designed. This implies the allocation and use of certain transport services to comply with the (customer's required) supply chain configuration. To comply with the specific components of the total transport chain, specific schedules for transport and transshipment services are sold, designed and managed for/between the various modalities. Multiple actors are involved in these activities. De Langen et al. (2013) define the major companies that play roles in the supply and transport chain design and management, specifically for hinterland transport:

- **Shippers**, also known as **Consignors**, are the parties that own the goods that have to be shipped, thus the initiators of container transport (Douma, 2008). They deliver the goods that have to be transported via containers and are therefore at the export sides of the transport chains. Next to shippers initiating container transport, scholars also acknowledge the receiving parties to be separate significant factors in supply chain development and design (e.g. Douma (2008) and Smeele (2009)). These parties are called the **Consignees** and are at the pulling ends of the transport chains, i.e. the import sides. Most shippers and consignees outsource their logistics activities. Accordingly, the designs of their transport chains are taken care of by third parties (De Langen et al., 2013). Thus, shippers/consignees are usually the customers of the transport chain designers.
- **Freight Forwarders** are mostly active in the design of door-to-door transport chains for their customers which deliver the goods to be transported. Usually, freight forwarders purchase services from transport operating companies instead of owning and operating transport-related assets by themselves.
- **Shipping Lines** are originally responsible for the (organization of) ocean transport of containers between ports, carried out with their own vessels and containers (Van den Berg and De Langen, 2015). However, since a few decades, shipping lines increasingly offer the services of having containers transported between ports and locations in the hinterland as well. This development, which forms the basis of this research, is further discussed next.

The way these actors and their corresponding activities are positioned with respect to the supply chain design and management practices and relative to each other within the logistical layer is largely dependent on the *hinterland haulage configuration.* This configuration determines the different parties' responsibilities within the transport chains, thus define the positions of the players in the hinterland transport playing field. Common from a shipping line perspective is to use the *bill of lading (B/L)* in order to define the leg(s) of the transport chain for which a carrier is responsible for the shipment (Veenstra et al., 2012). In general, three types of haulage configurations can be defined based on common B/L agreements; *Merchant Haulage*, *Carrier Haulage* and *Terminal Haulage* (Figure 2.2).

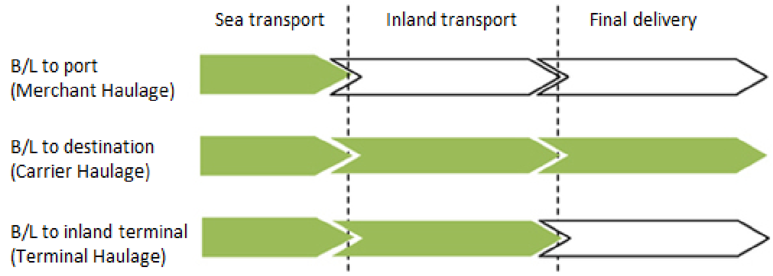


Figure 2.2: Variants of Bill of Lading (B/L) configurations (edited from Veenstra et al., 2012).

In **Merchant Haulage (M/H)**, the B/L states that the shipping line is responsible to move the goods along the maritime leg (from port to port). A customer (shipper/consignee) arranges sea transport with the shipping line, but takes care of the hinterland transportation on its own. The hinterland transport leg is usually arranged by consulted third parties such as freight forwarders or logistics service providers, so called *Third Party Logistics* (*3PL,* Alireza and Alagheband, 2011). In the **Carrier Haulage (C/H)** configuration, B/L responsibility lasts until the final destination of the goods. A customer (shipper/consignee) arranges the complete transport from origin to final destination with the shipping line. Thus, the shipping line is responsible for both the maritime leg and the inland leg from the port to the final destination. This is in contrast to the original role of the shipping line, which was limited to long-distance transport of containers in seagoing ships. However, Carrier Haulage becomes more common since shipping lines increasingly aim at expanding their activities to the hinterlands by means of vertical integration (Franc and Van der Horst (2010). By offering door-to-door services, shipping lines have expanded their markets from partly to totally covering the transport chain. Reasons for this development include the need for an improved competitive position in the container transport market by reducing overall costs and the amount of involved parties in the hinterland transport chains (Franc and Van der Horst, 2010) and improved repositioning strategies by having better insight into the positions and flows of the shipping lines' containers within the hinterland[2] (Frémont, 2009; Song and Dong, 2015; Van den Berg and De Langen, 2015).

The scope of the door-to-door service provision is much larger than that from the port-to-port service provision. Next to ocean transport, the shipping line offers services for three landside modes (if available), in order to comply with customers' hinterland needs. Since the shipping line does not have vehicles and other kinds of assets in the hinterlands, it has to outsource these operations to inland transport and terminal operating companies. The development towards designing such door-to-door transport chains increases the activity of the shipping line within the logistical layer of the container port hinterland. It also implies an increasing competitiveness between shipping lines and freight forwarders, since the latter originally designed these transport chains and served as customers of the shipping lines by taking care of transporting their containers inland (Van den Berg and De Langen, 2015). Important to notice (with regards to this study) is the fact that in these value propositions the shipping lines do not develop, own or control inland terminals. This lies outside of the scope of shipping lines in the conventional door-to-door configurations. However, by being actively engaged with these inland terminals, the potential to effectively use the inland terminal services in order to improve the (design of the) inland transport chain is increased. Franc and Van der Horst (2010) furthermore indicate the fact that having a dedicated inland terminal can be used by shipping lines to convince shippers of the ability to secure container flows and consequent service reliability. A dedicated inland terminal would give the shipping line a unique selling point, interesting for customers because of the higher service compared to

[2] In contrast: when no adequate repositioning strategies are used, empty containers will mostly be transported from their final inland destinations back to the seaports, after which they are returned to their next export location in the hinterland, implying extra transport operations and corresponding costs (Theofanis and Boile, 2009).

competitors' inland service offers.

Another configuration mentioned in the figure is **Terminal Haulage (T/H)**, in which the B/L states a transport responsibility for the sea leg and the hinterland transport leg until an inland terminal combined (De Langen and Chouly, 2009). Although this set-up is mostly practiced by seaport terminal operating companies in order to commercialize transport operations and decongest seaport space by pushing containers quickly from the seaports towards the hinterlands, shipping lines can offer T/H services as well (Van den Berg and De Langen, 2015). However, T/H contracts account for substantially less transactions compared to M/H and C/H. Therefore, it is not further considered in the scope of this research.

2.2.2. Transport layer contents

In order to realize the designed transport chain services, actual transport and transshipment operations have to be executed. Such operations include the movements of containers at and between locations in the hinterland as well as affiliated services (e.g. storage). While transport operations are based on the particular transport mode, transshipment operations occur between such modes (e.g. transferring loads from one mode to another). This is especially the case for intermodal transport, in which at least one transshipment operation exists between either rail or barge and truck. The actors involved in the transport layer are the inland transport and the inland terminal operators (De Langen et al., 2013). **Transport Operators** take care of actually performing the transport of goods between origins and destinations. They work for the shippers, forwarders and shipping lines which design the transport chain service to be realized. Three main transport operating company types are defined:

- **Trucking Companies** own and operate trucks which they use for road transport services. In the case of intermodal transport, they usually perform the pre-/end-haulage legs between customer locations (*doors*) and inland terminals.
- **Rail Operators** provide inland railway transport by running scheduled train services from and to (inland) terminals. In the case of intermodal transport, they operate in the main haulage parts.
- **Barge Operators** provide inland waterway transport by operating barges. Usually they have contracts with individual barge owners (captains) instead of owning the barges. In the case of intermodal transport, they operate in the main haulage parts.

Terminal Operating Companies (TOCs) operate terminals and thus provide terminal handling activities and management of container flows through their terminals. A distinction is made between ocean terminal operators and inland terminal operators. Although there exists overlap since some ocean terminal operators also operate inland terminals (Franc and Van der Horst, 2010), in this research only the inland terminal operators are considered to be relevant to the inland terminal location evaluation and selection. Several *levels of service* are used to classify inland terminals based on their operational fit within transport chains. de Villiers (2015) distinguishes:

- **Level 1:** *Basic logistics services* are offered based on the available core infrastructure. These services mainly facilitate flow, storage and distribution of goods/containers. On top, Rodrigue et al. (2010) mention three functions for characterizing the basic logistics services of the inland terminal:
  - *Consolidation/deconsolidation:* bundling or breaking down batches of goods to be transported, according to shipper's/consignee's needs.
  - *Transloading*: if needed, maritime containerized units can be transloaded into domestic units or vice versa. Domestic units are locally used container standards which can vary per geographic region, e.g. 53 foot in North America and 45 foot in Europe (differing from the maritime 20/40 foot standard). Most often, transloading is combined with consolidation/deconsolidation.

  - *Postponement*: the inland terminal can be used to store goods (according to available dwell times) in order to enable last minute/last mile trucking. Hence, the inland terminal functions as a buffer within the transport chain, called "warehousing-based terminalization" (Rodrigue and Notteboom, 2009).

- **Level 2:** *Value-Added Services (VAS)* can be offered on top of the basic services. They include extra services which improve the (cost-)efficiency of the movement and storage of the goods within the transport chain. Rodrigue et al. (2010) define VAS as *light transformations*; product and package transformations including e.g. packaging, labeling and customization to national/cultural/linguistical market characteristics. As this is usually done in seaports, inland terminals closer to customers can provide improved supply chain management flexibility.

- **Level 3:** Once VAS are available at an inland terminal, *commercial and financial services* can be offered on top. This is often by default the case, since they are required to sustain and serve the value added services. These services are however not directly related to the transport and transshipment operations in the transport layer, thus they are not taken into account in the remainder of this research.

2.2.3. Infrastructural layer contents

The infrastructural layer contains the physical facilities used to serve the container movements, handlings and other related activities performed by transport and terminal operators. These include the specific container handling equipment (e.g. vehicles and cranes) as well as the infrastructure networks including the specific sites at which transshipment facilities (e.g. inland terminals) are developed are represented (De Langen et al., 2013). The most common practice in the characterization of such infrastructure networks is the distinction between links and nodes. Whereas links represent the infrastructure used for the movement of vehicles/goods *between* certain points in the network (e.g. roads, rail tracks and inland waterways), nodes represent the infrastructure *at* these points in the network (which could be either origin/destination points or intermediate points used for transshipment operations). Based on this distinction, the main actors involved in the development, operation and ownership of the infrastructure are also distinguished:

- **Link infrastructure:** Link infrastructure consists of the road, railway, inland waterway and other kinds of longitudinal infrastructure which connect the points in a geographical area with each other. These networks mainly have a public function of making locations within such geographical areas accessible, thus are usually initiated and owned by public actors such as governments or governmental authorities (Bergqvist and Monios, 2014; De Langen et al., 2013). Since the extent of this public task on maintaining and increasing public well being is larger than only related to inland terminals, the decisions made with regards to link transport infrastructure development are considered to be outside of the scope of this research.

- **Node infrastructure:** Node infrastructure consists of the transshipment facilities at the origins, destination and intermediate facilities from and to which containers are transported. Main actors in this regard are the inland terminal owners[3] (De Langen et al., 2013). The inland terminal owner could be a single party or a combination of multiple parties sharing the ownership of one inland terminal, possibly including both private and public parties (Bergqvist and Monios, 2014). Hence, governmental entities also need to be taken into account as important actors. However, they usually only (partly) define context rather than actually take part in the (final) decision-making regarding node infrastructure.

The inland terminal serves as an infrastructural node within the hinterland container transport network. Three major infrastructural functionalities for inland terminals, which characterize their position within the hinterland networks, are identified (Rodrigue et al., 2010);

[3] Usually, the inland terminal owners are the same companies as the inland terminal operators, thus these actors are present in both the transport and the infrastructural layer

the *satellite terminal* (1), the *transmodal center* (2) and the *load center* (3). These concepts are graphically displayed in Figure 2.3

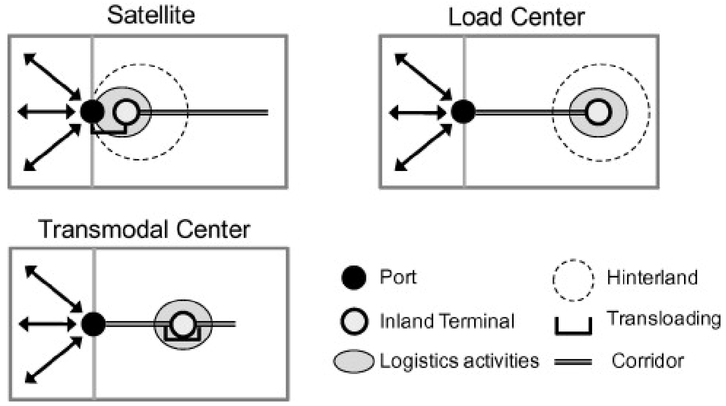


Figure 2.3: Three types of ILT functionalities (from Rodrigue et al., 2010).

1. The satellite terminal can mostly be seen as an addition to the seaport capacity; it serves the seaport terminal by accommodating additional traffic and other functions beneficial to the seaport activities. If needed it gets transloaded into container types sufficient for the subsequent transport leg modality. A comparison can be made with the *extended gateway* concept, in which the inland terminal basically forms a direct capacity extension of the seaport terminals by facilitating direct transit from the seaport to the inland terminal, from where the cargo can be moved further inland. In the extended gateway concept, the inland terminal is also owned and controlled by the seaport TOC (Veenstra et al., 2012).
2. The transmodal center serves as a point where freight flows from a certain port get consolidated with rail or barge flows (e.g. from other inland terminals). Thus, it mostly serves as an intermediate point in the network between seaports and shippers'/consignees' locations. If needed, goods get transloaded into container types sufficient for the subsequent transport leg modality.
3. The load center is located in and directly serves a certain region, often at a considerable distance from the sea(port), in which substantial volumes between this area and the seaport find their origins or destinations. It forms a point in the hinterland network at which container flows to/from specific shippers/consignees in the region get (de)consolidated. Transloading is usually not applicable to the load center, because the container flows between the seaport and this type of inland terminal mostly consist of maritime containers directly loaded from the ocean vessel to a train/barge or vice versa.

The inland terminal functionality of the load center (3) can be considered as most applicable to the interest of shipping lines, since these facilities are usually located close to and/or focused on (large) shippers. The load center terminal can function as an extended storage area and facilitate efficient services from the shipping line for its customers (Rodrigue et al., 2010; Van den Berg and De Langen, 2015). Hence, the effectiveness of the load center terminal within the inland transport chain is mainly based on the distances between the terminal and the customer locations rather than between the terminal and the seaport(s), since the former determine the effectiveness of the terminal functionality for the particular shippers/consignees. Based on the load center's contribution to further integration between inland terminals and shippers/consignees and to integration of shipping lines into the hinterland (Van den Berg and De Langen, 2015), the added value of the load center terminal for the specific inland transport chain is implied. The development in which the inland terminals increasingly integrate within these transport chains is referred to as *supply chain terminalization* by Rodrigue and Notteboom (2009).

2.2.4. Locational layer contents

Lastly, the locational layer of the container port hinterland contains the geographical locations of the infrastructures in the economical space of the hinterland. As a major part of this economic space consists of the positions of container volume generating/attracting entities (e.g. factories and distribution centers), the locations of the infrastructures in the locational layer are relative to these points. In the locational layer, centrality measures thus determine the (relative) distances between infrastructures and points which should benefit from these infrastructures (e.g. by being/becoming accessible). Accordingly, the location of infrastructure can be contributive to as well as dependent on such volume generating and attracting points. Because of the aim of this study, this is an important notion with regards to the selection of the infrastructure location. Generally, deciding on the location of the infrastructure is based on the provision as well as the operation of the facilities. Hence, the decision is made by the actors involved in the infrastructural layer. In the sense of this study, another decision-maker with regards to the selection of the inland terminal location is the shipping line, because this actor aims at incorporating the infrastructure operations in its designed inland transport chain.

2.3. Synthesis of the review of the inland terminal within the multi-layer structure of the container port hinterland

In this chapter, the research system and the context determining the research system inputs are discussed. The research system, being the inland terminal location, is viewed as a component of the broader container port hinterland of which the structure exists of multiple layers. By making use of the four-layer model of Notteboom and Rodrigue (2017), the *logistical layer*, the *transport layer*, the *infrastructural layer* and the *locational layer* are identified. All layers are considered to be important for the assessment of the container port hinterland due to *demand pull effects* from a higher layer towards the layer below and *valorization effects* from a lower layer towards the layer above. From each layer, the components, activities and related actors relevant to the evaluation and selection of the inland terminal location can be extracted. With regards to the actors, a distinction can be made between *key actors* and *contextual actors*. Key actors are directly involved in the main activities taking place within the respective layer, whereas contextual actors are associated with these activities but not actively involved (in the scope of this research). The latter ones are therefore not taken into account as decision-makers in the remainder of the study.

- The **logistical layer** contains the organization of supply and transport chains. Originally, these transport chains are mostly designed by freight forwarders or other third parties for shippers/consignees in so called Third Party Logistics. However, in recent times, shipping lines increasingly tend to expand their scopes and gain more control in the design of transport chains (which is the basis of this research, see also Sections 1.1 and 1.4). Shipping lines aim at increasing the *Carrier Haulage* set-ups (compared to *Merchant Haulage* set-ups) in the hinterlands, which enlarges their controlled scopes from port-to-port to door-to-door transport. A means of stimulating this development is by actively engaging with inland terminals in the hinterland transport network, as this enables local facilitation of transport and transshipment operations contributing to the effectiveness of inland transport chains. Hence, with regards to the shipping line's design objectives for its inland transport chains in the logistical layer, the shipping line is considered to be a key actor. Freight forwarders and the shippers/consignees are considered to be contextual actors (in the form of competitors and customers respectively).
- The **transport layer** contains the transport and transshipment operations that realize the designed transport chain services as described above. Main haulage legs, in the form of either rail or barge transport, are performed by intermodal transport operators while pre-/end-haulage legs are conducted by truck transport operators. Since these transport operators actively make use of inland terminals in their operations, they are

considered to be key actors with regards to inland terminal location evaluation. Transshipment operations are performed at inland terminals by inland terminal operators, which are thus also regarded as key actors in the transport layer. Next to *basic logistics services*, *Value-Added Services (VAS)* can be offered which involve extra services aimed at improve the (cost-)efficiency of the broader transport chain.

- The **infrastructural layer** contains the transport and transshipment infrastructure used to facilitate the above mentioned transport and transshipment operations. Link infrastructure (e.g. roads, railways and inland waterways) is usually developed and owned by governmental actors, based on maintaining and increasing public well being in a larger sense than only related to inland terminals. Therefore, the decisions made with regards to link transport infrastructure *development* are considered to be outside of the scope of this research[4]. The government as a key actor with regards to infrastructure is thus not considered in this research. Node infrastructures such as inland terminals are commonly owned by private or public-private entities. With regards to inland terminals, the key actor is the inland terminal owner operator, implying its presence in both the transport layer and the infrastructural layer. Whereas the inland terminal operators are considered as key actors, public(/governmental) actors which might be involved with inland terminal ownership are not because of their rather non-executive roles. With regards to the infrastructural function of the inland terminal within the inland transport chain, the *load center* facilitating integrated transport and transshipment solutions close to the locations of shippers/consignees is most applicable to the shipping line aiming at setting up the facility as a component of its offered inland services.

- The **locational layer** contains the geographical locations of the above described infrastructural components within the economic space of the container port hinterland. Since these infrastructure locations are relative to the container volume generating/attracting points in this economic space, they define the distances between these locations and the actual infrastructure and thus the relative effectiveness of the infrastructure. Accordingly, the location of infrastructure can be contributive to as well as dependent on the economic space. *Selecting* infrastructure locations is shaped by these relations as well. The infrastructure operator is a key actor with regards to the infrastructure location selection, since it is involved with the actual provision as well as the operation of the infrastructure. As this study is aimed at selecting a location for inland terminal infrastructure to be specifically used in the inland transport chain designed by the shipping line, the latter is also a key actor in the location selection process.

An overview of the container port hinterland layer contents applicable to this study, including the key activities and the actors making the (final) decisions with regards to these activities, is given in Table 2.1.

Layer	Key activity	Key actor
Logistical	Organize inland transport chains	Shipping line
Transport	Transport containers	Intermodal transport operator, truck transport operator
	Transship containers	Inland terminal operator
Infrastructural	Provide transshipment infrastructure	Inland terminal operator
Locational	Select infrastructure location	Shipping line, inland terminal operator

Table 2.1: Overview of container port hinterland layers, corresponding key activities and actors making decisions with regards to these activities.

The information from the container port hinterland structure review is further used as system

[4]However, the *availability* of link transport infrastructure is taken into account because this does influence the decision-making regarding inland terminal location selection.

input in the remainder of this study. Based on the review outcomes, the inland terminal location selection process considered in this study can be configured as follows:

- The actual decision-making actors with regards to the location selection of the inland terminal are the **shipping line** and the inland **terminal operator**.
  - The shipping line evaluates an inland terminal location and makes the decision to select it based on the objective to *incorporate the terminal in the designed inland transport chain*.
  - The terminal operator evaluates an inland terminal location and makes the decision to select it based on the objective to *ensure profitability of transshipment operations at the site*.
- The transport operators, i.e. the **terminal users**, are not actually involved in the decision made on the location of the terminal. However, they are *influenced* by this decision, as the eventual location of the terminal defines between which locations in the broader network transport operations have to be performed. The fit of the selected location within the transport operation scheme of the terminal user consequently affects the (cost-)efficiency of the transport operations and eventually of the whole inland transport chain. Accordingly, the evaluation of the inland terminal location by the transport operators is based on the objective to *use the inland terminal to optimize the transport operation scheme*. This evaluation is important for eventually selecting a location beneficial to these transport operations, thus ultimately beneficial to the designed inland transport chain.

Figure 2.4 shows this study configuration graphically.

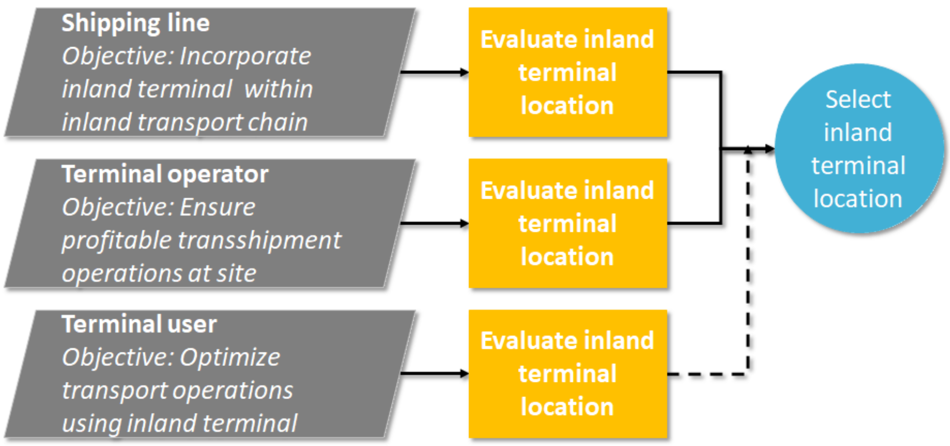


Figure 2.4: Inland terminal location selection configuration

As can be noticed, there is a clear distinction between the actors which evaluate and eventually *select* the inland terminal location and the actor which only *evaluates* the location. The dashed arrow indicates the importance of the evaluation by the terminal user on top of the evaluations by the decision-making actors for the ultimate location selection. Theories on the methods for evaluating and selecting inland terminals are reviewed in Section 3.1. Specific factors included in these processes commonly observed in literature are discussed in Section 3.2. An eventually proposed methodology for assessing stakeholders' preferences with regards to such factors is described in Section 3.3.2. The proposed methods for using these preferences for inland terminal evaluation and selection is presented in Sections 3.3.4, 3.3.5 and 3.3.6. Ultimately, the application of this methodology to multiple alternative locations in a case study leads to selecting an inland terminal location, which is discussed in Chapter 4.

3

Location selection model development based on inland terminal location selection literature review

In this chapter the inland terminal location selection context is shaped. This context involves a theoretical background used to define the location selection methodology. This theoretical background is discussed in Section 3.1. Additionally, common factors used particularly in literature on inland terminal location selection are reviewed in Section 3.2. Based on the theoretical background on location selection modeling and features, a six-step research framework is proposed (Section 3.3).

3.1. Common practices in handling inland terminal location selection problems

In this section, literature on the location decision-making process with regards to inland terminals is reviewed. Finding the best location for an inland terminal can be considered as a typical location problem. Location problems exist in several ways and have multiple approaches and solving techniques. With regards to finding appropriate locations for inland terminals, two general approach categories can be defined (Wiegmans and Behdani, 2018); the quantitative mathematical modeling approach and the (qualitative or semi-quantitative) multi-criteria analysis approach.

3.1.1. Quantitative methods for inland terminal location selection problems: location selection through optimization

In general, location optimization by means of mathematical modeling is dependent on the (transport) network considered. A classic approach to the location problem is the *p-Median problem*, in which the demand weighted average distance between demand nodes and selected facilities is minimized (Daskin and Maass, 2015). Other classical location problems are the *Fixed-Charge Facility* problem, which determines facility location and service allocation (Fernández and Landete, 2015) and *p-Center problems* in which the demand weighted maximum distances between demand and supply points are minimized (Calik et al., 2015). These classic location problem solving techniques have been the basis for more advanced methods, such as *facility location under uncertainty*, *multiple-criteria location problems* and *hub location problems* (Laporte et al., 2015). Especially the latter one is a typical method to solve location problems for inland consolidation/distribution facilities within a larger (transport) network, such as inland intermodal terminals. In this approach, hub facilities are located within a network including demand nodes, in order to route traffic between origins and destinations making use of these hubs. Important is the relationship between the locations of the hubs and the flows within the network, which are consolidated in hubs on their routes (e.g. based on transport cost minimization). Thus, in hub location problems, not only the allocation of the distribution facilities takes place, but also the optimal set-up of routing within the network (Alumur and Kara, 2008).

Basically, these kinds of classical (based) location problem solving techniques make use of an optimization task in order to get to a final optimal solution. When considering inland terminal location optimization studies, a majority uses the minimization of transportation costs as optimization objective on which the optimal location is based, e.g. Ambrosino and Sciomachen (2014); Ishfaq and Sox (2010, 2011); Jeong et al. (2007); Limbourg and Jourquin (2010); Meers and Macharis (2014); Sörensen et al. (2012). With respect to inland terminal locations specifically, Wiegmans and Behdani (2018) also indicate the explicit inclusion of transshipment and handling costs in order to optimize inland terminal location selection, e.g. by Arnold et al. (2004); Limbourg and Jourquin (2007, 2009). Next to approaches including optimization, network-based scenario studies are applied by e.g. Pekin et al. (2013), in which they assess the effects of different network and inland terminal location configurations on resulting total (generalized) costs.

In other studies, location problems are approached by considering the multiple attributes and criteria involved in the decision-making processes with regards to allocating facilities (e.g. Farahani and Asgari (2007) and Żak and Węgliński (2014)). Major difference is the fact that no *optimal* configuration of facility locations and service set-up is tried to be found, but that the assessment of the multiple factors involved, from the point of view of (a) decision maker(s), leads to a ranking/best of considered options within a studied setting. These are the qualitative and/or semi-quantitative multi-criteria approaches, discussed in the next section.

3.1.2. (Semi-)qualitative methods for inland terminal location selection problems: location selection through Multi-Criteria Decision-Making

Apart from studies using quantitative data to approach location problems, scholars also notify the importance of qualitative information for location problems. Although these kinds of data are not always easily quantifiable, they can be important for the determination of inland terminal locations. The use of qualitative data is praised for it allowing the preservation of integrity and elimination of complexity in studies (Atieno, 2009). However, it also brings limitations since qualitative analyses are prone to ambiguities and findings of qualitative studies are not easily extendable to other/wider subjects with the same level of certainty as quantitative studies. For these reasons, amongst others, a large amount of studies make use of both quantitative and qualitative data. The combination of using both quantitative and qualitative data is usually facilitated by *Multi-Criteria Decision-Making (MCDM)* methods. These techniques make the qualitative data quantifiable and the different kinds of information able to be evaluated by relevant experts and compared to each other (Long and Grasman, 2012).

The MCDM approach basically consists of systematically pursuing multiple decisions and/or objectives. The concept has been academically popularized since the 1970s (Zionts, 1979) and can be divided into *Multi-Objective Decision Making (MODM)* and *Multi-Attribute Decision Making (MADM)* (Farahani et al., 2010). Whereas MODM is aimed at solving continuous problems, MADM is aimed at solving discrete problems (Zavadskas et al., 2014). In MODM, a decision maker designs an alternative (instead of choosing it from a predetermined set) by considering the interactions, constraints and objectives it has to meet. Therefore, it can be stated that MODM studies aim at a certain optimized objective, similar to the previously described traditional location problem solving techniques (e.g. Feng and Huang (2005); Lv and Li (2009)). In contrast, more distinct to the optimization approaches, MADM considers a predetermined number of alternatives which each satisfy certain objectives to some extent, making up the selection set for a decision maker. The decision maker selects the best objective-reaching solution from this set, according to the priority of each objective and the interactions between the objectives. Generally, this approach is mathematically displayed in a matrix form (Rezaei, 2015):

$$A = \begin{matrix} & c_1 & c_2 & \cdots & c_n \\ a_1 & p_{11} & p_{12} & \cdots & p_{1n} \\ a_2 & p_{21} & p_{22} & \cdots & p_{2n} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ a_m & p_{m1} & p_{m2} & \cdots & p_{mn} \end{matrix}$$

In the matrix, $\{a_1, a_2, \cdots, a_m\}$ is a set of alternatives; $\{c_1, c_2, \cdots, c_n\}$ is a set of criteria on which the decision has to be based; and p_{ij} is the score of alternative i regarding corresponding criterion j. Score p_{ij} is based on the particular data representing the criterion for the corresponding alternative. As data for various criteria differ in contentual and numerical characteristics, p_{ij} represents the *normalized* score of the corresponding data. Normalization of the data generally implies the transformation necessary in order to obtain numerical and comparable input by making use of a common scale (Vafaei et al., 2016). Several normalization techniques exist, of which typically used ones include *Linear Max normalization* (Çelen, 2014); *Linear Max-Min normalization* (Patro and Sahu, 2015); *Linear Sum normalization*, *Vector normalization* and *Logarithmic normalization* (Jahan and Edwards, 2015). The most suitable normalization technique to apply on the data relies on the particular MCDM method considered in the study (Vafaei et al., 2016, 2018a,b, 2019). Subsequent to the normalization procedure, the normalized scores of p_{ij} add up to overall score V_i for alternative a_i. The best overall scoring a_i then represents the most desirable option from this set of alternatives. The value of overall score V_i is not obtained by simply summing the values of p_{ij}, but is in most MCDM techniques produced by the *Additive Value Function* (Keeney and Raiffa, 1976):

$$V_i = \sum_{j=1}^{n} w_j p_{ij}$$

, in which $w_j \geq 0, \sum w_j = 1$, represents a weight factor for criterion j. Basically, it is the summation of all scores p_{ij} in which weights w_j determine the degree of importance given to criterion j by the decision maker.

MADM or discrete MCDM, in existing literature most often simply referred to with the global term MCDM, thus allows including the various criteria considered important to some (relative) extent for reaching objectives by the stakeholders involved in a certain project. With regards to inland terminals, MCDM approaches are used by several scholars in order to handle the several actors and criteria involved in assessing their (proposed) locations. Ka (2011) and Özceylan et al. (2016) approach the inland terminal location problem from an administrative point of view, by involving governmental actors in the MCDM study. A different perspective is applied by Karaşan and Kahraman (2019), which let the assessments of criteria included in their study be performed by supply chain experts. In several studies, broader perspectives based on more kinds of relevant actors' inputs are involved. Regmi and Hanaoka (2013) and Roso et al. (2015) include a.o. governmental actors, logistics service providers, terminal operators and other business professionals. The eventual study outcomes are then based on the evaluations of these several types of actors combined, which leads to certain compromise solutions based on the combination of preferences of all stakeholders involved, typically useful to policy-makers who need to take into account such varieties of different preferences. Kayikci (2010) also shows that multi-actor MCDM models are supportive in inland terminal location problems from a policy point of view. However, different than in the earlier mentioned studies, the qualitative information is gathered from and processed *individually for* the stakeholders in the decision-making process (i.e. transport service organizers, terminal operators and transport operators).

A common characteristic of the above mentioned MCDM studies on inland terminal location selection is the fact that fixed decision criteria sets are used for each actor involved. This means that every actor evaluates the same criteria, regardless of the relevancy of particular factors with regards to the stakeholder's objective. Because of the differing stakeholders' objectives involved in many multi-criteria problems (e.g. in the inland terminal location selection problem, as discussed in Section 2.3), criteria relevant to certain actors might also differ (Macharis et al., 2012). A useful methodology in which every stakeholder group can be assigned its own criteria set is *Multi-Actor Multi-Criteria Analysis (MAMCA)* (Macharis, 2005; Macharis et al., 2012). Through the MAMCA framework, the different criteria and the various criteria-evaluating actors can be combined and analyzed structurally. The approach consists of a stepwise process, which is graphically displayed in Figure 3.1.

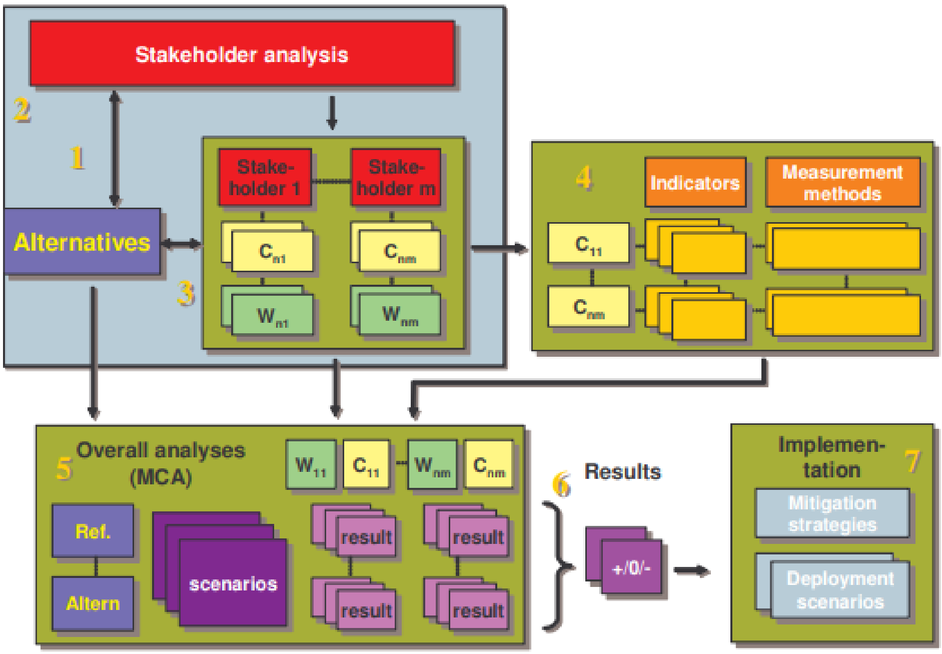


Figure 3.1: Basic MAMCA methodology (from Macharis, 2005)

Step 1: Defining the problem and the alternatives

The first stage of MAMCA involves the problem definition and the consequent identification of alternatives to be submitted for evaluation. As the problem definition essentially includes the research objective, the alternatives are naturally derived from that objective. In some studies alternatives are pre-determined, which prompts straightforward definition. Other studies involve a range of alternatives from which the ones eventually included in the study have to be selected. Selection can be done through specific screening techniques (e.g. Macharis et al. (2004)) or by stakeholders being involved early in the process (e.g. Turcksin et al. (2011)). In the latter case, possibly revealed stakeholder objectives can serve as input for the next step, which involves the stakeholder analysis.

Step 2: Stakeholder analysis

The stakeholder analysis is used to determine[1] and examine the actors which are likely to use or get influenced by the researched system. The stakeholders thus have interest in the consequences of the decision(s) to be made. Multiple scientific methods are described which are supposed to lead to appropriate lists of relevant stakeholders. Macharis et al. (2012) indicate the approaches of Weiner and Brown (1986), based on the potential reasons for people get involved with any aspect of the problem; and Munda (2002), based on document analysis combined with in-depth interviews, to be particularly suitable for the MAMCA methodology. Next to the determination of the particular actors involved, an important part of the stakeholder analysis is the identification of their objectives.s. Generally, the stakeholders with varying objectives are either on the demand or the supply side of the problem (e.g. Turcksin and Macharis (2009)). In most cases, stakeholder groups instead of single stakeholders are

[1]Note that if the stakeholders are involved earlier in the process as described in Step 1, determination of stakeholders is already performed.

involved in a study. Within a certain group, homogeneity in the particular criteria to be evaluated is usually expected. Weights of certain criteria might differ, but in general the same criteria are deemed important for evaluation in the first place (Macharis et al., 2012).

Step 3: Determination of criteria and criteria weights
The criteria determined to be evaluated are mainly based on the stakeholders involved in the study. The general practice of determining the criteria to be involved in the study starts by generating a preliminary list based on literature applicable to the particular problem. Next, each stakeholder group is asked to evaluate and validate the pre-defined criteria from the list. This can be done through interactive personal discussions with the stakeholders (Macharis et al., 2012), which (potentially) allows for in-depth understanding of the respondents' perspectives; or by means of surveying the actors (e.g. Sun et al. (2015)), which is less time-consuming, thus with which a higher number of stakeholders can be involved in the same amount of time. Eventually, a definitive set of criteria can be taken into account for the MCDM study.

One of the fundamental parts of MCDM approaches in general and of MAMCA in particular is the determination of the criteria weights. Multiple techniques to calculate these weights exist. A widely used technique is the *Analytic Hierarchy Process (AHP)*, in which weighting gets based on the arrangement of the relevant factors in a hierarchical order; the ultimate goal at the top level, specific alternatives at the bottom level and in between criteria and subcriteria (Saaty, 1990, 2013). Other commonly used techniques include *Analytic Network Process (ANP)*, in which the hierarchy structure used in AHP is replaced by a network structure (Saaty, 1996); *TOPSIS* (Lai et al., 1994) and *VIKOR* (Opricovic and Tzeng, 2004), which are based on the compromise principle: the chosen solution is supposed to have the shortest distance from the best solution as well as the longest distance from the worst solution; and *PROMETHEE* (Brans et al., 1986) and *ELECTRE* (Roy, 1990), which are based on the assessment of alternatives outranking each other. A recent development in MCDM techniques is the *Best-Worst Method (BWM)* (Rezaei, 2015, 2016), in which the best (most desirable) and worst (least desirable) criteria are identified. Consequently, the best criterion is compared to the remaining criteria and the remaining criteria are compared to the worst criterion and weights are defined by minimizing the maximum absolute difference between the weight ratios and their corresponding comparisons.

Step 4: Determining criteria indicators and measurement methods
Next to weighting the criteria involved in the study based on the stakeholders' assessed preferences, criteria need to operationalized by means of defining the criteria metrics that can be used to measure whether or to what extent an alternative contributes to each individual criterion. The operationalization enables quantifying the data scores p_{ij} which get multiplied with the corresponding weights w_j, as introduced in the beginning of this section. Criterion operationalization starts with determining the particular indicator (e.g. unit of measurement) for the factor (Macharis et al., 2012). Subsequently, an appropriate measurement method can be defined. An alternative's performance value on a certain criterion can then be assessed through available information sources and/or through expert consultation. Finally, alternatives' criteria scores can be compared to each other through pairwise comparisons (e.g. Saaty (2008)) or evaluation matrices (e.g. Brans et al. (1986)).

Step 5: Overall analysis and ranking of alternatives
The fifth step of the MAMCA framework involves the Multi-Criteria Analysis (MCA) in which the alternatives from Step 1 are evaluated on the various criteria, weighted based on the inputs from each stakeholder in Step 3, by means of the metrics gathered in Step 4 (Macharis et al., 2012). By making use of scenarios, the alternatives submitted for evaluation can be defined more broadly, including the environment in which the alternatives are assessed (e.g. market conditions or other kinds of socio-economic settings). Any MCDM technique can eventually be used to to calculate the alternatives' evaluation scores based on the scenario settings and the inputs from Steps 1 to 4. These lead to the results and a certain ranking of the alternatives, discussed next.

Step 6: Results and sensitivity analysis
Based on the outcomes of the MCA in Step 5, a classification of the evaluated alternatives can be defined. In general, the alternatives are ranked hierarchically based on total utility from high to low (e.g. Nguyen and Notteboom (2016); Rezaei et al. (2016)). Besides the scored and ranked alternatives, the analysis provides insight in the critical stakeholders and criteria which have led to the model results (Macharis et al., 2012). By testing such critical components by means of sensitivity analyses, the elements with a clearly positive or clearly negative impact on the alternatives can be pointed out. The understanding of these impacts reveals what is important to each of the stakeholders involved, which is the aim of this step in particular and of the broader MAMCA framework in general.

Step 7: Implementation of the results
The results of applying the MAMCA methodology to a multi-actor multi-criteria decision-making problem provide the involved decision-makers with information which can be used to develop recommendations towards the specific problem being subjected to the research. Actual implementation strategies based on the MAMCA results can be further assessed by means of e.g. *cost-benefit analyses* (Macharis, 2005). As been indicated earlier with regards to MCDM studies specifically on inland terminal selection studies, problems can be viewed from the perspectives of several different actors individually or combined. Therefore, implications of the MAMCA results also rely on the specific actors involved and, nonetheless, on the point of view applied by the researcher, such as a policy point of view in which a compromise solution for all stakeholders involved is tried to be found (e.g. Macharis and Januarius (2010)); or an individual point of view specifically from one of the certain actors involved (e.g. Kayikci (2010)).

A key component of MAMCA in particular and MCDM studies in general consists of the actual criteria used. Such criteria depend on the subject of the decision-making study. However, various studies of the same subject often include different kinds of criteria. Therefore, the next section involves a review of the criteria typically observed in MCDM studies on inland terminal location selection.

3.2. Factors typically considered in inland terminal location selection studies

The determination of a suitable location for an inland terminal involves multiple factors stemming from the different interrelated features of the container port hinterland. Both quantitative and qualitative factors are often applied to such location studies (Notteboom, 2011). These factors, in MCDM studies denoted as criteria, and their evaluations by decision makers eventually determine the outcomes of theoretical and practical applications of decision-making models. This section describes the most commonly observed criteria with regards to the location decision-making problem for inland terminals. The review is done using Scopus[2] as primary academic database and Google Scholar[3] as additional bibliographic search engine. In this regard, literature specifically concerned with the location selection of inland terminals is considered. Since the terminology used for denoting inland terminal facilities often varies, attention is also paid to location selection studies for *dry ports* and *freight villages*. Although these terms and definitions might vary, the common characteristic of the referenced location selection literature is the fact that the facilities subject to research are all focused on inland intermodal transshipment of *containerized cargo*. This ensures that the reviewed factors are correct for the goal of this study.

The eventual literature basis reviewed in this study consists of MCDM studies specifically focused on inland terminal location selection. Not all observed criteria are taken into account for the remainder of this study, in the first place because of practical reasons; it is not desirable to have an overly long list of criteria, since this implies (time-)intensive data gathering

[2]https://www.scopus.com/
[3]https://scholar.google.com/

and criteria weighting processes. Next to that, as the (combinations of) decision-makers, (geographical) scopes and used methods vary per reviewed study, criteria do as well. Therefore, not all observed factors are considered eligible for this particular research. In order to involve only the most suitable factors, *prioritization of observed criteria* is performed, which entails specific requirements that have to be met by observed factors:

- First of all, a minimum threshold value of two observations in literature is used to filter out infrequently mentioned factors.
- Secondly, factors that are not relevant with regards to this research's particular case study (see Chapter 4) are filtered out. These include:
  - factors that are not generically applicable because they are location-specific (e.g. criteria aimed at particular local legislation).
  - factors indicating *existing* properties/performances of a facility, not applicable because this study is specifically aimed at finding a location for a *new* inland terminal.
  - factors considered with conditions that are preliminarily taken into account when selecting alternative locations, thus not relevant to assess (e.g. connection to infrastructure network).
  - factors concerned with certain terminal functionalities not applicable to the considered *Load center* terminal type (see Section 2.2.3).

The complete overview of criteria as observed in the literature is given in Appendix A. This overview contains the indications for criteria taken into account for the remainder of this study as well as criteria filtered out, including the reason for filtering out the criterion. If factors *are* included, it is also indicated if they are grouped under more comprehensive criteria denominations or otherwise alternative names (relevant for the criteria determination survey, as introduced in Section 3.3.2). Furthermore, if included in the paper[4], the estimated (global) weights of the criteria are given in order to indicate the relative importance of a factor based on the particular source. These are further touched upon when comparing the criteria weighting results of this study with the reviewed literature findings.

The prioritized criteria are further reviewed in the remainder of this section. This review is structured according to the container port hinterland layer structure; factors are stored in main categories being *logistical layer factors*, *transport layer factors*, *infrastructural layer factors* and *locational layer factors*.

3.2.1. Logistical layer factors

Factors used for inland terminal location selection affiliated with logistical layer aspects are mostly related to local market characteristics and related indicators. These are characteristics and indicators which influence the decisions involved in the organization of transport chains (at those locations), for which they are considered to take place in the logistical layer. One of the most observed factors concerned with these organizational decisions is *market volume potential*, which relates to the entities in a certain area generating and/or attracting freight volumes, often also denoted as *demand* (Nguyen and Notteboom, 2016; Regmi and Hanaoka, 2013). Such volume potential/demand is usually presented as the amount of freight (e.g. TEU) moved to/from an area in a certain time unit (e.g. Roso et al. (2015); Rožić et al. (2016)). Other often proposed economical factors concerned with organizing inland transport chains are the *labor market* as a resource for conducting the inland facility operations (e.g. Karaşan and Kahraman (2019); Long and Grasman (2012)); as well as the more general *socio-economic development* of an area, often indicated by indicators such as an area's GRP[5] per capita (e.g. Kayikci (2010); Li et al. (2011)). Multiple factors are used in order to indicate a local investment climate. On a market level, *transport and logistics competition* is used to indicate the amount of potential competitors offering inland facility services

[4] The papers of Li et al. (2011) and Long and Grasman (2012) do not include weight estimates for the considered criteria.
[5] Gross Regional Product

(Karaşan and Kahraman, 2019; Long and Grasman, 2012). On an administrational level, *governmental policies* factors are proposed to indicate the local/regional/national regulatory and/or political stances on the development of inland facilities at a certain location (e.g. Ka (2011); Roso et al. (2015)). As can be noticed, the factors mentioned reveal the use of broad perspectives used in most inland facility location studies, ranging from factors explicitly focused on transport and/or logistics (e.g. *Market volume potential*) to factors describing more general market indicators (e.g. *Socio-economic development*). In this regard, criteria related to the logistical layer context are relatively high in number because multiple characteristics from several kinds of market(-related) components/developments may have an influence on decisions made with regards to companies' transport chain set-ups. An overview of all *prioritized* logistical layer factors taken into account in this study based on the observations in literature and the applicability to the location of the inland intermodal container terminal in the case study area is presented in Table 3.1.

Factor	***Explanation***	**Observations in literature**
Market volume potential	*Amount of container volumes forecasted to be generated in and/or attracted to the area*	Ka (2011); Kayikci (2010); Komchornrit (2017); Li et al. (2011); Nguyen and Notteboom (2016); Regmi and Hanaoka (2013); Roso et al. (2015); Rožić et al. (2016); Wei et al. (2010)
Governmental policies	*Local/regional political, administrational and regulatory circumstances with regards to inland terminal (related) developments/activities*	Ka (2011); Karaşan and Kahraman (2019); Li et al. (2011); Long and Grasman (2012); Nguyen and Notteboom (2016); Regmi and Hanaoka (2013); Roso et al. (2015)
Local labor market	*Local supply of sufficiently skilled labor for inland terminal related activities*	Karaşan and Kahraman (2019); Long and Grasman (2012); Nguyen and Notteboom (2016); Rožić et al. (2016); Wei et al. (2010)
Regional economic development	*Local/regional socio-economic characteristics indicating development of population and economy*	Ka (2011); Kayikci (2010); Li et al. (2011); Roso et al. (2015)
Regional transport/logistics competition	*Amount of companies involved in inland terminal (related) activities in area*	Karaşan and Kahraman (2019); Long and Grasman (2012)

Table 3.1: Logistical layer criteria observed in literature

3.2.2. Transport layer factors

Factors used for inland facility location selection affiliated with transport layer aspects are directly related to the operational activities at and around the inland facility. These can be *conditions* under which these operations (have to) take place, but also effects as a consequence of such operations. Costs for operations are often used, such as *costs for transport* (e.g. Ka (2011); Regmi and Hanaoka (2013)) and costs for operating the inland facility (Ka, 2011; Nguyen and Notteboom, 2016). Furthermore, local traffic characteristics influencing transport operations are mentioned. These are mostly characterized by *traffic congestion* indicators (e.g. Li et al. (2011); Wei et al. (2010)). Sometimes, these are directly translated into *delivery times* (Karaşan and Kahraman, 2019). Next to that, environmental effects of the operations are observed. Whereas sometimes it is indicated if these effects are on local scale (e.g. Nguyen and Notteboom (2016); Özceylan et al. (2016)) or global scale (Kayikci, 2010), this scale is often not indicated[6]. Other transport and transshipment related factors concerned with the effects of the operations on the environment are *noise pollution*, which can be considered as a local effect (e.g. Roso et al. (2015)) and *energy consumption* effects, which can be regarded indirect increases or decreases of emissions as a result of energy usage due to the transport and transshipment operations at/near a site (Kayikci, 2010). An overview of all *prioritized* transport layer factors taken into account in this study based on the observations in literature and the applicability to the location of the inland intermodal container terminal in the case study area is presented in Table 3.2.

Factor	***Explanation***	**Observations in literature**
Total inland transport costs	*Overall costs for inland transport, including (if applicable) trucking costs, rail/barge costs and inland terminal handling costs.*	Ka (2011); Kayikci (2010); Nguyen and Notteboom (2016); Regmi and Hanaoka (2013); Wei et al. (2010)
Traffic congestion	*Local congested infrastructure causing delays in transport flows*	Karaşan and Kahraman (2019); Kayikci (2010); Long and Grasman (2012); Nguyen and Notteboom (2016); Wei et al. (2010)
Environmental effects[6]	*Effects of inland terminal (related) operations on environment, e.g. release of hazardous materials or emissions in surroundings.*	Kayikci (2010); Nguyen and Notteboom (2016); Özceylan et al. (2016); Regmi and Hanaoka (2013)
Inland terminal operational costs	*Costs for operating inland terminal and related activities (e.g. handling)*	Ka (2011); Nguyen and Notteboom (2016)

Table 3.2: Transport layer criteria observed in literature

3.2.3. Infrastructural layer factors

Factors used for inland facility location selection affiliated with infrastructural layer aspects are first of all related to local infrastructure and its characteristics. In this sense, *local transport infrastructure* metrics (e.g. Komchornrit (2017); Rožić et al. (2016)) are used to indicate the properties of the link infrastructure relevant to (potential) inland facilities in the area. Criteria with regards to the *development/construction* of the infrastructure are also commonly proposed. These factors are associated with the infrastructural layer since it also involves the *provision* of the infrastructures. Such factors are e.g. regarding investments costs for setting up an inland facility, which are most usually subdivided into *costs for land* (e.g. Özceylan et al. (2016); Yıldırım and Önder (2014)), *costs for construction* (e.g. Karaşan and Kahraman (2019); Regmi and Hanaoka (2013)) or *other kinds of investment costs* (Ka, 2011; Nguyen and Notteboom, 2016)[7]. Next to monetary factors, the resource availability factor of *expansion possibilities* in order to be able to develop *more* inland facility infrastructure if necessary/wanted is also indicated (e.g. Özceylan et al. (2016); Roso et al. (2015)). In this regard, the *spatial development* criterion is also proposed in order to indicate potentially unfavorable land use types close to the (potential) inland facility (e.g. Kayikci (2010); Komchornrit (2017)). An overview of all *prioritized* infrastructural layer factors taken into account in this study based on the observations in literature and the applicability to the location of

[6]As the literature is often unclear if the *environmental effects* factor is concerned with *local* effects or *global* effects, this criterion is subdivided into *Local environmental effects* and *Global environmental effects* in the eventual criteria selection survey sent to transport chain experts (see Appendix B).

[7]In order to limit the total amount of selectable decision criteria, these investment costs factors are stored under the encompassing *Inland terminal CAPEX* in the eventual criteria selection survey sent to transport chain experts (see Appendix B).

the inland intermodal container terminal in the case study area (see Section 4.1) is presented in Table 3.3.

Factor	***Explanation***	**Observations in literature**
Transport infrastructure network in area	*Characteristics of transport infrastructure network (e.g. lengths, density) in area*	Ka (2011); Karaşan and Kahraman (2019); Kayikci (2010); Komchornrit (2017); Li et al. (2011); Regmi and Hanaoka (2013); Roso et al. (2015); Rožić et al. (2016)
Expansion possibilities	*Available land which could potentially be used to physically expand inland terminal*	Karaşan and Kahraman (2019); Nguyen and Notteboom (2016); Özceylan et al. (2016); Roso et al. (2015); Yıldırım and Önder (2014)
Land purchase costs	*Costs for purchasing land for inland terminal*	Nguyen and Notteboom (2016); Özceylan et al. (2016); Regmi and Hanaoka (2013); Yıldırım and Önder (2014)
Construction costs	*Costs for building inland terminal*	Karaşan and Kahraman (2019); Nguyen and Notteboom (2016); Regmi and Hanaoka (2013)
Land use near location[8]	*Land use at sites neighboring the inland terminal location*	Kayikci (2010); Komchornrit (2017); Nguyen and Notteboom (2016)
Other investment costs	*Other costs with regards to set-up of inland terminal (e.g. for equipment)*	Ka (2011); Nguyen and Notteboom (2016)

Table 3.3: Infrastructure layer criteria observed in literature

3.2.4. Locational layer factors

Factors used for inland facility location selection affiliated with locational layer aspects are basically only involved with *proximity* measures. These can regard distances of inland facility locations towards various objects in the economic space of the container port hinterland represented by the locational layer. The factor most observed in literature as well as most applicable to this study on inland terminal location selection is *market proximity*, i.e. the distances between the inland facility site and locations in the area at/to which a certain amount of container volumes are generated/attracted (Karaşan and Kahraman, 2019; Long and Grasman, 2012; Nguyen and Notteboom, 2016; Özceylan et al., 2016; Roso et al., 2015; Yıldırım and Önder, 2014). The entities at these locations are the ones that make up the total market volume potential in a certain area, as previously described in Section 3.2.1. *Market proximity* is the only *prioritized* location layer factor taken into account in the remainder of this research.

3.3. Multi-actor multi-criteria location selection methodology

This section involves the elaboration on the research methodology used in this study. Because of the multiple actors and multiple criteria involved in the decision-making process on inland terminal location selection, the methodology is largely based on the MAMCA framework as discussed in the literature review. As the methodology is applied specifically to this inland terminal location selection problem initiated by the shipping line, the corresponding problem definitions and relevant stakeholders including their objectives are already defined in Chapter 2. Therefore, the original MAMCA Steps 1 (problem definition) and 2 (stakeholder analysis) are merged into one step, aimed at defining the particular case study location problem on which this framework can be applied. Next to that, since a fundamental part of this research is involved with using the Best Worst Method to determine the actor-specific criteria weights, this weighting procedure (in the original MAMCA framework together with the

[8] Although often called *Spatial development* in literature, the name is changed to *Land use near location* in the eventual criteria selection survey sent to transport chain experts (see Appendix B) in order to clearly indicate factor representation.

criteria determination procedure in one step) is presented as a separate sub-step within Step 2. The eventual methodology framework thus consist of 6 main steps, which will each be discussed accordingly. The framework is graphically displayed in Figure 3.2.

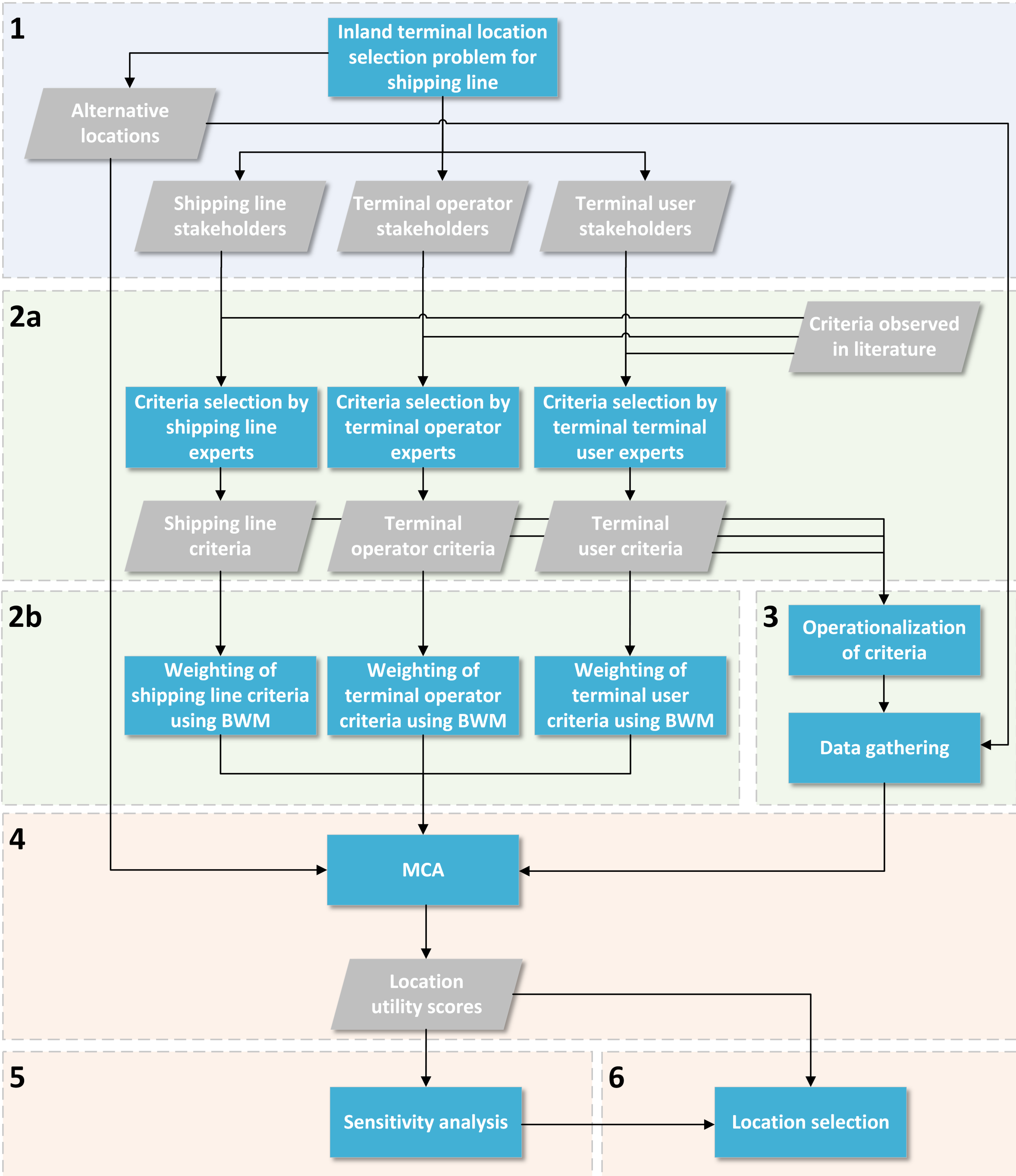


Figure 3.2: Six-step research methodology framework

3.3.1. Research step 1: Definition of the location selection problem

The first step of the research methodology involves the preparation of the multi-actor multi-criteria decision-making study by defining the inland terminal location selection problem of the particular case study considered. Defining the problem starts with determining the geographical scope of the location selection study. Within this scoped region, the specific locations submitted for evaluation can be selected, i.e. the study alternatives. In this research this set is given, hence there is no further focus on its formation. Next to that, the particular stakeholder experts from either one of the three key actor groups user can be determined. These can be representatives of companies already doing business in or willing to enter the particular regional market, but also relevant experts from the same types of companies operating in other regions. In the latter case, the experts' evaluations are predominantly used for their perceptions on the general matters regarding intermodal transport and/or transshipment rather than on locally specific characteristics. When at least one expert from each stakeholder-type is selected to take part in the study, Step 2 of the framework can commence.

3.3.2. Research step 2: Determination of criteria and criteria weights

Research step 2 consists of two sub-steps. Firstly, in Step 2a, the actual criteria to be taken into account for the inland terminal location multi-criteria analysis are determined for each stakeholder. Secondly, in Step 2b, the weights of these criteria are calculated using the Best Worst Method.

Research Step 2a: Determining decision criteria through criteria selection survey

First of all, the definitive criteria to take into account for each stakeholder are determined. This is done through criteria selection by each of the stakeholders involved. The basis of the criteria selection is formed by the observed and prioritized criteria from the reviewed literature on inland terminal location problems. This collection of factors is compiled into a general list of criteria. Through a *criteria selection survey*, the list is sent to and assessed by the experts as determined in Step 1. They are asked to indicate the criteria they find most important for evaluating a location for an inland terminal (see Appendix B for the template of this survey). Based on these indications, a list of relevant decision criteria for each stakeholder is developed. These are further considered for determining the particular criteria weights by making use of the Best-Worst Method.

Research Step 2b: Determining decision criteria preferences and weights using Best-Worst Method

In order to determine the weights for each criterion, the Best-Worst Method (BWM) is used. BWM is a relatively recent MCDM technique, in which the best (most desirable) and worst (least desirable) criteria are identified, after which the best criterion is compared to the remaining criteria and the remaining criteria are compared to the worst criterion. The original BWM involves a non-linear model for calculating optimal criteria weight values as well as a consistency ratio in order to check the reliability of the comparisons made by the decision-maker (Rezaei, 2015). Next to the original non-linear model, a linear approximation is proposed (Rezaei, 2016) as well as a multiplicative version which can be transformed into an equivalent linear program as well (Brunelli and Rezaei, 2019). An extension of the method to group decision-making is also presented (Mohammadi and Rezaei, 2019), besides hybrid extension such as *BWM-VIKOR* (Garg and Sharma, 2018) and *BWM-MULTIMOORA* (Hafezalkotob et al., 2019). Applications of the method include a.o. transport and logistics (Groenendijk et al., 2018; Rezaei et al., 2019), supply chain structures (Onstein et al., 2019) and management (Ahmadi et al., 2017; Gupta and Barua, 2018), energy systems (Ren, 2018) and risk management (Torabi et al., 2016). Favorability of BWM over other MCDM methods is first of all based on the fact that the method involves a criteria comparison procedure which is relatively clear to involved decision-makers, which results in more consistent pairwise comparisons (Rezaei, 2015). The use of integers rather than e.g. fractions in the BWM approach is also considered to be less problematic (Van de Kaa et al., 2017). Next to that, BWM requires *fewer* comparisons for estimating consistent weights compared to e.g. the commonly used AHP method. Based on the relatively few amounts of data as well as the relatively low computation times needed to result in reliable weights, BWM is considered to be a rather data- and time-efficient technique (Rezaei, 2015). Furthermore, particularly beneficial to the aims of this study is the possibility to take into account multi-optimality in not-fully consistent cases with more than three criteria or alternatives when using the (original) non-linear BWM model (Rezaei, 2016). Multi-optimal solutions increase the flexibility in studies where multiple decision-makers are involved, resulting in higher chances for desirable compromise solutions compared to models resulting in unique solutions. This is further touched upon when introducing Models 3.4 and 3.5 (further in this section).

For estimating the criteria weights (mathematically denoted as w_j) making use of BWM, two steps are taken; the *criteria preference statement (1)* and the *calculation of optimal weights (2)*:

1. In order to be able to calculate the optimal weight factors, *preference statements* of the criteria are gathered. These preference statements are done by the stakeholder experts as defined in Step 1. The reasoning behind the preference statements is to gain understanding in how these stakeholders perceive the importance of the several criteria used for inland terminal location assessment. Through a preference statement survey, the stakeholders are asked to indicate which one of the decision criteria they find most important (**Best**) and which one of the decision criteria they find least important (**Worst**) for evaluating inland terminal locations. Next to that, they are asked to use a scoring system (ranging from scores of 1 - 9) in order to indicate;

   - the preference of the **best** criterion over **all other** criteria. This results in a *best-to-others (BO) vector*: $A_B = (a_{B1}, a_{B2}, ..., a_{Bn})$, where a_{Bj} indicates the preference of the best criterion B over criterion j.
   - the preference of the **all other** criteria over the **worst** criterion. This results in an *others-to-worst (OW) vector*: $A_W = (a_{1W}, a_{2W}, ..., a_{nW})$, where a_{jW} indicates the preference of criterion j over the worst criterion W.

   A graphical visualization of these vectors is shown in Figure 3.3.

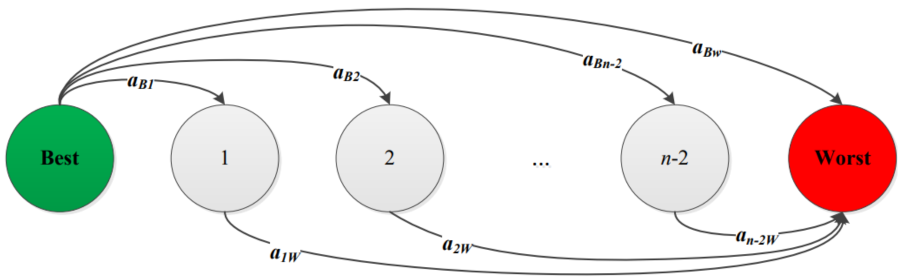


Figure 3.3: Reference comparisons in the Best-Worst Method (from Rezaei, 2015)

   The survey template used to gather the stakeholders' indications of the importance/unimportance of each other criterion relative to the best and the worst criterion is given in Appendix D.

2. The next step in the weight determination contains the calculation of the optimal weights w_j^*, for which the relatively evaluated rankings from the first step are used as input. The optimal weights for the criteria are determined by setting the conditions where for each pair of w_B/w_j and w_j/w_W, $w_B/w_j = a_{Bj}$ and $w_j/w_W = a_{ajW}$. To satisfy these conditions for all j, a solution in which the maximum absolute differences $\left|\frac{w_B}{w_j} - a_{Bj}\right|$ and $\left|\frac{w_j}{w_W} - a_{jW}\right|$ for all j are minimized, formulated by the following model:

$$\min \max_{j} \left\{ \left| \frac{w_B}{w_j} - a_{Bj} \right|, \left| \frac{w_j}{w_W} - a_{jW} \right| \right\}$$
$$\text{subject to:}$$
$$\sum_j w_j = 1, \tag{3.1}$$
$$w_j \geq 0, \forall j$$

Model 3.1 gets converted into model:

$$\min \xi$$
$$\text{subject to:}$$
$$\left| \frac{w_B}{w_j} - a_{Bj} \right| \leq \xi, \forall j$$
$$\left| \frac{w_j}{w_W} - a_{jW} \right| \leq \xi, \forall j \tag{3.2}$$
$$\sum_j w_j = 1$$
$$w_j \geq 0, \forall j$$

, which is solved accordingly to obtain optimal weights $w_1^*, w_2^*, ..., w_n^*$ and ξ^*.

To assess the reliability of the comparisons, the *consistency* measure as proposed by Rezaei (2015) is considered. A comparison is fully consistent when $a_{Bj} \times a_{jW} = a_{BW}$, $\forall j$. As full consistency is an unrealistic expectation, a *Consistency Index* (Table 3.4) is used to calculate the level of consistency, i.e. the *Consistency Ratio*.

a_{BW}	1	2	3	4	5	6	7	8	9
Consistency Index	0,00	0,44	1,00	1,63	2,30	3,00	3,73	4,47	5,23

Table 3.4: Consistency Index values (from Rezaei, 2015)

The Consistency Ratio (CR) is then computed using ξ^* and the consistency index value corresponding to a_{BW}, as follows:

$$CR = \frac{\xi^*}{ConsistencyIndex} \tag{3.3}$$

In general, the closer the Consistency Ratio value is to 0, the more consistent a comparison is. Eventually, to assess if comparisons are consistent or not based on the Consistency Ratio value, consistency threshold values from the study of Liang et al. (2019) are considered. These threshold values are based on the number of criteria considered in the comparison and on the corresponding value of a_{BW}. The threshold values are displayed in Table 3.5. A comparison is considered to be consistent if the Consistency Ratio does not exceed the corresponding consistency threshold value. If the Consistency Ratio is larger than the corresponding consistency threshold value, the comparison is not consistent.

As multiple decision criteria per actor-specific set are considered, the BWM model can result in multiple *optimal* values for the weight factors (Rezaei, 2016). Since each optimization corresponds to an approximation of an optimal setting of criteria weight factors,

a_{BW}	Number of criteria 3	4	5	6	7	8	9
3	0,2087	0,2087	0,2087	0,2087	0,2087	0,2087	0,2087
4	0,1581	0,2352	0,2738	0,2928	0,3102	0,3154	0,3273
5	0,2111	0,2848	0,3019	0,3309	0,3479	0,3611	0,3741
6	0,2164	0,2922	0,3565	0,3924	0,4061	0,4168	0,4225
7	0,2090	0,3313	0,3734	0,3931	0,4035	0,4108	0,4298
8	0,2267	0,3409	0,4029	0,4230	0,4379	0,4543	0,4599
9	0,2122	0,3653	0,4055	0,4225	0,4445	0,4587	0,4747

Table 3.5: Consistency Ratio thresholds for different combinations of numbers of criteria and a_{BW} (from Liang et al., 2019)

each optimization is considered to represent the real-life preferences of the decision-makers in an optimal way as well. Therefore, it is preferred to take into account all these optimal weight values instead of single solutions. The use of *weight intervals* enables taking into account these multiple optimal solutions by representing each solution within the range of the minimum optimal solution and the maximum optimal solution for the criterion weight determination. The lower and upper bounds of the weight intervals $w_j^{\min}$ and $w_j^{\max}$ are calculated after having solved Model 3.2, by solving models:

$$\begin{aligned} &\min w_j \\ &\text{subject to:} \\ &\left|\frac{w_B}{w_j} - a_{Bj}\right| \leq \xi^*, \forall j \\ &\left|\frac{w_j}{w_W} - a_{jW}\right| \leq \xi^*, \forall j \\ &\sum_j w_j = 1 \\ &w_j \geq 0, \forall j \end{aligned} \tag{3.4}$$

$$\begin{aligned} &\max w_j \\ &\text{subject to:} \\ &\left|\frac{w_B}{w_j} - a_{Bj}\right| \leq \xi^*, \forall j \\ &\left|\frac{w_j}{w_W} - a_{jW}\right| \leq \xi^*, \forall j \\ &\sum_j w_j = 1 \\ &w_j \geq 0, \forall j \end{aligned} \tag{3.5}$$

Eventually, the minimum and maximum weight values for criterion j are used to form weight interval $W_j = [w_j^{\min}, w_j^{\max}]$, of which the center as derived through $w_j^* = (\min w_j + \max w_j)/2$ can be used as a representative weight for criterion j (Rezaei et al., 2015).

This process is executed for each stakeholder k with corresponding stakeholder-specific criteria. Thus ultimately, a collection of weight intervals W for each criterion j from each stakeholder k is generated: W_j^k. These intervals can then be multiplied with the corresponding criterion scores p_{ij} in order to calculate the corresponding utility intervals V_i. This is further elaborated upon in Research Step 4 (Section 3.3.4), in which the evaluated criteria are applied to the alternatives using Multi-Criteria Analysis.

Aggregated criteria weights per stakeholder type

The criteria of the different actors from the same stakeholder type are aggregated in order to get an indication of the common notion between these related actors. Aggregation of criteria weights can be performed using several techniques. For example, the average of the interval centers can be taken (*averaging*) or the sum of the estimated aggregate weights (based on the intervals) can be minimized (*minsum*). A problem with considering the averages is the fact that these are sensitive to outlying values, which can lead to certain stakeholder preferences taken into account more or less than others. A problem with the *minsum* technique, which implies minimizing the sum of the distances from the estimated aggregate weight value to each individual actor's weight, is the fact that the operation takes into account only the values for the actor's optimal criterion weights closest to the estimate for the aggregate weight value, thus neglecting the actor's optimal weight values lying further away from this point, which means that the complete range of possible optimal solutions for the criterion weight is not taken into account. For those reasons, interval aggregating by making use of a *minmax* function is considered. By applying *minmax* aggregation on the intervals, which basically looks for the minimum of the maximum differences between the value to be determined for w_j^{agg} and each actor's utility value $w_j^k \in [w_j^{k,\min}, w_j^{k,\max}]$, all weight values within the ranges of these intervals are taken into account equally, thus the common notion is most optimally supported by each actor's inputs. Based on the criteria weights w_j^k from each actor k, an aggregate value w_j^{agg} is determined. This is done by solving the following minimax model:

$$\begin{aligned} &\min\max\left|w_j^{agg} - w_j^k\right| \\ &\text{subject to:} \\ &w_j^{\min} \le w_j^k \le w_j^{\max}, \forall i, k \end{aligned} \tag{3.6}$$

This model is converted to the following model:

$$\begin{aligned} &\min \omega \\ &\text{subject to:} \\ &\left|w_j^{agg} - w_j^k\right| \le \omega, \forall j, k \\ &w_j^{\min} \le w_j^k \le w_j^{\max}, \forall i, k \end{aligned} \tag{3.7}$$

Solving Model 3.7 results in the aggregate weights of the stakeholder types based on the individual actors' inputs.

3.3.3. Research step 3: Criteria operationalization and data gathering

Next to calculating the criteria weights, the outcomes of Research Step 2a are also used for determining the criteria indicators and measurement methods by means of *operationalization*. Determining the measure units makes it possible to know the types of data that have to be gathered in order to sufficiently represent the criteria. The operationalization is also used to define the criteria as comparable factors. This means that the criteria with absolute data values can be expressed into relative values so that the same type of data for different locations/areas is comparable to each other. Another purpose of the operationalization step is to determine if factors are *benefit criteria* or *cost criteria*; benefit criteria imply quantitative values which contribute to a certain alternative (positive), whereas cost criteria imply quantitative values which depreciate a certain alternative (negative). After operationalization of the data, the gathering methods for specific data types can be determined. As the operationalization and corresponding data gathering methods are specific to each criterion, they are described individually per criterion in Appendix C.

3.3.4. Research step 4: Determination of utilities using Multi-Criteria Analysis

Research Step 4 consist of the Multi-Criteria Analysis (MCA) performed on the inland terminal location selection study. The inputs for the MCA are threefold;

- The alternatives to be assessed from Step 1

- The actor-specific criteria weight intervals from Step 2b
- The data corresponding to the criteria specific to each alternative from Step 3

The goal of the MCA is to determine the utilities of each alternative based on the weighted criteria and data. To do so, each actor's criterion weight interval W_j^k gets multiplied with corresponding data score p_{ij} to result in utility intervals for each actor k. A pre-processing step of this operation is the determination of criterion scores p_{ij} by means of *normalization* of the corresponding data. In this research, max - min normalization is used. The advantage of using this technique is that the scale measurement of the data lies precisely between 0 and 1 for each criterion, which supports containing the relationships between the original data (Çelen, 2014; Patro and Sahu, 2015; Vafaei et al., 2018b). This makes the relative proportions within a particular criterion set comparable with the proportions within the other criteria sets. Accordingly, the eventually resulting utilities based on corresponding normalized data scores and criteria weights are similarly comparable[9], which is beneficial for analyzing the individual criterion utilities as well as the overall utility scores with regards to each other. Accordingly, the first step in order to obtain normalized scores p_{ij} is to identify the *benefit* and *cost criteria*. This is per data type indicated in Appendix C. Next, max - min normalization is applied on each data point r_{ij}, as follows:

$$p_{ij} = \begin{cases} \frac{r_{ij} - r_j^{\min}}{r_j^{\max} - r_j^{\min}} & \text{if benefit criteria} \\ \\ \frac{r_j^{\max} - r_{ij}}{r_j^{\max} - r_j^{\min}} & \text{if cost criteria} \end{cases} \tag{3.8}$$

Eventually, the normalized scores p_{ij} can be used further in combination with the earlier computed weight intervals $W_j^k = [w_j^{\min}, w_j^{\max}]$ for the utility interval calculations. The utility intervals are computed based on interval arithmetic as follows:

$$p_{ij} W_j^k = \left[\, p_{ij} w_j^{k,\min},\ p_{ij} w_j^{k,\max} \,\right] \tag{3.9}$$

These separate actor-specific utility intervals for each criterion for each alternative are the *utility sub-intervals*. Consequently, the lower bounds and upper bounds of the sub-intervals $p_{ij} W_j^k$ are summed according to the following interval operation:

$$\sum_{j=1}^{J} p_{ij} W_j^k = \left[\textstyle\sum_{j=1}^{J} p_{ij} w_j^{k,\min},\ \sum_{j=1}^{J} p_{ij} w_j^{k,\max}\right] \tag{3.10}$$

This operation generates actor-specific *gross utility intervals*, in which the lower and upper bounds result from actor k's criteria evaluations: $[V_i^{k,\min}, V_i^{k,\max}]$. With the gross utility intervals of each actor k (with a total amount of actors $k = 1, 2, \cdots, k$) for each alternative i known, each alternative's set of gross utility intervals is used to determine the overall final utility score for the alternative. For the same line of reasoning as applied to the weight aggregation procedure (Model 3.6), aggregation of utility scores is applied, resulting in the alternative's aggregate utility value V_i^{agg}. By aggregating the utility intervals, each actor's individually assigned utility score are taken into account in an equal manner, thus individual preferences are equally represented. To determine the final aggregated utility value, the following model is solved:

$$\begin{aligned} &\min \max \left| V_i^{agg} - V_i^k \right| \\ &\text{subject to:} \\ &V_i^{\min} \le V_i^k \le V_i^{\max}, \forall i, k \end{aligned} \tag{3.11}$$

[9]Note that in this research this only applies to utilities assigned by actors from the same stakeholder types, since criteria weights are not comparable between different stakeholder types due to the actor-specific criteria sets.

, which basically looks for the minimum of the maximum differences between the value to be determined for V_i^{agg} and each actor's utility value $V_i^k \in [V_i^{k,\min}, V_i^{k,\max}]$. This model is converted to the following model:

$$\begin{aligned} & \min \zeta \\ & \text{subject to:} \\ & \left|V_i^{agg} - V_i^k\right| \leq \zeta, \forall i, k \\ & V_i^{\min} \leq V_i^k \leq V_i^{\max}, \forall i, k \end{aligned} \tag{3.12}$$

Solving Model 3.12 results in the aggregate utility scores for the alternatives, based on the inputs of the different stakeholders. These scores can then be ranked and a most desirable alternative can be selected based on this ranking.

3.3.5. Research step 5: Sensitivity analysis

Based on the results from the MCA, the elements which have clearly positive or negative impacts on the study results are pointed out. By means of a sensitivity analysis, the model inputs which highly influence the final results can be tested. The goal of the sensitivity analysis is twofold:

- The first goal of the sensitivity analysis is to assess the influences of the stakeholders' preferences on the outcomes of the model. Accordingly, it is tested to which extent the inputs of specific stakeholders involved in the study determine the final aggregate utility scores. In this regard, the sensitivity analysis serves as an alternative to *expert validation* in order to assess the accuracy of the results; by manipulating stakeholder weights, the underlying preferences of a particular stakeholder can be indicated and validated.

- The second goal of the sensitivity analysis is to assess the influences of particular criteria involved in the study. Accordingly, criteria which distinctively contribute to the utility of (a) certain alternative(s) are tested in order to assess their impacts on the final ranking of all alternatives.

The sensitivity analysis consists of adapting the corresponding model parameters and comparing the results of these adaptations with the initial results of Step 5. Accordingly, the parameters to be adjusted rely on the results of Step 5 as well. Each parameter adjustment is represented by a certain *sensitivity analysis scenario*, which involves the particularly specified model parameter settings. In this regard, the model results of of Step 5 are represented by *Scenario 0*, to which the sensitivity scenario results are compared.

3.3.6. Research step 6: Location selection

Based on the results of the initial model (Step 5) and the insights gained from the sensitivity analysis (Step 6), final recommendations on the inland terminal location selection problem can be given. In this study, the practical implications are given in Section 5.2.1, after concluding and discussing the important assumptions, methods, inputs and other research features that led to the results of the study.

3.4. Model verification and validation

In order to check if the models composed of the equations as described in Sections 3.3.2 and 3.3.4 deliver the right outcomes, they are verified and validated. The purpose of *verification* is to ensure the models work as they are intended to do, i.e. if they produce the correct results. The purpose of *validation* is to ensure the models actually represent the system well, i.e. if they produce realistic(/predictive) results corresponding to (yet despite of) the model inputs.

3.4.1. Verification

To verify the models, it is checked if all constraints of the separate models of Research Step 2b and 4 are satisfied. These separate models are the non-linear Weight Interval Determination

Models 3.4 and 3.5, Weight Aggregation Model 3.7 and Utility Aggregation Model 3.12. The model input data gathered in Research Step 3 is also used for these verification checks. The complete verification including results is presented in Appendix E.

3.4.2. Validation

The validation process involves the same models as for the verification procedure to be considered. Validation of Models 3.4 and 3.5 is done by checking if the resulting criteria weight intervals are in line with the expected solutions. In order to do so, an experimental weight interval determination problem is constructed in which the Best-to-others and others-to-Worst vectors are linearly ascending and descending (respectively), which supposedly leads to a predictable criteria weight *ranking* without detailed analysis. Next to that, although the Best-to-others and the others-to-Worst vectors are linear in terms of score distribution, they are not entirely asymmetrical with respect to each other, which leads to the expectation that the solution should consist of weight intervals rather than discrete weight values. The validation of Models 3.4 and 3.5 is then conducted by comparing the *expected* results of this experimental weight determination problem (i.e. the expected ranking and weight intervals instead of single solutions) with the *actual* results after running the model with the corresponding settings. This procedure and the results are presented in Appendix F.

Since Weight Aggregation Model 3.7 and Utility Aggregation Model 3.12 are basically the same mathematical models (only their inputs are different), validation of both models is conducted by testing one. In this sense, another experimental problem is constructed using the aggregation of weight intervals as a follow-up of the earlier introduced experimental weight interval determination problem. The determined weight intervals from this first problem are therefore used as inputs for the experimental weight aggregation model. Accordingly, the weight intervals are duplicated and the second set of intervals is doubled, resulting in two sets of five weight intervals $W_j^1 = [w_j^{min,1}, w_j^{max,1}]$ and $W_j^2 = [w_j^{min,2}, w_j^{max,2}]$, of which the corresponding sets are each others halves/doubles respectively. Aggregation of these intervals using the aggregation model (to be validated) should thus result in aggregate values within the range of $w_j^{max,1}$ and $w_j^{min,2}$, since it opts for the minimum of the differences between the weight values within the intervals W_j^1 and W_j^2 and the aggregate weight values w_j^{agg} to be determined. Next to that, since the linearly weighted values of the experimental weight interval determination are used in the Weight Aggregation model, the ranks of the Aggregate weights should end up the same as the ranks of the initial weights relative to each other. The validation procedure and the results are presented in Appendix F.

4

Application of Multi-Actor Multi-Criteria Location Selection Framework: Case Study on hinterland region

In this section the application of the six-step research methodology is discussed and the results of this application are presented. For the application of the framework, the real-life case study of shipping line Maersk is considered.

4.1. Results of Research Step 1: Location selection problem definition

The inland terminal location selection problem for shipping line Maersk involves the case study region which broadly encompasses the urban and catchment areas of the cities of A, B and C. In total, six alternatives locations within this scoped region are submitted for evaluation, of which two per city, which are generically called *A1*; *A2*; *B1*; *B2*; *C1*; *C2*. All alternatives meet the conditions of being at least 50 hectares in area and being located next to road and rail infrastructure, as preliminarily set by Maersk. The geographical locations within the study region are displayed in Figure 4.1.

Figure 4.1: Figure is not available due to confidentiality reasons.

Next, relevant stakeholders are selected. Besides having shipping line and terminal operator as decision-making stakeholders, two types of terminal user stakeholders are taken into account for their evaluations. First of all, these include truck transport operators as representatives of pre-/end-haulage transport operators. Secondly, these include rail transport operators as representatives of intermodal transport operators. Only rail operators are approached due to the geographical scope of this study, being a region not having extensive inland waterway networks and/or a correspondingly extensive (focus on the) barge transport market within the intermodal hinterland transport. Therefore, the focus of this study with regards to intermodal transport is on rail transport only[1]. A selection of relevant employees of Maersk and of relevant vendors[2] of the company are considered to represent the stakeholder expert groups. In total, 12 shipping line experts, 8 terminal operator experts, 3 rail transport operator experts and 2 truck transport operator experts are taken into account.

[1] This means that barge operators are excluded from the surveys and inland waterway networks and features are excluded from the analyses

[2] The vendors are the supplier companies of the shipping line, i.e. the terminal and transport operators performing the inland services as offered by Maersk.

Despite the fact that the actor configuration in the inland terminal location selection process consists of the actual decision-making actors (i.e. shipping line and terminal operator actors) and the evaluating actors (i.e. terminal users) as been discussed in Section 2.3, it is chosen to take all stakeholders and their preferences equally into account in the initial MCDM model set-up. Hence, no particular weights are used for certain stakeholders in order to reflect their assumed relevancy towards the actual decision-making problem. However, the assumed differences in relevancy is further looked into in the sensitivity analysis (Section 4.6.1).

4.2. Results of Research Step 2a: Decision criteria

The actor-specific decision criteria are based on the particular expert evaluations of the criteria as observed in the literature gathered through the criteria selection survey (of which the template is presented in Appendix B). On top of the criteria gathered in the literature review, the survey also includes two additional criteria as proposed to be relevant by the case shipping line Maersk (although not observed in the literature review); *Intermodal market profitability* and *Terminal market profitability*. Surveys sent out to the experts lead to the following survey response level as presented in Table 4.1.

Stakeholder	Invitations	Responses	Response rate
Shipping line	12	6	50%
Terminal operator	8	2	25%
Rail transport operator	3	2	67%
Truck transport operator	2	1	50%
Total	*25*	*11*	*44%*

Table 4.1: Response overview of criteria selection survey.

The details of the criteria selection survey results are presented in Appendix G. The determination of criteria to be definitively taken into account in the remainder of this study is based on certain threshold values. Since the amount of responses of the criteria selection survey vary per stakeholder, these thresholds for determining which criteria to take into account and which not are based on the amounts of responses and thus differ between the stakeholder types.

Shipping line criteria

As shipping line experts see a large response amount, variations exist in selected criteria. In order to keep a limited amount of decision criteria, a threshold value of *two mentions* is applied to this stakeholder type. This means that eight of the literature criteria are taken into account. Next to the literature criteria, *intermodal market profitability* is included based on preliminary input from the case shipping line. The additionally mentioned criterion of *depot capacity in area* is taken into account because this technical capacity criterion was not identified in the literature review, yet it is regarded as important for becoming active in the inland terminal business as a newcomer. The additionally mentioned criterion of *uniqueness* is excluded from the definitive criteria list because this factor is not straightforwardly measurable in a quantitative way. An overview of the definitive criteria for the shipping line actors is presented in Table 4.2.

Criterion	As observed in
Gathered through literature review, selected by experts	
Expansion possibilities	Karaşan and Kahraman (2019); Nguyen and Notteboom (2016); Özceylan et al. (2016); Roso et al. (2015); Yıldırım and Önder (2014)
Governmental policy	Ka (2011); Karaşan and Kahraman (2019); Li et al. (2011); Long and Grasman (2012); Nguyen and Notteboom (2016); Regmi and Hanaoka (2013); Roso et al. (2015)
Inland terminal CAPEX	Ka (2011); Karaşan and Kahraman (2019); Nguyen and Notteboom (2016); Özceylan et al. (2016); Regmi and Hanaoka (2013); Yıldırım and Önder (2014)
Intermodal market profitability[3]	-
Market proximity	Karaşan and Kahraman (2019); Long and Grasman (2012); Nguyen and Notteboom (2016); Özceylan et al. (2016); Roso et al. (2015); Yıldırım and Önder (2014)
Market volume potential	Ka (2011); Kayikci (2010); Komchornrit (2017); Li et al. (2011); Nguyen and Notteboom (2016); Regmi and Hanaoka (2013); Roso et al. (2015); Rožić et al. (2016); Wei et al. (2010)
Regional transport/logistics competition	Karaşan and Kahraman (2019); Long and Grasman (2012)
Total inland transport costs	Ka (2011); Kayikci (2010); Nguyen and Notteboom (2016); Regmi and Hanaoka (2013); Wei et al. (2010)
Transport infrastructure network	Ka (2011); Karaşan and Kahraman (2019); Kayikci (2010); Komchornrit (2017); Li et al. (2011); Regmi and Hanaoka (2013); Roso et al. (2015); Rožić et al. (2016)
Additionally added, as proposed by experts	
Local depot capacity	-

Table 4.2: List of selected criteria relevant to the shipping line actors.

The total amount of shipping line criteria is thus ten. For the use of the BWM method in the third research stage, it is recommended to cluster criteria into certain clusters if the total amount of criteria exceeds nine [4]. Therefore, clustering of criteria is applied in order to limit the numbers of (sub-)criteria to be compared to each other by respondents and to guarantee a certain level of consistency between comparisons of criteria more related to the other criteria within the cluster than to criteria of other clusters. The first step of clustering is to categorize the criteria according to the main categories as considered in Section 3.2. However, for the sake of clarity towards the preference statement survey respondents, the names of the clusters are adjusted towards more common category identifiers: Logistical layer criteria are to be called *Local market characteristics*; Infrastructural layer criteria are to be called *Technical characteristics*. Furthermore, another cluster is made to distinguish cost- and benefit-related criteria (which initially occurred in all layers) from the others. The reason for this is because it is expected that criteria related to costs and benefits are perceived as a distinct category to decision-making actors from each layer rather than factors inherent to a specific layer (which is also commonly the case in the literature, e.g. Dobrota et al. (2015); Farahani et al. (2010); Pramanik et al. (2016); Regmi and Hanaoka (2013); Wang et al. (2014); Wei et al. (2010)). An overview of the clustering of shipping line criteria is presented in Table 4.3.

[3] Although not found in these particular forms in literature, criteria *Intermodal market profitability* and *Terminal market profitability* are added to the survey list based on preliminary input from the case shipping line.
[4] http://bestworstmethod.com/

Layer	Cluster	Criterion
Infrastructural[5] *Logistical*[5] *Transport*[5]	Costs and benefits	Inland terminal CAPEX Intermodal market profitability Total inland transport costs
Logistical	Local market characteristics	Governmental policy Market proximity Market volume potential Regional transport/logistics competition
Infrastrucural	Technical characteristics	Expansion possibilities Local depot capacity Transport infrastructure network in area

Table 4.3: List of clusters and corresponding criteria relevant to the shipping line actors

Terminal operator criteria

Survey response amounts of the terminal operators are lower, thus the selection threshold value is chosen to be *one mention*. This results in seven literature criteria to be taken into account. Terminal operator experts have also indicated additional criteria, of which the *Anchor customer proximity* and the *Enabling modality shift* factors are taken into account for the remainder of the study because of their added value to the case study and possibility of quantitative measurement. An overview of definitive terminal operator criteria is presented in Table 4.4.

Terminal operator criteria	As observed in
Gathered through literature review, selected by experts	
Inland terminal CAPEX	Ka (2011); Karaşan and Kahraman (2019); Nguyen and Notteboom (2016); Özceylan et al. (2016); Regmi and Hanaoka (2013); Yıldırım and Önder (2014)
Market volume potential	Ka (2011); Kayikci (2010); Komchornrit (2017); Li et al. (2011); Nguyen and Notteboom (2016); Regmi and Hanaoka (2013); Roso et al. (2015); Rožić et al. (2016); Wei et al. (2010)
Regional economic development	Ka (2011); Kayikci (2010); Li et al. (2011); Roso et al. (2015)
Regional transport/logistics competition	Karaşan and Kahraman (2019); Long and Grasman (2012)
Total inland transport costs	Ka (2011); Kayikci (2010); Nguyen and Notteboom (2016); Regmi and Hanaoka (2013); Wei et al. (2010)
Transport infrastructure network in area	Ka (2011); Karaşan and Kahraman (2019); Kayikci (2010); Komchornrit (2017); Li et al. (2011); Regmi and Hanaoka (2013); Roso et al. (2015); Rožić et al. (2016)
Additionally added, as proposed by experts	
Anchor customer proximity	-
Enabling modality shift	-

Table 4.4: List of definitive criteria relevant to the terminal operator actors

Terminal user criteria

Since survey response amounts of the terminal users are lower as well, the selection threshold is also *one mention* (for both subgroups). No additional criteria have been mentioned by either one of the subgroups. This results in the following overviews, which partially overlap (Table

[5]Note that the layers of the Costs and benefits cluster do not necessarily comply with each other. However, as been described, the cluster is developed so the corresponding criteria are not specifically linked to a layer

4.5 for the criteria selected for rail transport operator actors[6] and Table 4.6 for the criteria selected for the truck transport operator actor[6]).

Rail transport operator criteria	As observed in
Expansion possibilities	Karaşan and Kahraman (2019); Nguyen and Notteboom (2016); Özceylan et al. (2016); Roso et al. (2015); Yıldırım and Önder (2014)
Inland terminal CAPEX	Ka (2011); Karaşan and Kahraman (2019); Nguyen and Notteboom (2016); Özceylan et al. (2016); Regmi and Hanaoka (2013); Yıldırım and Önder (2014)
Market proximity	Karaşan and Kahraman (2019); Long and Grasman (2012); Nguyen and Notteboom (2016); Özceylan et al. (2016); Roso et al. (2015); Yıldırım and Önder (2014)
Market volume potential	Ka (2011); Kayikci (2010); Komchornrit (2017); Li et al. (2011); Nguyen and Notteboom (2016); Regmi and Hanaoka (2013); Roso et al. (2015); Rožić et al. (2016); Wei et al. (2010)
Transport infrastructure network in area	Ka (2011); Karaşan and Kahraman (2019); Kayikci (2010); Komchornrit (2017); Li et al. (2011); Regmi and Hanaoka (2013); Roso et al. (2015); Rožić et al. (2016)

Table 4.5: List of definitive criteria relevant to the rail transport operator actors

Truck transport operator criteria	As observed in
Expansion possibilities	Karaşan and Kahraman (2019); Nguyen and Notteboom (2016); Özceylan et al. (2016); Roso et al. (2015); Yıldırım and Önder (2014)
Intermodal market profitability[7]	-
Land use near location	Kayikci (2010); Komchornrit (2017); Nguyen and Notteboom (2016)
Market proximity	Karaşan and Kahraman (2019); Long and Grasman (2012); Nguyen and Notteboom (2016); Özceylan et al. (2016); Roso et al. (2015); Yıldırım and Önder (2014)
Market volume potential	Ka (2011); Kayikci (2010); Komchornrit (2017); Li et al. (2011); Nguyen and Notteboom (2016); Regmi and Hanaoka (2013); Roso et al. (2015); Rožić et al. (2016); Wei et al. (2010)
Regional transport /logistics competition	Karaşan and Kahraman (2019); Long and Grasman (2012)
Terminal market profitability[7]	-
Total inland transport costs	Ka (2011); Kayikci (2010); Nguyen and Notteboom (2016); Regmi and Hanaoka (2013); Wei et al. (2010)
Transport infrastructure network in area	Ka (2011); Karaşan and Kahraman (2019); Kayikci (2010); Komchornrit (2017); Li et al. (2011); Regmi and Hanaoka (2013); Roso et al. (2015); Rožić et al. (2016)

Table 4.6: List of definitive criteria relevant to the truck transport operator actors

4.3. Results of Research Step 2b: Decision criteria weights determined with BWM

The definitive criteria for each actor are weighted by means of BWM. The first step in this process is gathering each actor's preference statements on the criteria through a preference

[6]As the terminal user actors did not propose any new factors, all criteria stem from the initial literature review as well.
[7]Although not found in these particular forms in literature, criteria *Intermodal market profitability* and *Terminal market profitability* are added to the survey list based on preliminary input from the case shipping line.

statement survey (see Appendix D for a template of this survey). Based on the results of the surveys, the weight intervals for each criterion per actor are calculated. In the remainder of this section, the survey results and each stakeholders' corresponding weight intervals are discussed accordingly.

4.3.1. Preference statements

An overview of the response level of the preference statement survey is presented in Table 4.7.

Stakeholder	Invitations	Responses	Response rate
Shipping line	12	3	25%
Terminal operator	8	3	38%
Rail transport operator	3	2	67%
Truck transport operator	2	1	50%
Total	*25*	*9*	*36%*

Table 4.7: Response overview of preference statement survey

The preference statement survey involves indicating the *most important (Best)* criterion and the *least important (Worst)* criterion. Next to that, scores of the remaining criteria compared to the most important criterion and scores of the least important criterion compared to the remaining criteria are noted. Since each actor has an own set of relevant criteria, the detailed results of the preference statement indications are presented for each actor separately in Appendix H. These outcomes serve as input for the calculation of the criteria weight intervals. The resulting comparison consistencies and weight intervals for each actor are discussed next.

4.3.2. Comparison consistency

Each comparison made by each actor in this study leads to the criteria weight intervals as described in the upcoming sections. Although in principle each comparison is consistent when evaluated with BWM (Rezaei, 2015), the reliability of the weight values is dependent on the *level* of consistency of the comparison. This reliability is therefore assessed through examining these comparison consistencies, which are measured by means of the Consistency Ratio. The values of the Consistency Ratios of each actor's comparisons are compared to corresponding consistency threshold values, as proposed by Liang et al. (2019). These indicate the maximum value of the Consistency Ratio corresponding to the amount of criteria and the value of a_{BW} to be sufficiently consistent (see also Table 3.5 in Section 3.3.2). If the Consistency Ratio value exceeds the threshold, the comparison is considered to be inconsistent. Details on the consistency of each individual comparison and on the corresponding consistency threshold values are given in Appendix I. As been presented in the appendix, each comparison is sufficiently consistent based on the Consistency Ratio values. The calculated weight interval values are therefore assumed to be sufficiently reliable, based on the corresponding comparisons consistency levels.

4.3.3. Criteria weights

In the next subsections the calculated criteria weight intervals for each actor are discussed. As can be noticed in some of the weight interval plots, displayed interval values might seem very close or similar to each other. However, the lower and upper bounds do actually differ, yet in smaller amounts than displayed by the decimal numbers in the plot. It is chosen to display both lower and upper bound values in these limited decimal numbers (despite the fact that they appear similar) in order to allow for readability of the plot, yet having consistent interval representation. The more detailed interval values are given in Appendix J. Next to the results of the individual actors being described, the aggregated weights for the stakeholder-types are discussed. These aggregated weights give an indication of the common notion between the different decision-makers of the same background.

To determine if the relative weights of criteria observed in the literature comply with the relative weights calculated in this study, the results of the weight calculations are compared with the findings from the literature review. An overview of the considered literature including observed criteria and their relative weights is given in Appendix A. As most observed relative criteria weights are (traditionally) based on the preferences of multiple stakeholders combined, special attention goes towards referenced studies which specifically include the individual decision-makers *comparable* to the respective actors of this study in order to make useful comparisons for each stakeholder-type. This also contributes to the particular purpose of this study to involve actor-specific criteria and evaluations. These include;

- for the shipping line actors, the studies of Kayikci (2010)[8], who assessed the preferences of transport service organizing experts; and the studies of Karaşan and Kahraman (2019) and Komchornrit (2017), who assessed the preferences of logistics experts.
- for both terminal operator and terminal user actors, the studies of Kayikci (2010)[8] and Nguyen and Notteboom (2016), who assessed the preferences of those stakeholder-type experts individually.

Shipping line criteria weights

The calculation of criteria weight intervals for the shipping line actors is a three-step procedure; firstly the global weight intervals are determined for the main criteria; secondly the local weight intervals are determined for the sub-criteria; eventually the final weight intervals are calculated by multiplying the global weights with the corresponding local weight values. The final weight intervals of shipping line actor 1 are displayed in Figure 4.2.

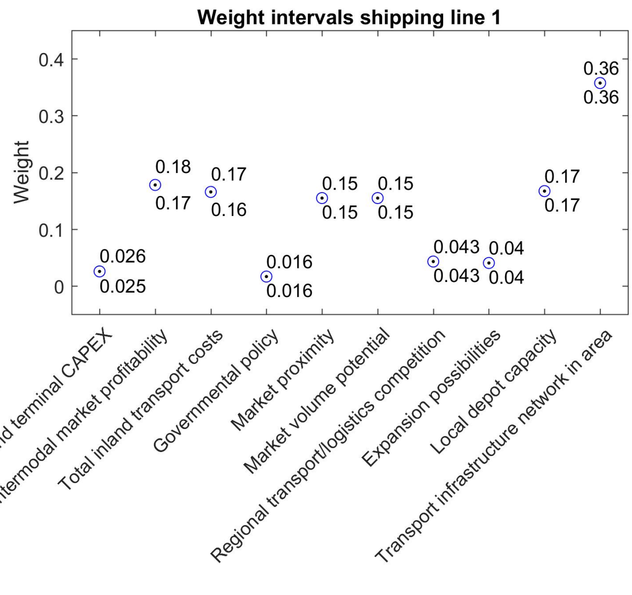


Figure 4.2: Weight intervals shipping line 1

For shipping line 1, the most important criterion is *Transport infrastructure network in area.* This is a higher relative evaluation (compared to the other evaluated factors) than observed in Kayikci (2010) and Komchornrit (2017), in which this factor is rated averagely; and Karaşan and Kahraman (2019), in which this factor is rated poorly. *Intermodal market profitability* and *Local depot capacity* are relatively averagely evaluated, closely followed by *Total inland transport costs*, *Market proximity* and *Market volume potential.* These evaluations are in line with Kayikci (2010). The values of the intervals are very close to each other (see Appendix

[8] Kayikci (2010) assessed the individual preferences of a.o. transport service organizers, terminal users and terminal operators.

J for numerical details), implying their relatively comparable perception to shipping line actor 1. The result of *Local depot capacity* scoring relatively high is to some extent interesting since the main factor of *Technical characteristics* was indicated as the least important main criterion by the respondent. However, the relative score of this Worst main criterion in combination with the relatively high scores of the technical sub-criteria of *Transport infrastructure network in area* and *Local depot capacity* is still sufficient to lift their final weights. The three least important criteria are *Governmental policy* ≺ *Inland terminal CAPEX* ≺ *Expansion possibilities*. The low score for *Inland terminal CAPEX* is in line with Karaşan and Kahraman (2019), however *Expansion possibilities* and *Governmental policy* were evaluated higher in their study. In the literature involving combined stakeholder preferences, these three factors are mostly scored relatively higher compared to these results (e.g. in Özceylan et al. (2016); Regmi and Hanaoka (2013); Yıldırım and Önder (2014)).

The weight intervals of shipping line actor 2 are displayed in Figure 4.3.

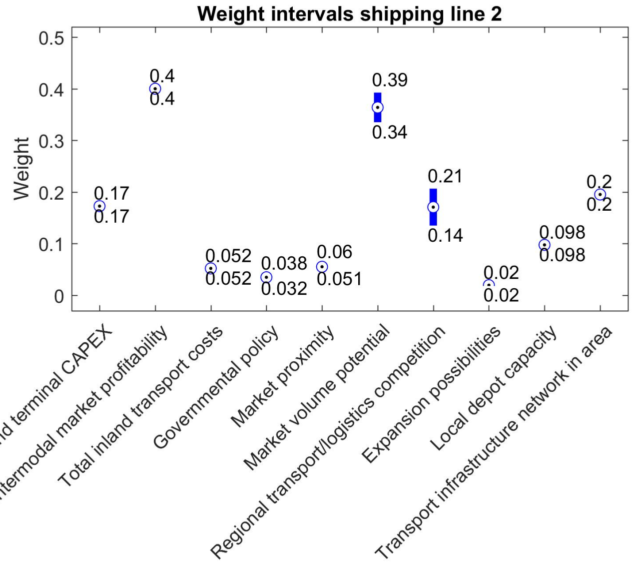


Figure 4.3: Weight intervals shipping line 2

The more detailed numerical interval values are given in Appendix J. For shipping line 2, the two most important criteria are *Intermodal market profitability*[9] and *Market volume potential*. The high score for *Market volume potential* is in line with the findings of Roso et al. (2015), which used combined decision-maker evaluations. It is to a lesser extent comparable to the transport service organizers' evaluations as observed in Kayikci (2010), which evaluate this factor slightly above average. *Transport infrastructure network in area* is fairly highly evaluated (which is slightly less than for shipping line actor 1), followed closely by *Inland terminal CAPEX* and *Regional transport/logistics competition*. The average evaluation for the latter factor complies with the findings from Karaşan and Kahraman (2019). The two least important criteria are *Expansion possibilities* and *Governmental policy*, which is comparable to the preferences of shipping line actor 1. Whereas *Inland terminal CAPEX* is scored fairly low by shipping line actor 1, it is evaluated averagely by shipping line actor 2 (fourth rank). This is more in line with findings from the literature review, especially from Ka (2011) and Regmi and Hanaoka (2013) (although they are based on combined decision-maker evaluations).

The weight intervals of shipping line actor 3 are displayed in Figure 4.4.

[9] Since this criterion is not observed in the literature, it cannot be compared to the findings of the literature review.

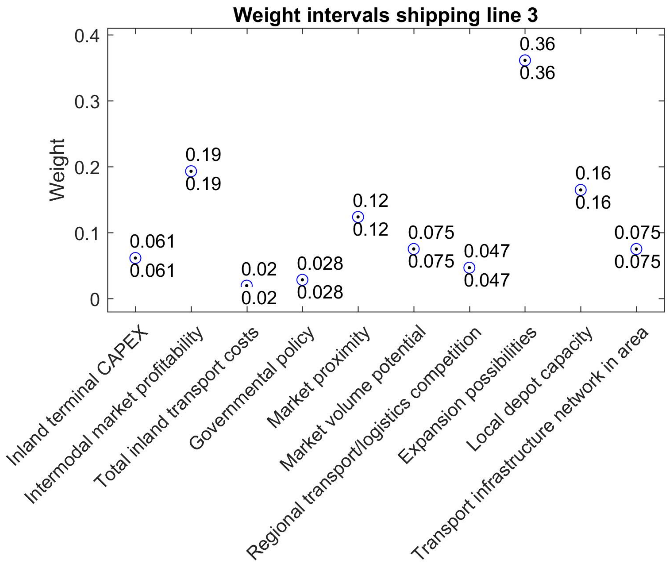


Figure 4.4: Weight intervals shipping line 3

The more detailed interval values are given in Appendix J. The most important criterion is *Expansion possibilities*, which is interesting since it was evaluated relatively low by the other shipping line respondents. The high score for this factor is relatively more than observed in the literature review (Karaşan and Kahraman, 2019; Özceylan et al., 2016; Roso et al., 2015). Averagely scored criteria are *Intermodal market profitability* and *Local depot capacity*. The preference for the *Local depot capacity* criterion is in line with the one of shipping line respondent 1, next to the fact that *Intermodal market profitability*[9] is scored high by all three. *Market proximity* is scored slightly below average, which complies with the findings of Karaşan and Kahraman (2019) and Roso et al. (2015). The two least important criteria are *Total inland transport costs* and *Governmental policy*. Especially the perception of the *Governmental policy* criterion is in line with the other shipping line actors, since they scored this factor relatively low as well.

The preferences of the shipping line actors combined result in the aggregate weights as displayed in Figure 4.5. The aggregate weight calculation results show *Intermodal market profitability*[9]. Second highest scoring criterion is *Transport infrastructure network in area*, which complies with the findings of Komchornrit (2017) who observes a similar rank for the infrastructure factor as well. Closely following is *Market volume potential*. This is in line with the evaluated weight for this factor found by Kayikci (2010), however higher than found by Komchornrit (2017). The high aggregate score of *Intermodal market profitability* is interesting since its main criterion *Costs and benefits* was only indicated once as Best criterion (compared to twice for *Local market characteristics*). However, this sub-criterion was indicated by all three respondents as most important within the *Costs and benefits*. This line of reasoning holds even more for the relatively high aggregate score of *Transport infrastructure network in area*, which belongs to main criterion *Technical characteristics* which is indicated as least important main criterion by all three respondents. Within *Technical characteristics*, the sub-criterion is indicated twice as most important compared to *Expansion possibilities* and *Local depot capacity*. The latter two have relatively intermediate aggregate weight values. Relatively poor scoring, yet not lowest, is *Total inland transport costs*, which is consistent with the findings of Kayikci (2010). The same holds for the relatively low score of *Regional transport/logistics competition* and the corresponding criterion weight in the research of Karaşan and Kahraman (2019). The lowest scoring criterion based on the aggregate weight value is *Governmental policy*, mostly due to it being poorly evaluated by by all shipping line respondents. As been mentioned before, the relatable decision-maker evaluation as observed by Karaşan and Kahraman (2019) shows a much higher preference for this factor.

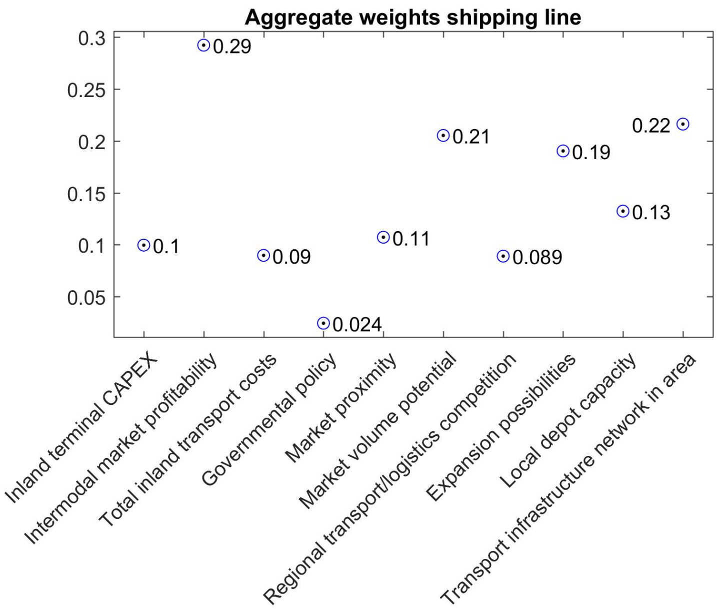


Figure 4.5: Aggregate weights shipping line

With regards to the overall aggregate scores, it must be noted that these weight aggregates, which can basically be regarded as compromise solutions, might not be representing compromise preferences too accurately. This is because the inputs for the calculations of the aggregate weights are quite distinct for some criteria (e.g. for the criterion of *Expansion possibilities*, which is scored low by both shipping line actors 1 and 2 but very high by shipping line respondent 3, leading to an aggregate value which is relatively far from preferred for each of the actors).

Terminal operator criteria weights

Since the amount of criteria relevant to the terminal operators does not exceed nine, the evaluation and corresponding criteria weight interval calculations are done in one step (hence no distinction between global and local weights to be considered). The criteria weight intervals for terminal operator actor 1 are displayed in Figure 4.6. The highest scoring criterion according to terminal operator 1 is *Regional economic development*. This is much higher than as indicated by Kayikci (2010) for the terminal operator experts. However, it does comply with the findings of Roso et al. (2015) (although these are based on the combined preferences of decision-makers). *Market volume potential*, *Transport infrastructure network in area*, *Anchor customer proximity*[10] and *Total inland transport costs* are scored intermediately. Since there is much overlap between the interval values of these criteria, they are to some degree comparably preferred. The averagely evaluated scores for *Market volume potential* and *Total inland transport costs* are similar to the findings of Kayikci (2010). However, *Transport infrastructure network in area* is evaluated much higher by the terminal operator actors involved in that paper. *Enabling modality shift*[10] and *Regional transport/logistics competition* are scored similarly as relatively low. Although not based specifically in terminal operator expert preferences, this is in line with the findings of Karaşan and Kahraman (2019). The lowest scoring criterion of *Inland terminal CAPEX* is interesting; firstly, it is evaluated much higher by terminal operators as observed by Nguyen and Notteboom (2016); secondly, the relative importance of all the other factors compared to the investment costs thus implies a relatively high value of sufficient (local) market conditions for the inland terminal to be successful (according to terminal operator actor 1).

[10] Since this criterion is not observed in the literature, it cannot be compared to the findings of the literature review.

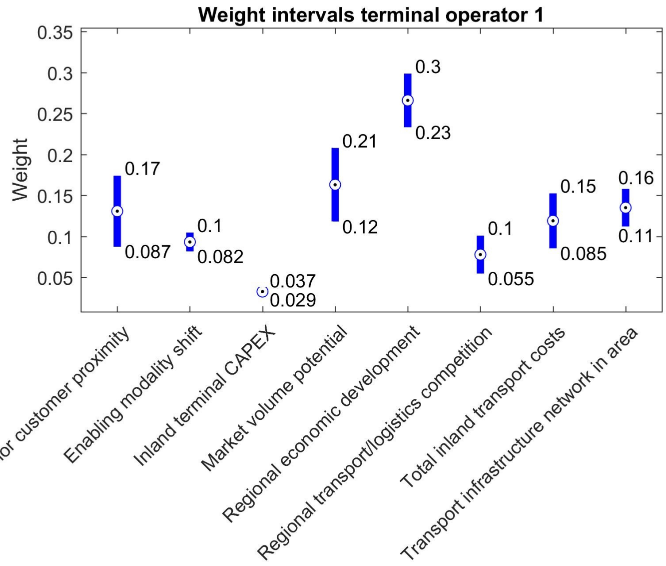


Figure 4.6: Weight intervals terminal operator 1

The criteria weight intervals for terminal operator actor 2 are displayed in Figure 4.7.

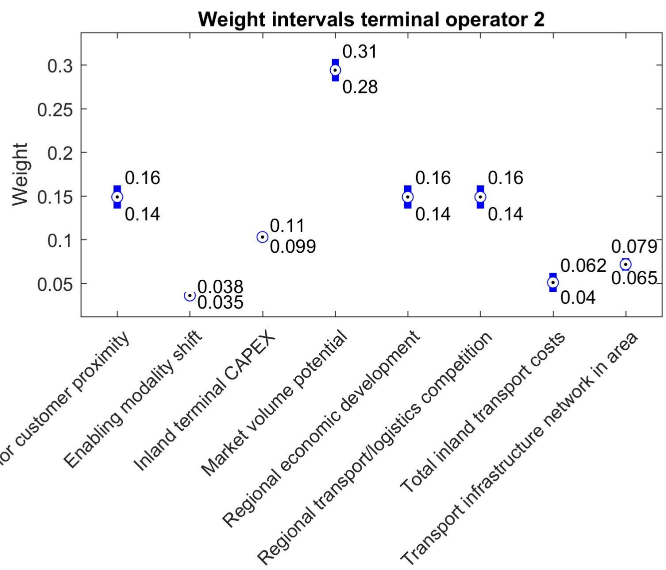


Figure 4.7: Weight intervals terminal operator 2

The highest scoring criterion according to terminal operator 2 is *Market volume potential*. This complies with the terminal operator evaluations of volume-potential (related) factors as found by Kayikci (2010). The intervals of *Regional economic development*, *Regional transport/ logistics competition* and *Anchor customer proximity*[10] practically fully overlap each other (details on the weight interval values are given in Appendix J), implying similar importance of these criteria. Especially the lower score for *Regional economic development* is more in line with Kayikci (2010) (as compared to the results of terminal operator actor 1). The three lowest scoring criteria are *Enabling modality shift*[10], *Total inland transport costs* and *Transport infrastructure network in area*. Interesting is the fact that for this respondent *Transport infrastructure network in area* scores relatively low compared to the higher score of this criterion for terminal operator actor 1. This also conforms less to the findings of Kayikci (2010) on this factor.

The criteria weight intervals for terminal operator actor 3 are displayed in Figure 4.8.

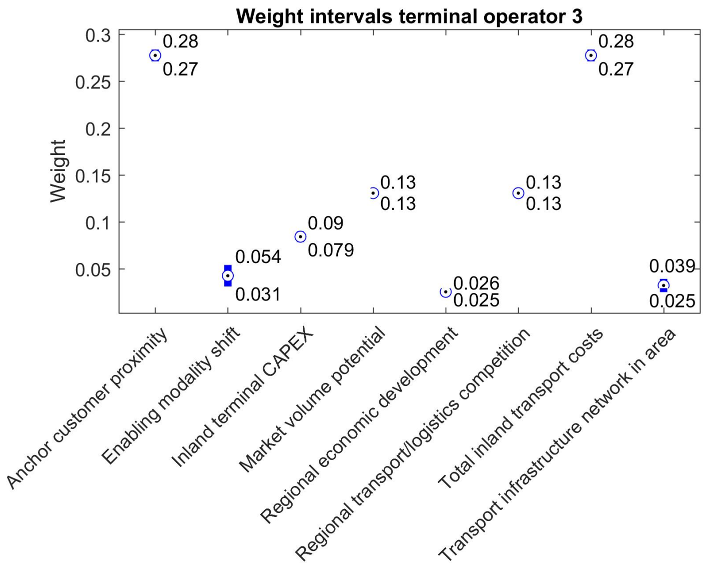


Figure 4.8: Weight intervals terminal operator 3

The two highest scoring criteria according to terminal operator 3 are *Anchor customer proximity*[10] and *Total inland transport costs*, which practically fully overlap each other (details on the weight interval values are given in Appendix J). The score for the latter criterion is much higher than as indicated by Kayikci (2010) for the terminal operator experts (which is scored averagely in that research). Overlap in intervals is also seen for *Market volume potential* and *Regional transport/ logistics competition*, although these are evaluated substantially less. This is more in line with Kayikci (2010), as well as with Karaşan and Kahraman (2019). The three lowest scoring criteria are *Regional economic development*, *Transport infrastructure network in area* and *Enabling modality shift*[10]. Worth to note is the fact that transport costs seem more important to this terminal operator respondent compared to the other two. The other way around, *Regional economic development* is considered to be less important by this terminal operator actor when compared to the other two.

The preferences of the terminal operator actors combined result in the aggregate weights as displayed in Figure 4.9. The highest scoring aggregate weight is the one of criterion *Anchor customer proximity*[10], closely followed by *Market volume potential* (which might suggest a direct relationship between the anchor customers and the local container volume potentials as perceived by the terminal operators). The relatively high aggregated score of *Market volume potential* is similar as been observed in Kayikci (2010) and Nguyen and Notteboom (2016). *Enabling modality shift*[10] and *Inland terminal CAPEX* have the lowest aggregate scores. With regards to the latter criterion, the relative importance of all the other factors compared to the investment costs once again implies the relatively high value of sufficient (local) market conditions for the inland terminal to be successful.

For the aggregate weights of the terminal operator actors it must also be noted that these weight aggregates might not be representing compromise preferences too accurately, since the inputs for the calculations of the aggregate weights are quite distinct for some criteria (e.g. for the criterion of *Regional economic development*, which is scored higher by terminal operator respondents 1 and 2 but much lower by terminal operator respondent 3, leading to an aggregate value which might be relatively far from preferred for each of the actors).

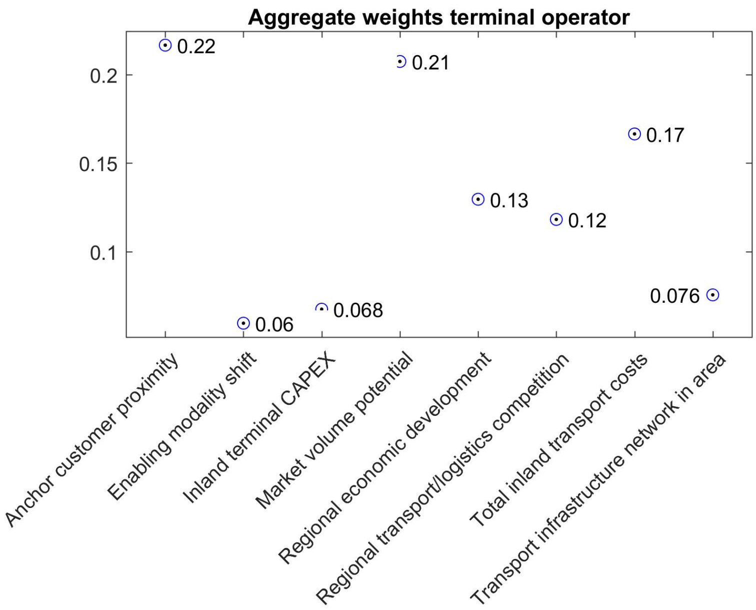


Figure 4.9: Aggregate weights terminal operator

Terminal user criteria weights

Since terminal users consist of both the intermodal (rail) transport operators (for main haulage operations) and the truck transport operators (for pre-/end-haulage operations), their criteria evaluations are assessed separately.

Rail transport operator criteria weights

Since the amount of criteria relevant to rail transport operators does not exceed nine, the evaluation and corresponding criteria weight interval calculations are done in one step (hence no distinction between global and local weights to be considered). The weight intervals of rail transport operator actor 1 are displayed in Figure 4.10.

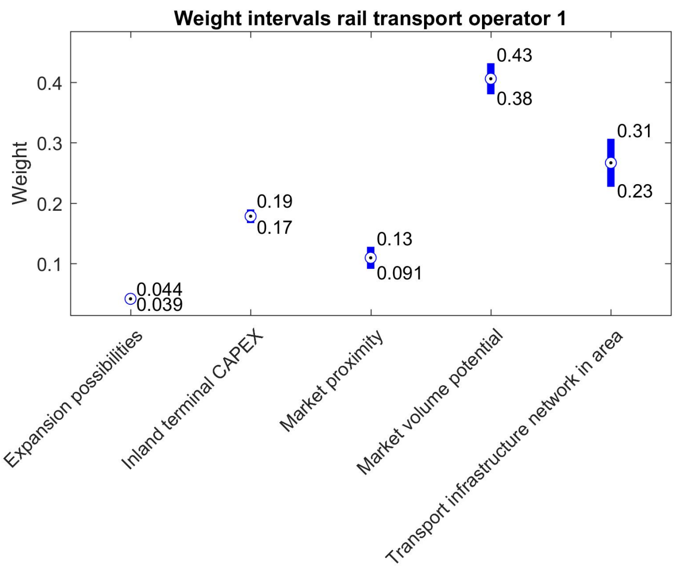


Figure 4.10: Weight intervals rail transport operator 1

More detailed numerical interval values are given in Appendix J. The two most important criteria as perceived by rail transport operator 1 are *Market volume potential* and *Transport in-*

frastructure network in area. This is higher than as been observed in Kayikci (2010), in which both these factors get evaluated averagely by the transport operator experts. However, the high evaluations for both these factors are in line with the findings of Rožić et al. (2016)[11]. Rated slightly below average is *Inland terminal CAPEX*. This complies with the findings of Regmi and Hanaoka (2013), although these findings are based on combined stakeholder inputs. The somewhat lower, yet not lowest score for *Market proximity* is very much in line with the evaluation of this factor by terminal users as observed by Nguyen and Notteboom (2016). As for the lowest score for *Expansion possibilities*, this criterion is not being assessed by comparable decision-making experts in the literature.

The weight intervals of rail transport operator actor 2 are displayed in Figure 4.11.

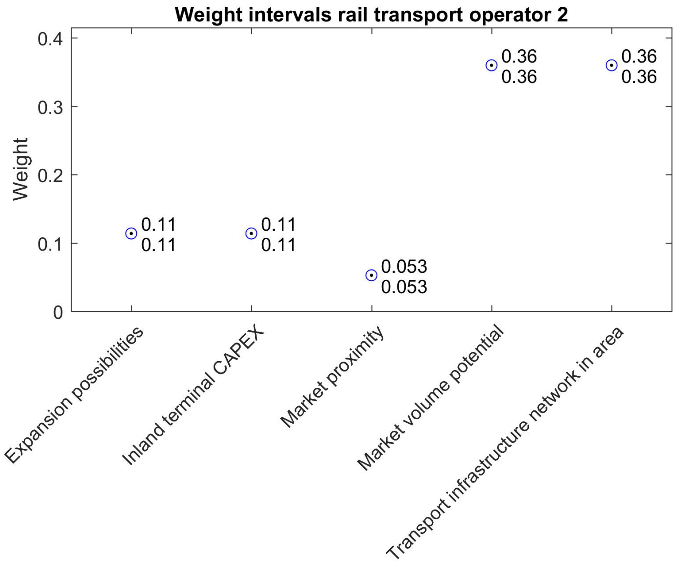


Figure 4.11: Weight intervals rail transport operator 2

The more detailed interval values are given in Appendix J. *Transport infrastructure network in area* and *Market volume potential* are both considered to be similarly more important compared to the other factors. The high scoring of both these factors is comparable to rail transport operator actor 1. The values for *Expansion possibilities* and *Inland terminal CAPEX* lie very close to each other as well. *Market proximity* is considered to be least important for this actor, which is to some extent in line with the findings of Nguyen and Notteboom (2016).

The preferences of both actors result in the aggregate weights, as displayed in Figure 4.12. Obviously, *Market volume potential* is the highest scoring aggregate weight since this criterion got the highest scores from both actors. The aggregated weight for *Expansion possibilities* is the lowest one, followed by the aggregated weight for *Market proximity*, which implies a higher relative score for the latter criterion from rail transport operator respondent 1 compared to respondent 2. Unlike the high variation in criteria scores between the shipping line and terminal operator actors respectively and the resulting *compromised* aggregate weight values, the aggregate weight values of the rail transport operator actors are more in line with the criteria perceptions of both actors individually. The compliance of these findings with the criteria weights as observed in the literature are therefore similar as described earlier for the individual actors' weight analyses.

[11] It must be noted that the decision-making experts in this study are undefined, thus it cannot be assessed if their perspectives are comparable to those of the rail transport operator.

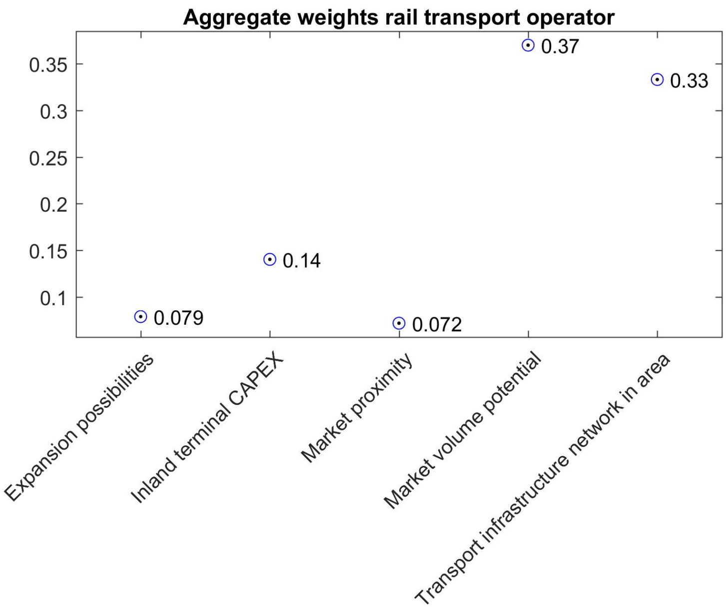


Figure 4.12: Aggregate weights rail transport operator

Truck transport operator criteria weights

Since the truck transport operator stakeholders had one response, one set of criteria weight intervals is calculated. The results are displayed in Figure 4.13.

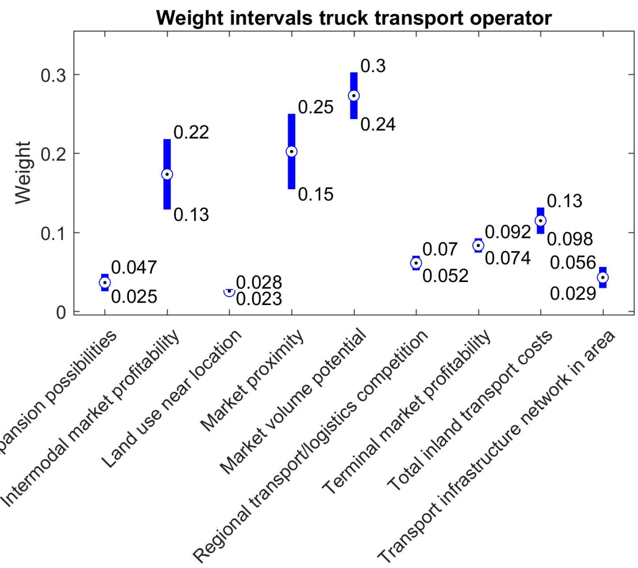


Figure 4.13: Weight intervals truck transport operator

The highest scoring criterion is *Market volume potential*, which conforms with the evaluations of this factor by the rail transport operator actors. *Market proximity* is scores second best, which is interesting because this factor is evaluated much less by the shipping line and rail transport operator actors (as well as by the terminal user decision-makers in Nguyen and Notteboom (2016)). A possible explanation for this is the fact that the costs for truck transport are more sensitive to distance (Pekin, 2010), which results in a higher importance of the proximity of customers for the operations of this stakeholder. *Intermodal market prof-*

itability[12] is ranked third. The evaluation of *Total inland transport costs* being slightly below average is in line with the findings of Kayikci (2010) on this factor. However, according to Nguyen and Notteboom (2016), this factor is evaluated higher by terminal user experts. The three lowest scoring criteria are *Land use near location*, *Expansion possibilities* and *Transport infrastructure network in area*, of which the weight values lie very close to each other. Especially the latter poorly scored criterion regarding the infrastructure is interesting, since it is observed as more important in Kayikci (2010), but even more since truck transport operators are assumed to be highly dependent on this infrastructure for their own operations/business. Since there is only one respondent from the truck transport operator stakeholder type, no aggregate intervals are calculated.

4.4. Results of Research Step 3: Operationalized criteria and corresponding data

Research Step 3 involves the operationalization of the criteria into measurable and comparable metrics. This operationalization leads to particular data gathering methods and eventually to a collection of quantitative data corresponding to each criterion for each alternative. As data type and gathering method are specific for each criterion, extensive descriptions per criterion are presented in Appendix C. The gathered data is also given in this appendix. In the next step, the data is normalized in order to be able to be processed in the MCA.

4.5. Results of Research Step 4: Utility assessment and initial ranking of alternatives

Research Step 4 involves the calculation of the alternatives' utilities based on the criteria weight intervals and the data obtained in the previous research steps. First of all, the gathered data is normalized using max - min normalization. The outcomes of the normalization of all criteria sets are presented in Table 4.8.

Criterion	**Alternative**					
	A1	**A2**	**B1**	**B2**	**C1**	**C2**
Anchor customer proximity	1,00	0,91	0,08	0,08	0,00	0,00
Enabling modality shift	1,00	0,94	0,00	0,00	0,04	0,07
Expansion possibilities	0,80	0,00	1,00	0,17	0,10	0,00
Governmental policy	1,00	1,00	1,00	1,00	0,00	0,00
Inland terminal CAPEX	0,00	0,33	0,78	0,44	0,89	1,00
Intermodal market profitability	0,00	0,08	0,61	1,00	0,92	0,89
Land use near location	1,00	1,00	1,00	0,00	0,00	0,00
Local depot capacity	0,00	0,00	0,58	0,58	1,00	1,00
Market proximity	0,89	1,00	0,05	0,05	0,00	0,00
Market volume potential	1,00	0,94	0,00	0,00	0,04	0,10
Regional economic development	1,00	1,00	0,61	0,61	0,00	0,00
Regional transport/logistics competition	1,00	1,00	0,15	0,15	0,00	0,00
Terminal market profitability	0,28	0,28	0,00	0,00	1,00	1,00
Total inland transport costs	0,96	1,00	0,00	0,19	0,47	0,45
Transport infrastructure network in area	0,56	0,36	0,00	0,11	1,00	0,98

Table 4.8: Normalized data scores for all criteria sets

By applying Equation 3.9, each distinct weight interval of each criterion for each actor is multiplied with the corresponding normalized data score of the alternative. This leads to a utility interval for each criterion belonging to the set of actor-relevant criteria for each alternative location, i.e. the *utility sub-interval*. For each alternative, the sub-intervals of each

[12] Since this criterion is not observed in the literature, it cannot be compared to the findings of the literature review.

actor are summed in order to result in a set of *gross utility* intervals per actor. Eventually, as the gross utility intervals of the different actor types cannot be straightforwardly compared to each other because the (amounts of) sub-intervals making up the gross utility assigned to each alternative vary for each actor type[13], the gross utility intervals are aggregated into a comparable *aggregate utility score* for each alternative (discussed in Sub-section 4.5.2).

This section is first of all involved with the examination of the utility sub-interval stemming from all criteria of all actors for each alternative in order to assess the sources of the (relative) utility contributions to each location. In this sense, the criteria which have the highest scoring utility intervals contribute most to the gross utility and can thus be considered as most essential to the alternative, whereas the lowest scoring utility intervals contribute least to the gross utility and can thus be considered as critical for the alternative. Consequently, the gross utility intervals are touched upon, after which the aggregate utility scores based on these gross utility intervals are presented.

4.5.1. Utility intervals

The utility sub-intervals stemming from each criterion are graphically presented in Figures 4.15, 4.16, 4.17, 4.18, 4.19 and 4.20 for each alternative location respectively. To allow for comparison between the several sub-interval plots, the utility scale (x-axis) is set to $[0, 0.45]$ for each plot. The utility sub-intervals for A1 are graphically presented in Figure 4.15. Examination of the sub-intervals shows that *Market volume potential* results as the factor mostly assigning large amounts of utility to the alternative. This is the case for shipping line actor 2, terminal operator actor 2 and all terminal user actors, mainly due to their high evaluations for this criterion in combination with the alternative's relatively large number of potential volumes. Large sub-utility scores are also assigned by *Anchor customer proximity*, evaluated relatively highly by the terminal operator actors, which is related to the container volume potential in the area in general. The alternative also scores considerably well on *Expansion possibilities* (especially for shipping line actor 3) and *Regional economic development* (especially for terminal operator actor 1). Relatively lower amounts of utility comes from shipping line actor 1, which evaluates *Transport infrastructure network in area* as important, however this factor is not a very outstanding characteristic for A1. Overall, the alternative scores low for *Inland terminal CAPEX* and *Intermodal market profitability* as well. This is because it has the highest investment costs of all alternatives as well as the lowest estimated margins to be gained from intermodal transport operations. By applying Equation 3.10, the utility sub-intervals are summed, resulting in the gross utility intervals for A1. These are referred to in Appendix K.

The utility sub-intervals for A2 are graphically presented in Figure 4.16. Likewise as for A1, the factors assigning high amounts of utility to the alternative are *Market volume potential* and *Anchor customer proximity*. This is explicable since these factors represent area-wide potential container volumes, thus both A alternatives score similarly high on these criteria. The same reasoning is also applicable to *Regional economic development* (which scores high) and *Regional transport/logistics competition* (which scores highest of all alternatives, but is not evaluated as very important by the corresponding actors). The alternative scores considerably well for *Total inland transport costs*, since these are the lowest compared to the other locations. As A2 does not have any *expansion possibilities*, the sub-utility scores for this criterion are 0. By applying Equation 3.10, the utility sub-intervals are summed, resulting in the gross utility intervals for A2. These are referred to in Appendix K.

The utility sub-intervals for B1 are graphically presented in Figure 4.17. As can be noticed, there are considerably less utility sub-intervals with high value ranges compared to the A alternatives. One exception is criterion *Expansion possibilities*, which has a high data score for the alternative. However, since this criterion is only evaluated highly by shipping line actor 3

[13] Each actor type-specific utility sub-interval is generated by the actor-specific $p_{ij}W_j^k$ operation. Since the values of weights W_j^k are dependent on the values of the other weights in the actor type-specific decision-criteria set, they can only be compared to each other within this specific set. Therefore, the same applies to the resulting utility (sub-)intervals.

and relatively low by the other actors, it only results in a relatively high utility score for this particular actor. Since B1 has the least container volume potentials around its location, it scores low on criteria related to these volumes (i.e. *Market volume potential*, *Market proximity*, *Anchor customer proximity* and *Enabling modality shift*). Furthermore, it scores low on *Total inland transport costs* because it is situated furthest away from the seaports (resulting in the highest inland transport costs of all locations) and *Transport infrastructure network in area* because the area in which it is located is relatively far away from any dense infrastructure network. By applying Equation 3.10, the utility sub-intervals are summed, resulting in the gross utility intervals for B1. These are referred to in Appendix K.

The utility sub-intervals for B2 are graphically presented in Figure 4.18. Overall, outlying scores (compared to the rest) are assigned to criterion *Intermodal market profitability*. The reason for this is that B2 has the highest intermodal profitability figure of all alternatives. Especially shipping line actor 2 causes for a substantial amount of utility for this criterion, since this actor evaluates this factor highest of all. The reason that B2 scores so much higher on this criterion than B1 (which is in the same area, thus similar market profitability scores would be expected) is the fact that B1 is located at some distance from any urban conglomeration compared to B2, which causes for larger pre-/end-haulage distances to most customers in the area and correspondingly higher average trucking costs. As these have a relatively large impact on the total transport costs (Pekin, 2010), the higher costs for transport eventually lead to lower margins gained from intermodal services. Furthermore, since container volume potentials around B are relatively low, the volume related criteria of *Market volume potential*, *Market proximity*, *Anchor customer proximity* and *Enabling modality shift* are scored low as well (which is similar to B1). By applying Equation 3.10, the utility sub-intervals are summed, resulting in the gross utility intervals for B2. These are referred to in Appendix K.

The utility sub-intervals for C1 are graphically presented in Figure 4.19. Notable for this alternative are the utility scores for *Transport infrastructure network in area*. These are relatively high, since this alternative is located in the area with the most dense infrastructure network (compared to the other alternatives). Especially shipping line actor 1 and rail transport operator actors 1 and 2 cause for these higher utilities, since they evaluate this factor high as well. As C1 also scores fairly well on *Intermodal market profitability*, the utilities coming from this criterion are also relatively high. The alternative scores high on *Local depot capacity*, since there are not as much existing container depots in the area compared to A and B. However, as container volumes in the area are also relatively low, volume-related utilities score poorly as well (comparable to B1 and 2). Since C1 has no customers with substantial container volumes (> 1.000 FEU p.a.) within a 25 kilometer reach, it scores 0 on *Anchor customer proximity*. *Enabling modality shift* also has low utilities because of the relatively high distances between the location and customers with substantial volumes. Next to that, the alternative scores 0 on *Governmental policy* as well (although this is a factor that is overall not very important to the actors). By applying Equation 3.10, the utility sub-intervals are summed, resulting in the gross utility intervals for C1. These are referred to in Appendix K.

The utility sub-intervals for C2 are graphically presented in Figure 4.20. Since this alternative is located in the same area as C1 and the high-scoring *Transport infrastructure network in area* represents the wider C area, the utility scores from this alternative for C2 are also relatively high. *Intermodal market profitability* is also considerably high for the location. It is noticeable that C2 scores slightly higher on *Market volume potential* and *Enabling modality shift* compared to C1. However, like C1, it is still too far away from customers with substantial container volumes to score anything on *Anchor customer proximity*. As the same local governmental situation applies to C2 as to C1, it also generates no utility from this criterion. Another 0 score is for criterion *Expansion possibilities*, which location C2 does not have. By applying Equation 3.10, the utility sub-intervals are summed, resulting in the gross utility intervals for C1. These are referred to in Appendix K.

As the ranges of the *overall* minimum and the *overall* maximum interval value of the gross utilities for each alternative vary, a graphical representation of these range differences is given in Appendix K. Although the differences in *total* gross utility interval ranges are visible in this plot, they cannot be straightforwardly deducted from comparing these interval sets with each other[13]. Therefore, aggregate utility scores based on these separate utility intervals for each alternative location are calculated. These are discussed in the next sub-section.

4.5.2. Aggregate utility scores

The aggregate utility scores for all alternatives is depicted in Figure 4.14.

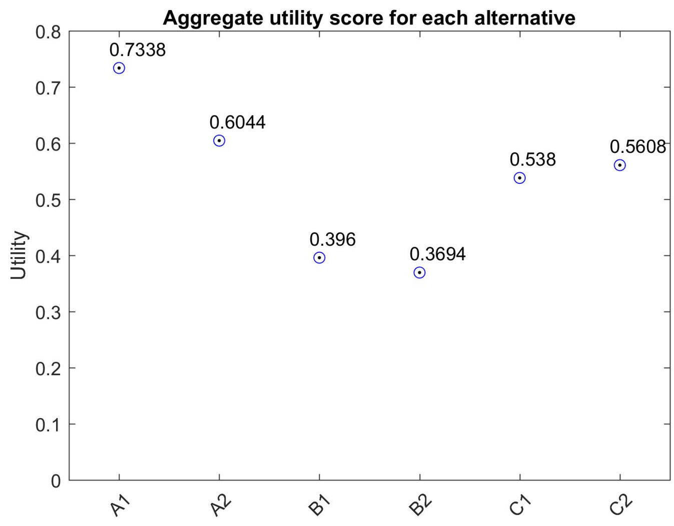


Figure 4.14: Aggregate utility scores

Based on these aggregates, the highest ranked alternative is A1 with a score of 0,7338, which is almost 21% higher than second best alternative A2. The high score of A1 is mostly based on the fact that this alternative has a combination of highly scoring factors such as *Market volume potential*, *Expansion possibilities* and *Transport infrastructure network in area*, which are also relatively highly valued by most of the respondents. This also explains the relatively high score of A2, as some of these criteria represent area-wide rather than location-specific characteristics (e.g. *Market volume potential*, which is measured by taking into account the locations of volume generating customers in the wider area). The lower score for A2 compared to A1 is thus most likely related to other factors than the previously mentioned. A factor on which A2 scores distinctively worse is *Expansion possibilities*, which are not existent at the location. The scores of the two C alternatives lie considerably close to each other, indicating the fact that their data scores do not differ that much. This is also the case for the B locations, although B1 scores somewhat better (most likely due to the high amount of *Expansion possibilities* around its location). Overall worst scoring alternative is B2. This alternative scores worse on the previously mentioned highly valued criteria, which results in a low final aggregate utility.

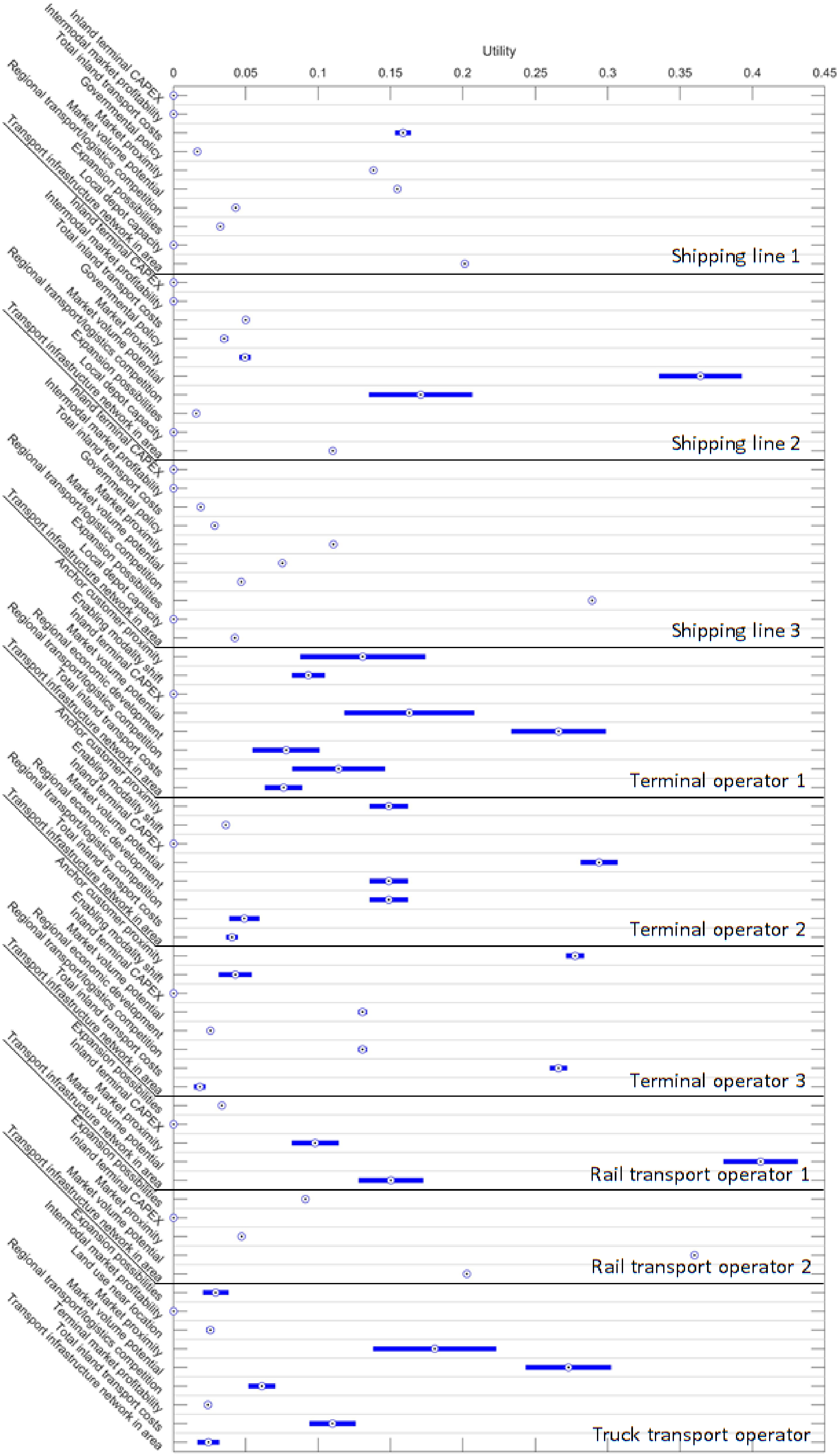


Figure 4.15: Utility sub-intervals for all criteria of each actor for A1

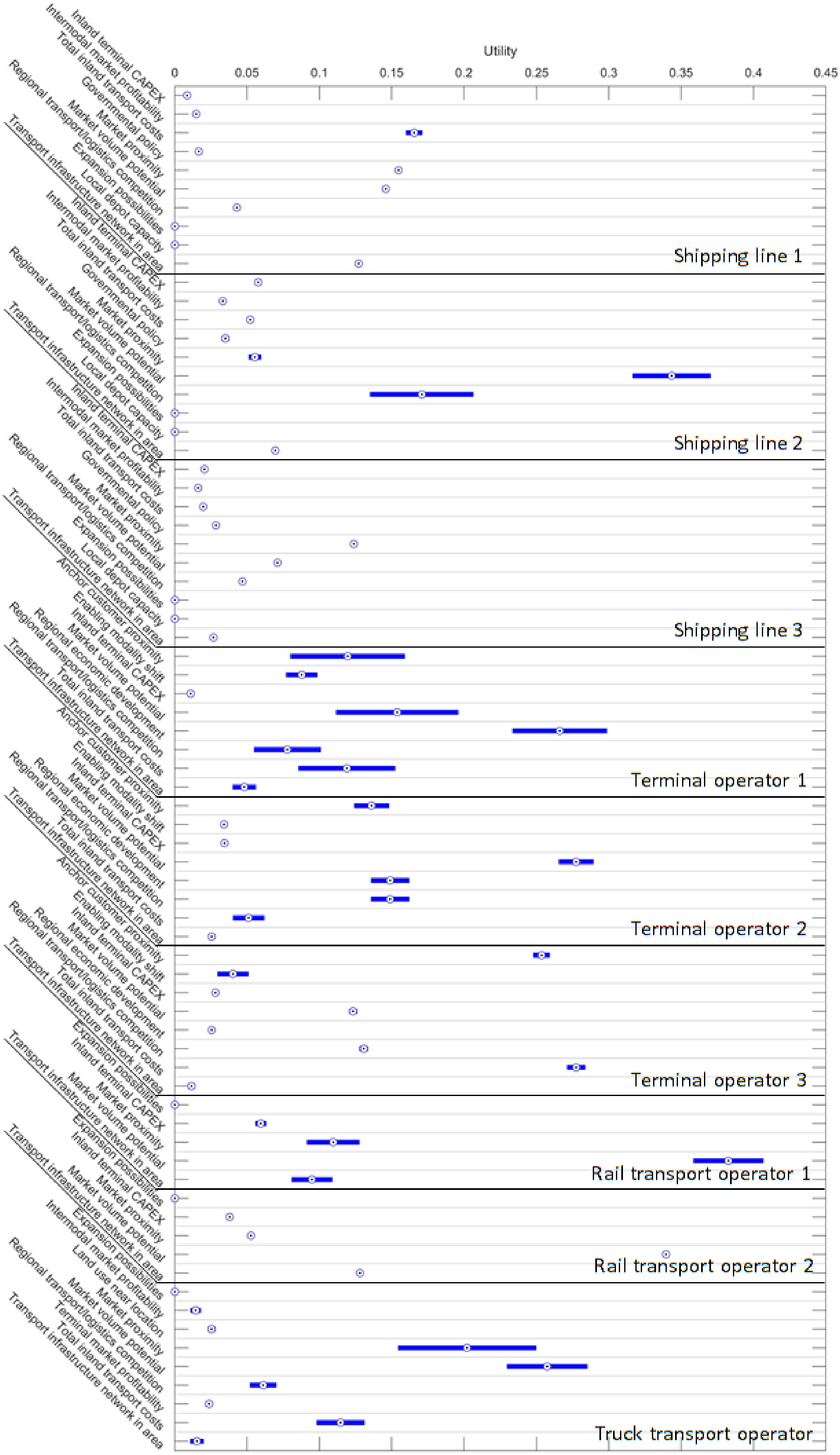


Figure 4.16: Utility sub-intervals for all criteria of each actor for A2

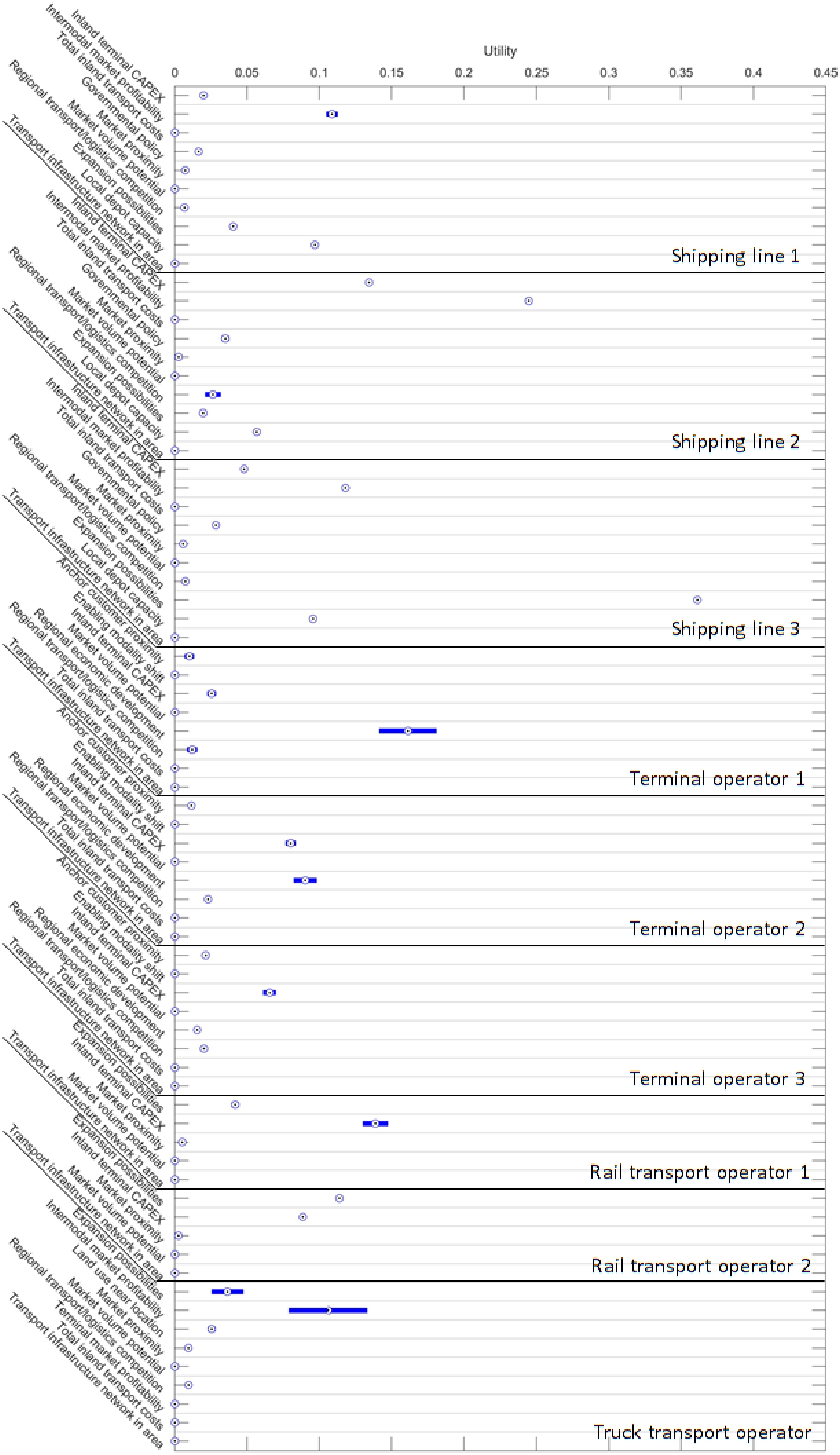


Figure 4.17: Utility sub-intervals for all criteria of each actor for B1

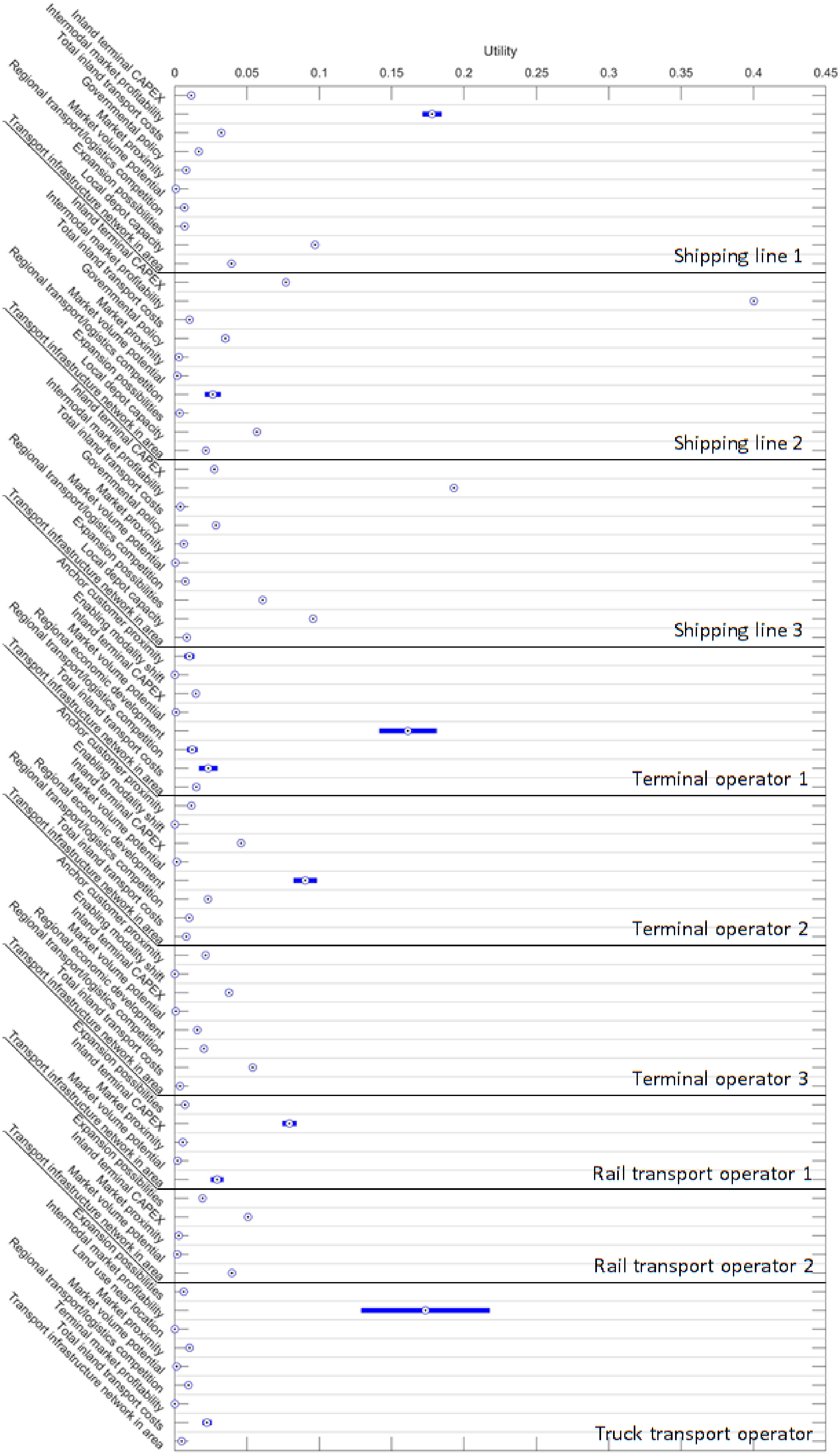


Figure 4.18: Utility sub-intervals for all criteria of each actor for B2

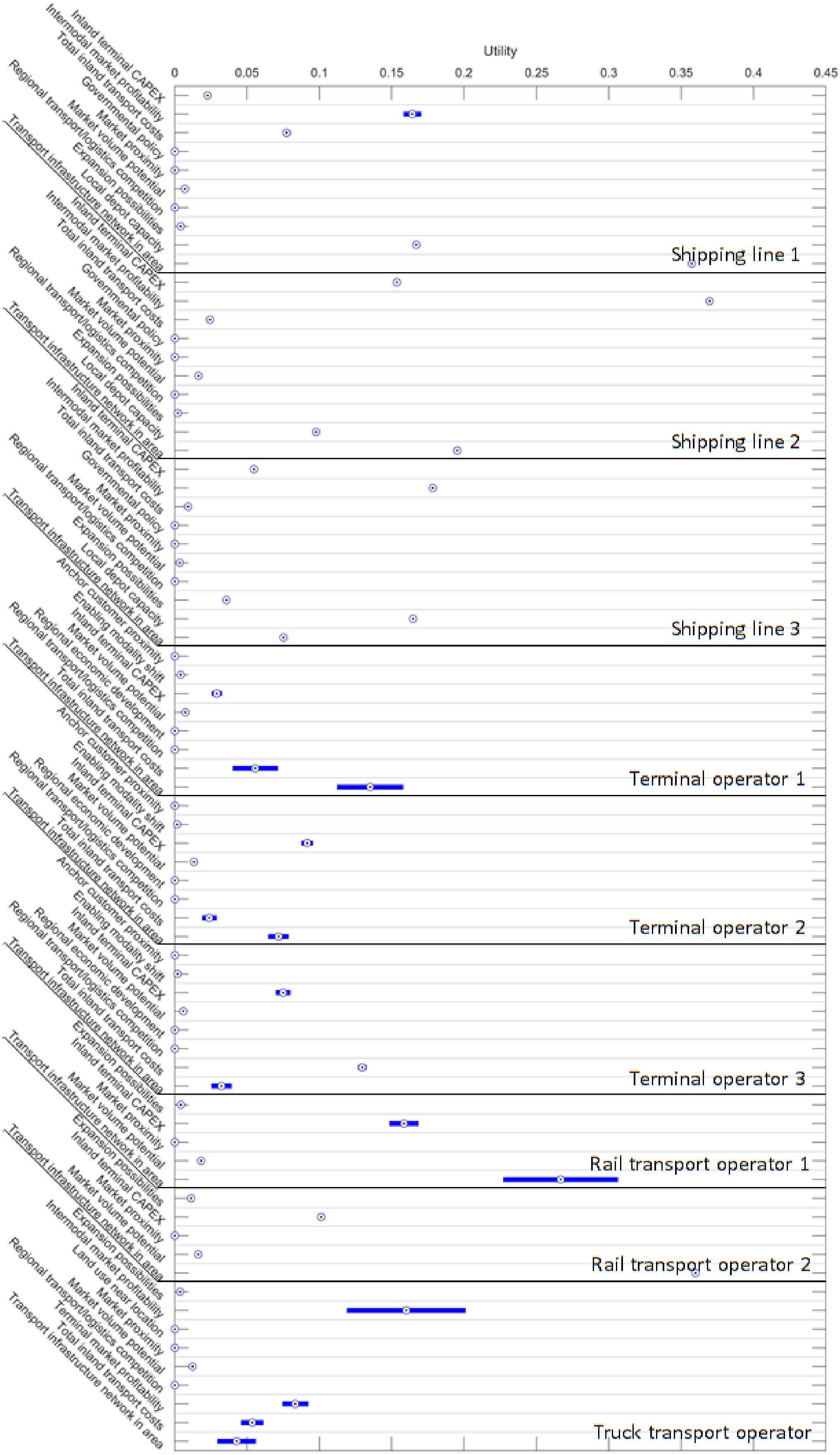


Figure 4.19: Utility sub-intervals for all criteria of each actor for C1

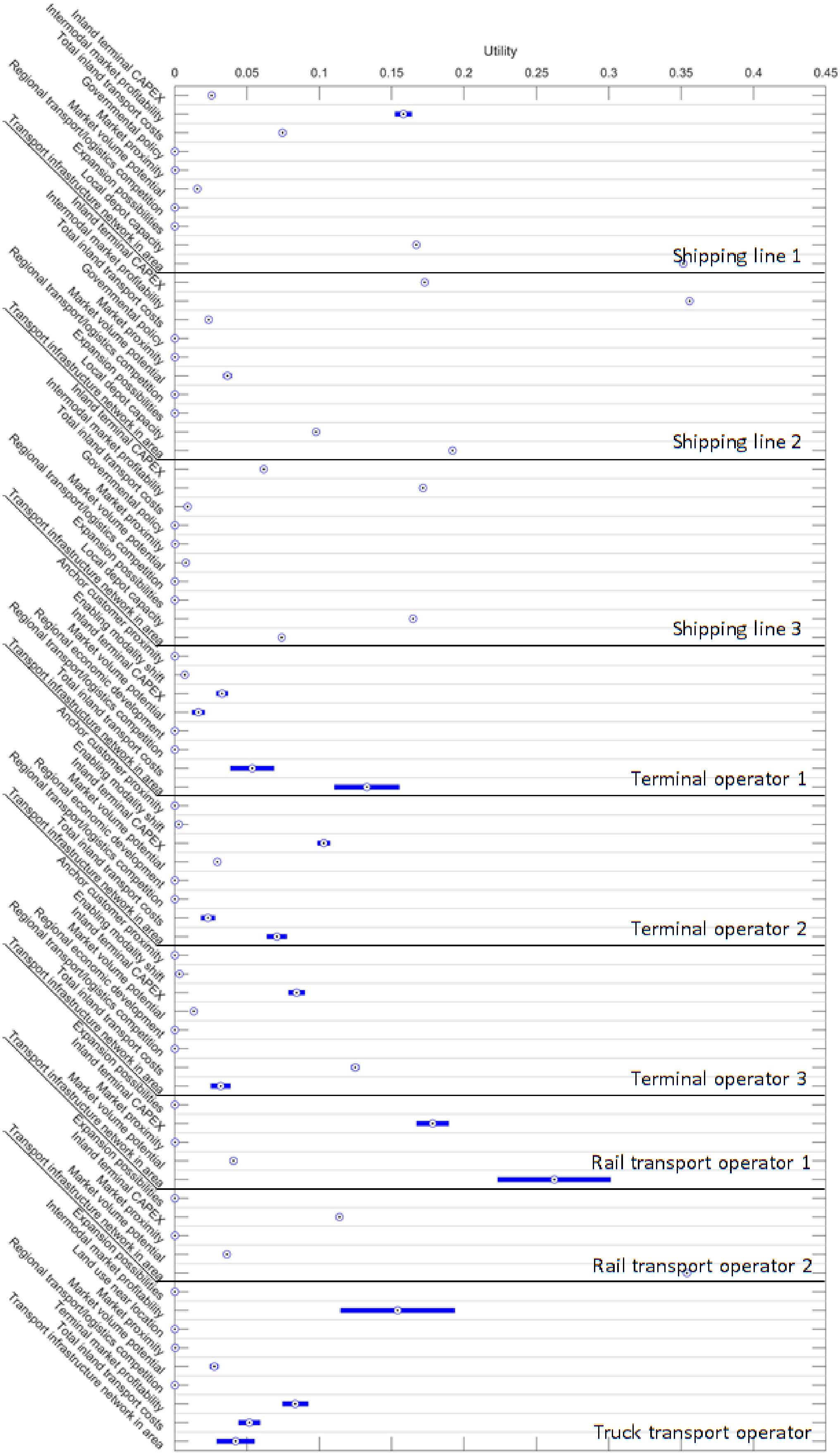


Figure 4.20: Utility sub-intervals for all criteria of each actor for C2

4.6. Results of Research Step 5: Sensitivity analysis

On top of the initial results of the inland terminal location selection model, a sensitivity analysis is conducted in order to test which model inputs have low and high impacts on the final model results. These impacts can be assessed by adapting the corresponding model parameters and comparing the results of these adaptations with the results of the model results in Section 4.5. In order to conduct the sensitivity analysis, *sensitivity model scenarios* are considered; each scenario involves certain specified model parameter settings. Two main scenarios are considered in order to reach the goals of the sensitivity analysis (Section 3.3.5), which both consist of certain sub-scenarios in which varying model settings for the same general alteration are applied; *Decision-maker relevance scenario* (consisting of three sub-scenarios), in order to assess the influences of the decision-making stakeholders' preferences on the outcomes of the model; and the *Container volume potential growth scenario* (consisting of two sub-scenarios), in order to assess the influences of the container-volume related criteria considered to be critical for the alternatives' final utility scores. The results of the scenario models ran with the corresponding scenario settings are then compared to results of the initial model (Step 5), which is called *Scenario 0* for the remainder of this chapter.

4.6.1. Scenario 1: Decision-maker relevance scenario

As explained in Section 2.3, the inland terminal location selection problem contains the three key stakeholders of the shipping line, the terminal operator and the terminal user. These are therefore all taken into account in the MCDM study. However, in reality, the actual decision concerning the location of the inland terminal is made either by the shipping line and the terminal operator combined, or by one of each individually. The transport operators, which only make use of the inland terminal in their operations, are only taken into account in the study for their *evaluation* of the inland terminal location. Hence, this sensitivity analysis is aimed at assessing the influences of the *actual* decision-makers involved in the inland terminal location selection process, regardless of the evaluations of the terminal users. Accordingly, a stepwise approach is considered for the analysis, consisting of three sub-scenarios.

Scenario 1.1: Influence of the combined shipping line and terminal operator actors' preferences on the final utility scores

The first sub-scenario involves the inland terminal location selection problem with the terminal user actors eliminated from the MCDM study. Consequently, the outcomes of the model are based on the preferences of just the shipping line actors and terminal operator actors. The final aggregate utility scores resulting from this procedure are displayed in Figure 4.21. The numerical differences in utility scores per alternative for the sensitivity analysis scenario compared to ***Scenario 0*** are presented in Table 4.9. Interestingly, it can be noticed that almost all aggregate utility scores for the alternatives in Scenario 2.1 are similar to the ones in Scenario 0. The only alternative with a different score is B2, which sees a 6% increase in final utility when the alternatives are evaluated by the shipping line and terminal operator actors only. This implies that the combined preferences of these two actors together lead to nearly the same results as all actors' preferences combined, including those of the terminal users. The preferences of the terminal users are thus in line with the combined preferences of the shipping line and terminal actors, since including the terminal user evaluations results in nearly the same aggregate utilities and consequent ranks for the alternatives. In that sense, it can be stated that the influence of the terminal users on the final outcome of the *original* model is limited. Although one alternative (B2) sees a rise in score after elimination of the terminal users, the overall ranking based on the final utility scores of Scenario 2.1 is the same as in Scenario 0.

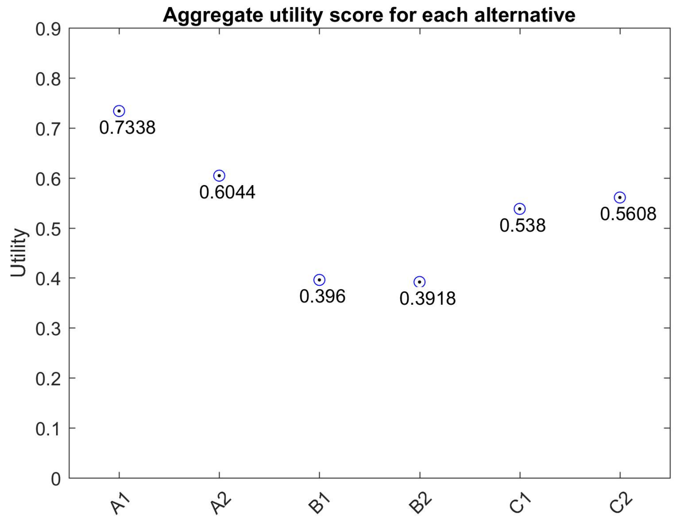


Figure 4.21: Aggregate utility scores of Scenario 1.1: Only shipping line and terminal operator actors considered.

Alternative	**A1**	**A2**	**B1**	**B2**	**C1**	**C2**
Utility score	***0,7338***	***0,6044***	***0,3960***	***0,3694***	***0,5380***	***0,5608***
Utility score	0,7338	0,6044	0,3960	0,3918	0,5380	0,5608
Percentage difference	0%	0%	0%	+6%	0%	0%

Table 4.9: Scenario 1.1: Aggregate scores and increase ratios.

Scenario 1.2: Influence of the shipping line actors' preferences on the final utility scores
The second sub-scenario involves the inland terminal location selection problem with the terminal user and terminal operator actors eliminated from the MCDM study. Consequently, the outcomes of the model are based on the preferences of just the shipping line actors. The final aggregate utility scores resulting from this procedure are displayed in Figure 4.22. The numerical differences in utility scores per alternative for the sensitivity analysis scenario compared to ***Scenario 0*** are presented in Table 4.10. In contrast to Scenario 2.1, the overall ranking of Scenario 2.2 does differ from the initial one of Scenario 0. With only the shipping line actors involved in the location selection process, alternative C1 results with the highest aggregate utility score (although the score for C1 in Scenario 2.2 (0,6892) is not as high as the score for A1 in Scenario 0 (0,7338). Second best ranking alternative is C2, closely followed by initial best scoring A1. The two B locations are again the lowest ranking alternatives, although their respective ranks have changed. The resulting high scores for both C alternatives imply well scoring location characteristics, evaluated highly by the shipping line actors. The most distinctive of these factors is *Intermodal market profitability*, which is relatively high in the C area. Next to that, the dense *transport infrastructure* in the C area, a characteristic which is also assessed as fairly important by the shipping line actors, results in relatively large portions of utility for the alternatives as well.

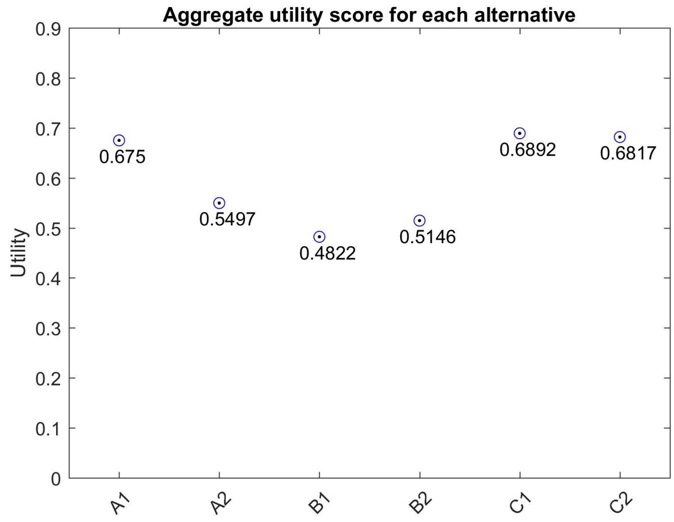


Figure 4.22: Aggregate utility scores of Scenario 1.2: Only shipping line actors considered.

Alternative	**A1**	**A2**	**B1**	**B2**	**C1**	**C2**
Utility score	***0,7338***	***0,6044***	***0,3960***	***0,3694***	***0,5380***	***0,5608***
Utility score	0,6750	0,5497	0,4822	0,5146	0,6892	0,6817
Percentage difference	−8%	−9%	+22%	+39%	+28%	+22%

Table 4.10: Scenario 1.2: Aggregate scores and increase ratios.

Scenario 1.3: Influence of the terminal operator actors' preferences on the final utility scores
The third sub-scenario involves the inland terminal location selection problem with the terminal user and shipping line actors eliminated from the MCDM study. Consequently, the outcomes of the model are based on the preferences of just the terminal operator actors. The final aggregate utility scores resulting from this procedure are displayed in Figure 4.23. The numerical differences in utility scores per alternative for the sensitivity analysis scenario compared to ***Scenario 0*** are presented in Table 4.11. The alternatives' aggregate utility scores based on the inputs of just the terminal operator actors results in the same first and second ranked locations as in Scenario 0, namely A1 and A2. However, the utility scores are very close to each other (0,8565 and 0,8563 respectively). Third and fourth ranks are also similar (C1 and C2 respectively), although the aggregate utility scores for the C alternatives are considerably lower in Scenario 2.3 than in Scenario 0. The same holds for B2 and B1, which are ranked fifth and sixth respectively. The substantially larger scores for the A alternatives as well as the substantially lower scores for the C and B alternatives emphasizes the suitability of the A locations compared to the other locations for the terminal operators (based on their stated preferences). These are mostly based on the highly evaluated *Market volume potential*, which is significantly higher in the A area compared to the other areas. Accordingly, the *Anchor customer proximity* in the A area, which is also highly assessed by the terminal operators, results in large portions of the utility scores as well. Furthermore, the area's higher *Regional economic development*, which is evaluated highly particularly by terminal operator 1 as well as fairly high by terminal operator 2, leads to substantial amounts of utility.

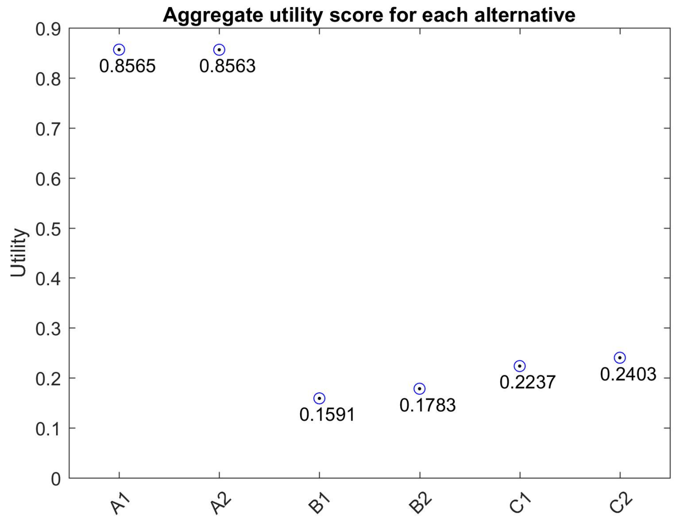


Figure 4.23: Aggregate utility scores of Scenario 1.3: Only terminal operator actors considered.

Alternative	**A1**	**A2**	**B1**	**B2**	**C1**	**C2**
Utility score	***0,7338***	***0,6044***	***0,3960***	***0,3694***	***0,5380***	***0,5608***
Utility score	0,8565	0,8563	0,1591	0,1783	0,2237	0,2403
Percentage difference	+17%	+42%	−60%	−52%	−58%	−57%

Table 4.11: Scenario 1.3: Aggregate scores and increase ratios.

4.6.2. Scenario 2: Container volume potential growth scenario

As container volume related characteristics are generally evaluated as considerably important by most of the stakeholders involved, they account for substantial amounts of utility for the alternatives. This is especially the case for the locations in the A area, in which the container volume potentials are significantly higher than for the other areas. This leads to substantial amounts of utility assigned to the A alternatives, whereas the other alternatives receive considerably less utility due to the fewer volumes. Consequently, the container volume related factors, i.e. *Market volume potential*, *Market proximity*, *Anchor customer proximity* and *Enabling modality shift*, can be considered as critical factors of the MCDM study. Next to being critical with regards to the location selection model, the container related characteristics of a region are also rather variable. Overall, a steady growth of containers use can be indicated (Diaz et al., 2011). However, due to particular economical events, container volumes generated in/attracted to a certain area might fluctuate more in shorter periods of time. An examples of such an event is a (new) shipper/consignee opening a new facility in the particular region (e.g. a factory or a distribution center), which is sufficiently large to cause for a relatively high influx of annual container volumes.

For those two reasons, the *Container volume potential growth scenario* is considered. The scenario involves assessing the hypothetical, yet not totally unrealistic situation of sudden container volume potential influx in the areas of B and C. These areas are selected because they have the lowest container volumes in the current situation (Scenario 0). Thus, manipulating their container volume related characteristics enables assessing the influence of these characteristics on the desirability of the respective locations compared to the A locations, which already have higher volumes. Because the hypothetical container volume potential influx is unlikely to happen for both locations simultaneously, it is chosen to assess them separately. This also enables evaluation of each manipulated location compared to the non-manipulated locations individually. The manipulation itself starts with increasing the *Market volume potential* factor of the corresponding area's locations. A stepwise container volume potential influx is considered; the minimal increase starts with 10.000 FEU *extra* potential p.a., up to a maximum increase of 30.000 FEU extra potential p.a., with intermediate steps of 5.000 FEU p.a.. As the criteria of *Anchor customer proximity*, *Enabling modality shift* and *Market proximity* are related to *Market volume potential*[14], they need to be manipulated as well. Therefore, the values of these particular factors are increased proportionally to the increase of the *Market volume potential.* Accordingly, two sub-scenarios are constructed. Each sub-scenario consists of the five container volume potential influxes for the particular location.

Scenario 2.1: Container volume potential influx for the B area

The stepwise development of the aggregate utilities for the alternatives as a result of the container volume potential influxes for the B area is given in Figure 4.24.

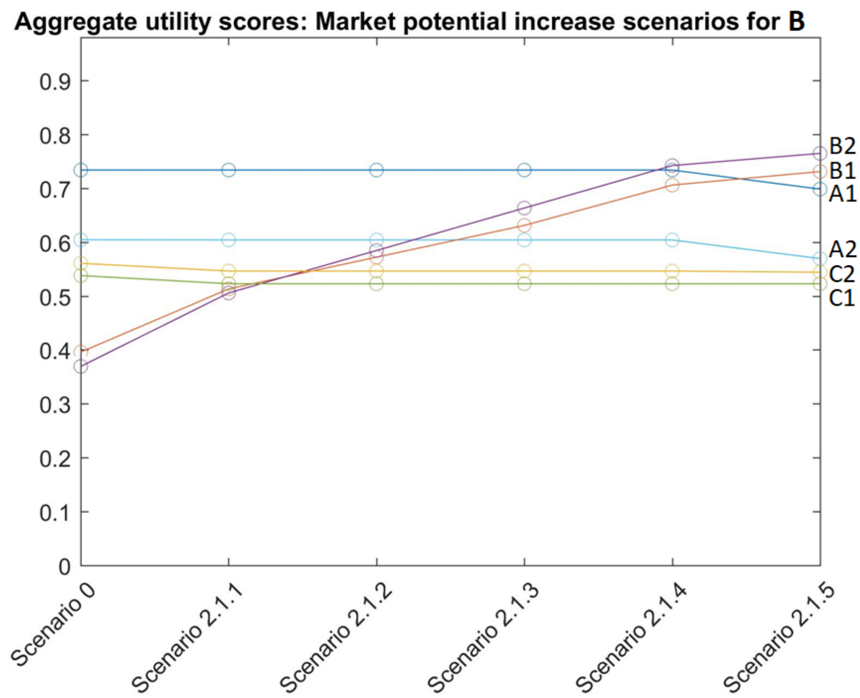


Figure 4.24: Aggregate utility scores of Scenario 2.1: Increased container volume potentials for B.

The numerical utility scores per alternative including comparisons to ***Scenario 0*** are presented in Table 4.12. As can be deducted from the figure, both B locations surpass the ranks of the C locations between a container volume potential influx of 10.000 to 15.000 FEU p.a. in the B area. Because of the max - min normalization applied in this study, the overall utility scores of the C alternatives decrease as a result of becoming the minimum data values in the respective criterion range. Between 15.000 to 20.000 FEU extra container volume potential p.a. for B, both B alternatives surpass A2 as well. At an influx level of 25.000 FEU p.a., B2 reaches rank 1 by surpassing A2. This is particularly interesting because at this influx level, the container volume potential amounts of A1 and B2 are similar to each other. The fact that B2 has surpassed A1 at this point implies that, if it were not for the distinctively high container volume characteristics in the A area in the current situation (Scenario 0), B2 would

[14] The data scores of *Anchor customer proximity*, *Enabling modality shift* and *Market proximity* are calculated using the *Market volume potential* data as input.

Alternative	A1	A2	B1	B2	C1	C2
Utility score	***0,7338***	***0,6044***	***0,3960***	***0,3694***	***0,5380***	***0,5608***
Utility score 2.1.1. +10.000 FEU p.a.	0,7338	0,6041	0,5132	0,5057	0,5228	0,5465
Percentage difference	0%	0%	+30%	+37%	−3%	−3%
Utility score 2.1.2. +15.000 FEU p.a.	0,7338	0,6041	0,5721	0,5845	0,5228	0,5465
Percentage difference	0%	0%	+44%	+58%	−3%	−3%
Utility score 2.1.3. +20.000 FEU p.a.	0,7338	0,6041	0,6311	0,6633	0,5228	0,5465
Percentage difference	0%	0%	+59%	+80%	−3%	−3%
Utility score 2.1.4. +25.000 FEU p.a.	0,7338	0,6041	0,7059	0,7421	0,5228	0,5465
Percentage difference	0%	0%	+78%	+101%	−3%	−3%
Utility score 2.1.5. +30.000 FEU p.a.	0,6984	0,5695	0,7310	0,7647	0,5228	0,5442
Percentage difference	−5%	−6%	+85%	+107%	−3%	−3%

Table 4.12: Scenario 2.1: Aggregate scores and increase ratios.

actually be a more desirable alternative based on its non-container volume related characteristics. B1 surpasses A1 in between 25.000 to 30.000 FEU p.a.. Because of the applied normalization technique, the aggregate utility scores of the A alternatives decrease as well after they get surpassed by the new maximum higher scoring B locations. Also worth noting is the fact that B2 surpasses B1 as a results of the influx (also between 10.000 to 15.000 FEU p.a. in the whole B area). This is because of the fact that B2 already has higher container volume related characteristics to begin with (in Scenario 0), whereas it scores less on the other factors compared to B1, resulting in an initial higher rank for the latter alternative. However, as the container volume related factors of the B locations are increased whereas the other factors stay the same, the overall utility assigned to B1 based on its relatively higher container volumes result in an overall higher aggregate utility as well.

Scenario 2.2: Container volume potential influx for the C area
The stepwise development of the aggregate utilities for the alternatives as a result of the container volume potential influxes for the C area is given in Figure 4.25. The numerical utility scores per alternative including comparisons to ***Scenario 0*** are presented in Table 4.13. As the C alternatives initially already score averagely as well as higher than the B alternatives in Scenario 0, it takes less container volume potential influx to let the respective aggregate utility scores surpass the ones from the A locations. As can be noticed in the plot, both C locations exceed A2 at less than 10.000 FEU extra volume potential p.a.. Initially first ranked A1 is surpassed by C2 just before the level of 10.000 FEU p.a. extra container volume potential and by C1 in between 10.000 to 15.000 FEU p.a.. Most interesting about this development is the fact that at the influx level at which both C alternatives surpass A1, the total container volume potential of the C area is still below the total container volume potential of the A area. Around the influx level of 25.000 FEU extra container volume potential p.a. for C, the volume potential level of the A area would be met. At this level, the final aggregate utility scores of both C alternatives are about 30% higher than the initial aggregate utility score of A1 in Scenario 0. This indicates the fact that of all alternatives, the C locations

have particularly high scoring non-container volume related characteristics and would be considerably good options compared to the A locations under relatively slightly improved market conditions.

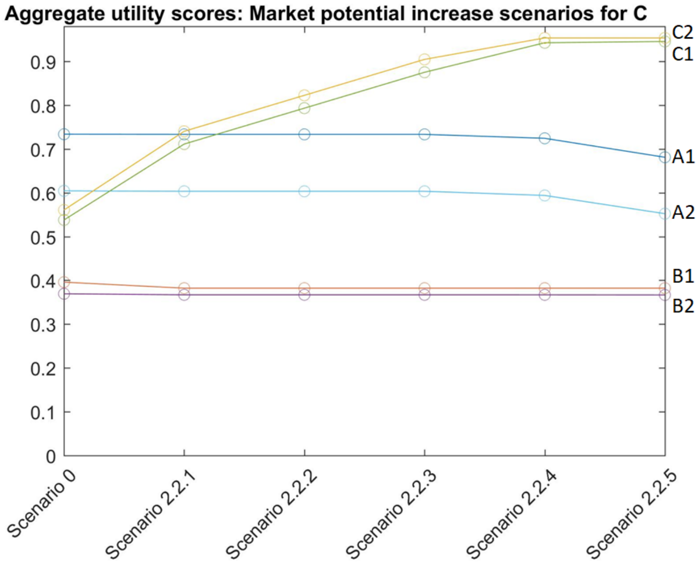


Figure 4.25: Aggregate utility scores of Scenario 2.2: Increased volume potentials C.

Alternative *Utility score*	**A1** *0,7338*	**A2** *0,6044*	**B1** *0,3960*	**B2** *0,3694*	**C1** *0,5380*	**C2** *0,5608*
Utility score 2.2.1. +10.000 FEU p.a.	0,7335	0,6035	0,3822	0,3671	0,7113	0,7405
Percentage difference	0%	0%	−3%	−1%	+32%	+32%
Utility score 2.2.2. +15.000 FEU p.a.	0,7335	0,6035	0,3822	0,3671	0,7933	0,8226
Percentage difference	0%	0%	−3%	−1%	+47%	+47%
Utility score 2.2.3. +20.000 FEU p.a.	0,7335	0,6035	0,3822	0,3671	0,8752	0,9047
Percentage difference	0%	0%	−3%	−1%	+63%	+61%
Utility score 2.2.4. +25.000 FEU p.a.	0,7245	0,5940	0,3822	0,3670	0,9427	0,9536
Percentage difference	−1%	−2%	−3%	−1%	+75%	+70%
Utility score 2.2.5. +30.000 FEU p.a.	0,6812	0,5523	0,3822	0,3667	0,9456	0,9536
Percentage difference	−7%	−9%	−3%	−1%	+76%	+70%

Table 4.13: Scenario 2.2: Aggregate scores and increase ratios.

5
Conclusions and discussion

This final chapter involves concluding and discussing the research and its results, aimed at finding a desirable location for a shipping line to set up an inland terminal which can be incorporated in the inland transport services offered to its customers. In that regard, the multiple different stakeholders with particular objectives which are involved are taken into account by considering the MAMCA framework as an approach for the Multi-Criteria Decision-Making study, in which BWM is considered for determining the optimal criteria weights for each stakeholder. While the use of MAMCA allows the inclusion of multiple stakeholders and their objectives, BWM allows to consider specific criteria sets for each stakeholder by means of the multi-optimality properties of the non-linear weight determination model. The multi-optimal weight intervals stemming from the different stakeholder-specific criteria sets are eventually used to calculate utility intervals, which are subsequently aggregated into final utility scores using a min - max model. Based on the study results, it has been demonstrated that the use of BWM within the MAMCA framework and the subsequent utility aggregation procedure is a successful method for determining an alternative's relative desirability based on equally taking into account all stakeholders' preferences. The conclusions based on these results are discussed in the next section. Next to that, the remainder of this chapter involves discussing the important assumptions, methods and inputs of the research that led to the results of the study. Practical implications and recommendations fur further research are also presented. Lastly, a reflection on the research process leading to the final outcomes is given.

5.1. Conclusions

The research is concluded by means of providing answers to the research question and sub-questions as introduced in Section 1.4. The following main research question was introduced:

"How can a shipping line select a location for setting up an own inland terminal in order to increase its control on the container port hinterland?"

Multiple sub-questions were developed in order to structurally and efficiently answer the research question. Therefore, first of all, these sub-questions are answered one by one. Eventually, this section is concluded by answering the main research question based on the answers to the sub-questions. The sub-questions are answered as follows:

1. *What is the structure of the contemporary container port hinterland?*

   The first step of the research involved defining the research system and the contextual setting in which this system exists. As the aim of this study is to find a location for a new inland terminal for the shipping line, the research system is defined as the *inland terminal location.* This location is positioned in the hinterland of the container seaports which (potentially) have services to/from the inland terminal. Therefore, the structure of the container port hinterland was assessed in order to gain insight in the components, activities and actors occurring in it, which influence/are influenced by the (presence of an) inland terminal. The structure of the container port hinterland was assessed by means of the four-layer model, consisting of the following interrelated layers:

- *Logistical layer*, involved with the organization and management of inland transport chains;
- *Transport layer*, involved with the transport and transshipment operations;
- *Infrastructural layer*, involved with the (provision of) transport and transshipment infrastructure;
- *Locational layer*, involved with the geographical locations of the infrastructure in the container port hinterland.

2. *How do shipping lines exercise control over the container port hinterland?*

   Since the aim of this research is to select a location for an inland terminal in order to specifically increase the shipping line's control on the container port hinterland, insight is gained in the activities and responsibilities of these shipping lines within the hinterland. The shipping line's ambition to increase its control in the hinterland is a relatively recent development. Initially, shipping lines were merely involved with ocean transport of containers between ports across the world, which is offered as *port-to-port services*. Inland transport was managed by third parties, meaning that the control of the shipping line on the total container transport chain was limited to only the maritime leg. Although maritime transport is still their core business, shipping lines have been increasingly providing *door-to-door services* in the last decades, which encompass not only the maritime transport legs but also the inland transport legs. By means of *vertical integration* the maritime and inland transport chains can be integrated with each other, which increases the control and market share of a shipping line in global and regional container transport/logistics markets. It also means that the shipping line is now concerned with the design and management of the inland transport chains as well. The shipping lines aim to increase *Carrier Haulage* transport set-ups, in which these door-to-door services are offered[1]. Whereas maritime transport is organized as well as actually executed by the shipping line itself (by using its own vessels), the inland transport chain is only designed by the shipping line and the actual transport and transshipment operations are outsourced to vendors such as transport and inland terminal operators. Therefore, to result in an effective organization of the inland transport chain, the design of the inland services may take into account the operations and perspectives from the multiple actors involved.

3. *How are inland terminals part of inland transport chains?*

   Inland transport can roughly be divided in *direct trucking* and *intermodal transport*. This study is focused on intermodal transport, which is composed of a main haulage leg (by means of intermodal vehicle) and a pre-/-end haulage leg (by means of truck), with transshipment operations in between taking place at an inland terminal. In this sense, the characteristics of the inland terminals influence the whole inland transport chain, since they determine a.o. the (amounts of) vehicles eligible to be served at the terminal, the lengths of the main- and pre-/end-haulage legs, the subsequent transport and transshipment costs, etc.. The (cost-)efficiency of the whole inland transport chain is therefore for a large part dependent on the inland terminal properties. Therefore, decision-making with regards to the design of the inland transport chain, taking place in the *logistical layer* of the container port hinterland, is for a substantial amount affected

[1] On the contrary, currently more common is the *Merchant Haulage* set-up, which is the more traditional form in which only the maritime leg is controlled by the shipping line whereas the inland leg is controlled by third parties such as freight forwarders

by these properties, which occur in the *transport*, *infrastructural* and *locational* layer, as follows:

- *Transport layer:* The proposed effectiveness of an inland terminal in a particular inland transport chain is dependent on the services it offers, which could range from *basic logistics services* (e.g. consolidation/deconsolidation and transloading) to *Value-Added Services (VAS)* (e.g. product and package transformations).
- *Infrastructural layer:* The terminal infrastructure determines which kinds of services can be offered at the facility, and in which quantities. It also determines which kinds of and how many (intermodal) vehicles can be served at the terminal.
- *Locational layer:* The location of the inland terminal determines the distances between the terminal and the seaport and customer locations. This in turn affects the transport times and costs for the main haulage and pre-/end-haulage legs respectively.

4. *Which and how are the relevant actors linked to the inland terminal related activities within the inland transport chains?*

Based on examining the structure of the container port hinterland and the (organization of the) inland transport chains within this structure, relevant actors involved with the inland terminal location problem are pinpointed. These actors are presented according to the container port hinterland layer structure and based on their key activities within these layers, as shown in Table 5.1.

Layer	Key activity	Key actor
Logistical	Organize inland transport chains	Shipping line
Transport	Transport containers	Intermodal transport operator Truck transport operator
	Transship containers	Inland terminal operator
Infrastructural	Provide transshipment infrastructure	Inland terminal operator
Locational	Select infrastructure location	Shipping line, inland terminal operator

Table 5.1: Overview of key actors relevant to inland terminal location selection within the inland transport chain

Within the logistical layer, the **shipping lines** take responsibility of the organization of the inland transport chains which they offer to their customers. These transport chains thus need to satisfy the various needs of these customers (e.g. acceptable transport times, acceptable transport costs, value-added services, etc.). To achieve this, the shipping line is first of all reliant on the operations performed by the intermodal and truck transport operators. These transport operators are the **terminal users**. Next to that, the shipping line relies on the inland **terminal operators** providing the inland terminal infrastructure and equipment as well as the transshipment operations performed at the facilities. These key actors have particular objectives with regards to the evaluation and selection of an inland terminal location within the inland transport chain, which can be configured as follows:

- The actual decision-making actors with regards to the location selection of the inland terminal are the **shipping line** and the inland **terminal operator**.
  - The shipping line evaluates an inland terminal location and makes the decision to select it based on the objective to *incorporate the terminal in the designed inland transport chain.*
  - The terminal operator evaluates an inland terminal location and makes the decision to select it based on the objective to *ensure profitability of transshipment operations at the site.*

- The transport operators, i.e. the **terminal users**, are not actually involved in the decision made on the location of the terminal. However, since they are affected by the inland terminal location, they evaluate it based on the objective to *use the inland terminal to optimize the transport operation scheme*. This evaluation is important for eventually selecting a location beneficial to these transport operations, thus ultimately beneficial to the designed inland transport chain.

5. *What factors are involved in evaluating an inland terminal location within the inland transport chain?*

   The evaluation and selection of a location for an inland terminal involves multiple factors. According to the structure of the container port hinterland in which this inland terminal is (supposed to be) located, factors can stem from the *logistical*, *transport*, *infrastructural* and/or *locational* layer. Therefore, the same structure is applied for categorizing factors that are determined to be (potentially) relevant to this specific inland terminal location selection study. The first step in determining relevant factors was by reviewing criteria used in the literature on finding locations for inland terminals. By means of prioritization, the relevant criteria observed in the literature were gathered. Eventually, the literature review resulted in an extensive collection of relevant criteria proposed in comparable academic studies. Since different types of actors are involved in this inland terminal location selection study, factors deemed relevant specifically to these actors are assumed to vary between the specific actor types. Therefore, a list of relevant decision criteria was composed for each actor type by letting them select from the initially collected criteria and add missing factors through a survey. The final decision criteria for each actor are given in Table 5.2.

Shipping line	**Terminal operator**
Inland terminal CAPEX	*Anchor customer proximity*
Intermodal market profitability	*Enabling modality shift*
Total inland transport costs	*Inland terminal CAPEX*
Governmental policy	*Market volume potential*
Market proximity	*Regional economic development*
Market volume potential	*Regional transport/logistics competition*
Regional transport/logistics competition	*Total inland transport costs*
Expansion possibilities	*Transport infrastructure network in area*
Local depot capacity	
Transport infrastructure network in area	
Rail transport operator	**Truck transport operator**
Expansion possibilities	*Expansion possibilities*
Inland terminal CAPEX	*Intermodal market profitability*
Market proximity	*Land use near location*
Market volume potential	*Market proximity*
Transport infrastructure network in area	*Market volume potential*
	Regional transport/logistics competition
	Terminal market profitability
	Total inland transport costs
	Transport infrastructure network in area

Table 5.2: Criteria to be taken into account in the study based on the criteria selection survey results

6. *How are these factors with regards to inland terminal location evaluation assessed by the different actors involved in the inland transport chain?*

   Since criteria used in a certain exercise are generally not perceived as equally important by decision makers, the Best-Worst Method was used to calculate the weights of the factors indicated by the respective actors. The following key findings were made:

- The factor generally perceived as most important by the **shipping line** actors is *Intermodal market profitability*. The overall relatively high evaluation for this factor makes sense with respect to the inland terminal location selection study as being initiated by the shipping line itself, since it is this stakeholder's aim to set-up an inland terminal in order to increase its profits made in the intermodal market. Next to that, there is an overall relatively high importance assigned to the *transport infrastructure network in the area* and to the local *market volume potential*. The latter factor is especially crucial to the decision-making process of the shipping line with regards to inland terminal location selection, since the *market volume potential* is not only potentially beneficial to the inland terminal business itself, but also to the local transport service arrangements which could be offered in a Carrier Haulage set-up by the shipping line to the (potential) customers generating these container volumes. The factor generally perceived as least important is *Governmental policy*. An important reason for this could be the fact that local policies with regards to transport and logistics activities in an area are generally examined in later stages of business development projects, in contrast to most of the other factors assessed (which could be considered to be more *essentially*).
- The factor generally perceived to be most important by the **rail transport operators** (which represent the earlier mentioned **intermodal transport operators**) is *Market volume potential*. This is in line with expectations, as an area's potentially generated container volumes imply transport (and thus business) possibilities for the intermodal transport operators. Another important factor is the local *transport infrastructure network*. Obviously, it is clear that the efficiency of the operations performed by the rail transport operators to/from/in a certain area depend on the infrastructure that they make use of. The factor considered to be least important is *Market proximity*. This can be explained by the fact that the rail transport operators just perform the main haulage transport operations between the seaports and the inland terminals, on which the distances between the inland terminals and the shippers/consignees generally have no influence. However, as *market proximity* does impact the generation/attraction of container transport business opportunities, it is still to some extent important to the rail transport operators.

  The factor generally perceived to be most important by the **truck transport operator** is also *Market volume potential*, likely with the same reasoning as for the rail transport operator. However, in contrast to the other terminal user actor, *Market proximity* is perceived as the second most important factor by the truck transport operator. This can be explained by the fact that the costs for truck transport are more sensitive to distance, which results in a higher importance assigned to the proximity of customers for the operations of this actor. Interesting is the high evaluation of the truck transport operator for criterion *Intermodal market profitability*, since they do not directly gain profits from offering complete intermodal transport services (which are offered by the transport chain designers such as the shipping line). However, the high evaluation could be explained by the fact that a more profitable area in terms of intermodal transport attracts business and generates business needs which could be responded to by the truck transport operators (e.g. increased needs for pre-/end-haulage transport). Poorly evaluated criteria include *Land use near location* and *Expansion possibilities*, which makes sense since the truck transport operators are not directly affected by these factors. On the contrary, the also poorly evaluated criterion of *Transport infrastructure network in area* raises interest, since truck transport operators are assumed to be highly dependent on this infrastructure for their own operations/business. However, it could be argued that the infrastructure needed for truck transport is relatively basic (i.e. roads) and apparent in most areas in which container transport demanding customers are already situated. Therefore, it is assumed that most of the times the truck transport operators do not take into account situations in which this infrastructure is not apparent, which results in a relatively low perception of the importance of the criterion.

- The factor generally perceived to be most important by the **terminal operators** is *Anchor customer proximity*. Interesting is the fact that this criterion is specifically important to the terminal operators, since neither shipping line nor terminal user respondents indicated this factor. The high evaluation for this criterion can be explained by the fact that setting-up and operating an inland terminal is highly *capital intensive*, resulting in a considerable need for reducing the risk of missing/losing business. By having anchor customers in the area, a substantial amount of volumes to be handled is ensured. Similar reasoning can be applied to the second highest evaluated criterion *Market volume potential*; more volumes generated in/attracted to the area means more (potential) transshipment business. Interesting is the fact that *Transport infrastructure network in area* is scored fairly low, which implies that the accessibility of the area around the inland terminal weighs little in evaluating the terminal location. Also interesting is the overall lowest evaluated *Enabling modality shift* factor, since this criterion was actually introduced by one of the terminal operator respondents. It could be argued that enabling a shift in modality is dependent on the effectiveness of the inland terminal within the inland transport chain, resulting in increased attractiveness of intermodal transport instead of direct trucking. However, the effectiveness of the inland terminal is initially dependent on other (i.e. *more important*) factors such as the *Anchor customer proximity* and *Market volume potential*. Therefore, *Enabling modality shift* could be considered as a less essential factor. Lastly, an interesting finding is the overall low score of *Inland terminal CAPEX*. The relative importance of the other factors compared to the investment costs implies the relatively high value of sufficient (local) market conditions for the inland terminal to be successful. In other words, as long as the transshipment operations in the area are sufficiently profitable to the inland terminal operator, the costs of setting up the facility are less important.

7. *How can the differently assessed factors be used to select a location for a shipping line's own inland terminal within the container port hinterland?*

The inland terminal location selection study first of all required the determination of alternative locations to choose from. A total of six alternative locations in the case study region were taken into account in this study; two alternatives in the A area; two alternatives in the B area; and two alternatives in the C area. Data on the factors determined by means of the literature review and the inputs of the surveyed experts were then gathered for each alternative. The factors' corresponding normalized data scores were then multiplied with the calculated criteria weights according to the Multi-Criteria Decision-Making methodology. Since criteria weight *intervals* were used, the multiplication operations resulted in *utility intervals* from each actor for each alternative location. Since these utility intervals are composed of utility scores based on the evaluations of the actor type-specific (amounts of) criteria, the utility intervals could not straightforwardly be compared or combined. Therefore, min - max aggregation of the utility scores was applied. Accordingly, the resulting aggregate utility scores for each alternative are considered to take into account each actor's assigned utility in an equal manner by equally representing the individual preferences.

The utility aggregation operation showed that A1 is ranked as the best scoring alternative. This location gains most of its utility from the high container volume potentials in the area of A, which cause for high scores for the already highly weighted criteria of *Market volume potential* and *Anchor customer proximity*. It also gains a substantial part of its utility from the *Expansion possibilities* present around the location. A2, which is ranked second best, also gains a high amount of utility from the local container volume potentials in the area of A. However, since it has no expansion possibilities around its location, it ends up with an aggregate utility which is about 21% lower than the one of its A counterpart. The scores of ranks three and four for C2 and C1 respectively lie close to A2 and to each other, whereas the utility scores for the two B locations end up considerably lower and thus least in ranks. This implies the fact that A1 clearly is an optimal location based on the model inputs and the alternatives set, predominantly because it scores high on overall highly evaluated factors related to local container volume potentials.

Sensitivity analyses were performed to assess the influence of critical model inputs. First of all, the influences of the actual decision-makers involved in the inland terminal location selection process were tested. As the initial model involved all actors equally weighted, the initial model outcomes (called Scenario 0) are based on all involved actors' preferences equally taken into account. Therefore, this first sensitivity analysis scenario involved taking into account just the *actual* decision-making actors involved in the inland terminal location selection process, i.e. the shipping line and terminal operator actors. A stepwise procedure was applied by making use of sub-scenarios:

- In the first sub-scenario, the terminal user actors were eliminated from the MCDM model, leaving the combination of the shipping line and terminal operator actors as decision-makers. The model outcomes showed aggregate utility scores and a ranking which were nearly the same as in in the initial Scenario 0. This implies that the combined preferences of all actors involved are not much influenced by the preferences resulting from the evaluations of the terminal user actors, since excluding these evaluations results in nearly the same aggregate utilities and consequent ranks for the alternatives.
- In the second sub-scenario, the terminal user and the terminal operator actors were eliminated from the MCDM model, leaving only the shipping line actors as decision-makers. The model outcomes showed increased aggregate utility scores for the B and C alternatives, whereas decreased aggregate utility scores for the A alternatives. This ultimately resulted in C1 and C2 ranking first and second respectively, followed by A1 and A2. These results imply that the C locations have relatively better characteristics which are evaluated highly by the shipping line actors, which is mostly applicable to *Intermodal market profitability* and *Transport infrastructure network in area.*
- In the third sub-scenario, the terminal user and shipping line actors were eliminated from the MCDM model, leaving only the terminal operator actors as decision-makers. The model outcomes showed a considerably high preference for both A alternatives, compared to a considerably low preference for the B and C alternatives. A1 was still ranked first, however followed closely by A2. The significantly higher preferences for the A alternatives can mostly be dedicated to the container volume potential (related) factors in the A area, which are substantially larger than in the other areas. Since these volume related factors are evaluated highly by the terminal operator actors, the utility scores for the A alternatives end up high as well.

A second sensitivity analysis involved assessing the hypothetical situation of a sudden container volume potential influx in a certain area. This scenario was considered because of the criticality of container volume related factors for the final outcomes of the initial model as well as because of the considerable possibility of market fluctuations. Since the container volume related characteristics of the B and C areas are lowest, testing the influences of these factors is applied by increasing them for these particular alternatives. Therefore, two sub-scenarios were considered:

- The first sub-scenario involved gradually increasing the container volume related criteria of the B alternatives. The model outcomes showed that for B2 an additional amount of 25.000 FEU p.a. is necessary to be ranked first, whereas for B1 an additional amount of over 25.000 FEU p.a. is needed to surpass formerly first ranked

A1. Interestingly, the total container volume potential of B2 including 25.000 extra FEU p.a. would be similar to the total potential of A1, implying the fact that B1 scores better on the non-container volume related characteristics (and would be more desirable if the container volume potentials of the A area would not be distinctively high compared to the other areas).

- The second sub-scenario involved gradually increasing the container volume related criteria of the C alternatives. For C2 to be ranked first, only 10.000 extra FEU p.a. would be needed, whereas for C1 slightly more than 10.000 extra FEU p.a. is needed to surpass formerly first ranked A1. Most interesting is the fact that for C1 and C2 to end up highest in ranks, the total container volume potential of the C area is considerably lower than the total potential of the A area in Scenario 0. This indicates that of all alternatives, the C locations have particularly high scoring non-container volume related characteristics. They would thus be considerably good options compared to the A locations under relatively slightly improved market conditions.

Subsequent to answering the sub-questions, the main research question -*"How can a shipping line select a location for setting up an own inland terminal in order to increase its control on the container port hinterland?"*- is answered. As the inland terminal can be incorporated in the inland services designed by the shipping line, it facilitates increasing the (cost-)efficiency of the broader inland transport chain. A (cost-)efficient inland transport chain supports the ability of the shipping line to successfully offer Carrier Haulage services to its customers and consequently increase its control on the container port hinterland. Therefore, selecting the location of the inland terminal is viewed from the perspective of the inland transport chain within the structure of the container port hinterland. Based on the contents of this structure, the decision-making process with regards to the inland terminal location selection should take into account the individual objectives of the shipping lines themselves, next to those of terminal operator and terminal user (i.e. transport operators) stakeholders.

As the objectives of these stakeholders vary, the factors deemed relevant for inland terminal location evaluation to each stakeholder involved differ as well. Overall, factors related to a location's container volume potential (e.g. the location's overall *market volume potential*) are evaluated highly by the majority of actors in the inland transport chain. In that regard, a location suitable to most of the stakeholders involved, thus most likely to contribute to the inland transport chain and the shipping line's control on the hinterland, is near a certain amount of (potential) customers' locations at/to which substantial container volumes are generated/attracted. Next to that, it should be noted that preferences for certain factors by particular decision-makers also influence the overall desirability of an inland terminal location, such as *intermodal market profitability* for shipping line actors and *anchor customer proximity* for the terminal operators. As a consequence, whereas the shipping line actors' preferences would lead to a most desirable location scoring higher on its intermodal market margins characteristics, the terminal operator actors' preferences would lead to a most desirable location scoring higher on its market volume potentials and related (possible) anchor customers located in the area. Therefore, it is important to be able to clearly indicate the importance of the final decision-maker in the inland terminal location selection process, since this can essentially determine the final study outcomes.

5.2. Discussion and recommendations

This section involves the discussion of important assumptions, methods and inputs of the research that led to the results of the study. Practical recommendations with regards to business implementations are given. Furthermore, the results, implications and research limitations lead to recommendations for further studies. Lastly, a reflection on the research process leading to the final outcomes is given.

A fundamental element of this research is concerned with the criteria used in the inland terminal location decision making process. As these are crucial to the study process and results, implications of the choices and assumptions made with regards to criteria are worth mentioning. To begin with, the determination of decision criteria is performed by letting relevant experts from the stakeholder types considered in this study evaluate a list of factors gathered through literature review. Eventually, a list of decision criteria is composed for each stakeholder *type*, which is based on the stakeholder type experts' survey indications. This means that, although there is a certain amount of consistency between the responses of each expert from the same stakeholder type, some expert indications have been left out of further examination in the study due to the practical reasons of limiting the amount of different decision criteria sets as well as limiting the amount of criteria within each decision criteria set. However, it could be argued that if each expert's survey indications would have been totally included in the further analyses regardless of the survey indications of the other experts from the same stakeholder type, the resulting aggregate utilities would represent each different actor's preferences in the MCDM model better. For further research on applying the preferences of actor-specific criteria for multiple different stakeholders in an MCDM model, it is therefore advised to have clearly indicated if it is more desirable to examine certain actor-*types* or the individual actors separately.

Another point worth noting with respect to the determination of decision criteria is the fact that some vendor companies of which experts are questioned actually offer both transport and terminal operations (either as an integrated service or separately). Although the surveyed experts from the companies have specific functions related to the either transport or transshipment operations, they might have filled in the survey from the perspective of the company providing both services instead of only from the perspective of the relevant service. This might for example have led to the truck transport operator respondent indicating *Terminal market profitability* as important, which is quite unexpected since actual truck transport operations do not directly profit from transshipment operations.

Further questioning with regards to the decision criteria can also be aimed at the clustering of the shipping line decision criteria. Although the clusters are based on the container port hinterland structure and verified by means of additional literature, it could have resulted in the final weights of the shipping line actor criteria being different than if no clustering had to be applied. While the clustering is scientifically backed by the use of literature, it might not have seem as straightforward to the actual survey respondents. This leads to the fact that the main clusters are not scored most accurately, which in turn affects the local scores of the actual decision criteria. For example, they score a certain cluster as very important because it contains two relatively important sub-criteria. On the other hand, they score another cluster as less important because it contains only one relatively important criteria. In the end, although all these sub-criteria might *in reality* be perceived as equally important, the first two might end up with higher final scores than the latter one. In other words, when no or other clusters would have been applied, the (final) scores of the actual shipping line decision criteria might have been different.

A final note on the factors applied and analyzed in this study is with regards to the definition of *benefit* and *cost* criteria. Although most of the times it is rather obvious if a factor belongs to either one of the two, for some criteria this determination is not as apparent. For example, criterion *Regional transport/logistics competition* is considered to be a negative aspect of a certain area in this study, thus it is defined as a cost criterion. However, it could also be argued that more transport/logistics companies in a certain area allow for more cooperations and partnerships, which would contribute to the attractiveness of the location with regards to inland terminal investment. The certain determination of criteria being either costly or beneficial could have impacts on the eventual utility for an alternative.

With regards to the data, a point of discussion is the operationalization of decision criteria into measurable units. One problem encountered in the study was the lack of sufficient data for some of the relevant criteria. The most striking example is criterion *Governmental policy*. Due to the lack of reliable sources on local governmental attitudes towards inland terminal developments, operationalization of this rather qualitative factor has been simplified to certain quantitative indicators representing if local governments are or are not willing to (administrationally) support inland terminal development. This simplification as well as sources for potential support are however questionable. Furthermore, as most factors included in this research can be interpreted in multiple ways, operationalization is influenced by this particular interpretation. To make factors measurable, assumptions had to be made in order to scope the operationalization and the measuring units as well as the eventual data score. An example is the operationalization of criterion *Transport infrastructure network in area*, which is measured in this study as the *total length of Autobahn, Bundesstraße and railway infrastructure within an area of 100 square kilometers around the alternative location*. Although the specific area measure is based on common catchment area figures from literature, the inclusion of only highways, regional roads and railways could be considered as arbitrary in terms of pointing out accessibility indicators. For instance, other types of roads (e.g. *Landesstraße* infrastructure) could have been included as well, which would have changed the ultimate data scores of the factors for the alternatives. Next to that, as a measuring unit, the total lengths of all types of infrastructure are taken equally after which they are summed, resulting in the infrastructure density indicator. It could be argued that the different types of hierarchies and modalities making use of the infrastructure should not be considered equally, which would also lead to different ultimate data scores.

5.2.1. Practical implications

As the goal of this research is to select a location for an inland terminal within the inland transport chain organization of the shipping line, insight in the factors and factor-evaluations of several relevant stakeholders is gained through the study results. First of all, it is clear that the most important factors to base the inland terminal location selection choice upon are related to an area's container volume potentials, which is in turn associated with the local container volume generating/attracting customers of the shipping line. Therefore, the shipping line setting-up a new inland terminal at a certain location should be in close touch with the (potential) customers in this area, in order to have a certain amount of container flows ensured for the new inland facility. Close cooperation with *anchor customers* ensuring the provision of substantial and continuous volumes is believed to be especially advantageous with regards to setting up the inland terminal. This will eventually benefit the profitability of both the inland terminal operations at the particular location and the inland transport chain as a whole. It is further advised to pay attention to the expansion possibilities of possible greenfield locations, since it is shown that alternative locations with no/limited expansion possibilities had considerably less utility scores because of this deficit. Sufficient room for (physical) expansion provides increased possibilities for (mostly uncertain) future developments within the local container transport and transshipment market.

Overall, it can be concluded that most weights from different stakeholders put on specifically relevant criteria eventually lead to comparable results in terms of preferability. This indicates the notion that, although business models and objectives from the different actors might vary, an increasingly (cost-)efficient inland transport chain ultimately benefits all stakeholders involved. With regards to the specific alternatives examined in this research, the most preferred inland terminal location would be A1. Based on the expert insights from the relevant actors involved as well as the data as input for the MCDM model, A1 is most desirable since it has the most optimally balanced characteristics, especially in terms of local market conditions and expansion possibilities.

5.2.2. Future research

As this is one of the first MCDM studies in which the alternatives' final utilities are composed of aggregated separate utility scores assigned based on actor-specific criteria evaluations, further research lies in extending the properties and applications of this utility aggregation methodology. As mentioned earlier, it would for example be interesting to look into the differences of calculating aggregate utilities based on actor-*types* (as has been done in this study) compared to aggregate utilities based on individual actors, regardless of a proposed group they belong to. To further test the applicability and practicality of utility aggregation, it could be applied in other (real-life) multi-actor MCDM problems tackled commonly with MCDM modelling. In addition to this, it is suggested to be able to make use of robust data sets to ensure reliable resulting utilities.

Furthermore, besides studies on the specific methodologies applied, further research can be conducted on the inland terminals itself and on the terminals within the container port hinterland in general. First of all, in reality there might be more actors involved in inland terminals than the key actors considered in this study. An example is the governmental actor, which is left out in this study. However, since they (can) also take part in the development of terminal infrastructure in the areas under their legislation, it would be interesting to assess their preferences on relevant criteria and resulting utility contributions as well. In a broader sense, more research can be done on the shipping line's vertical integration into the container port hinterland, which is an increasingly interesting development. Before, when shipping lines did not provide door-to-door services, the inland transport services were fully managed by third parties such as freight forwarders, making them *customers* of the shipping lines. However, due to the developments as described in this research, shipping lines actively operating in the container port hinterlands are becoming *competitors* of their former customers. With regards to research on inland terminals and their locations, it would thus be interesting to acquire more insights in the changing dynamics between the shipping lines and their customer-competitors, especially since implications of these changing dynamics could also influence the suitability of inland terminals located in certain inland transport chains.

5.3. Reflection

The initial goal of this research, finding a location for an inland terminal for the shipping line, has led to the complete study as presented in this report. As the goals from the business side were clear, the approaches to reach these goals were anything but. This section involves a reflection on the important steps taken from the start of the research until the presumed achievement of the research objectives.

Reflection on problem definition

The first step in the research was defining the exact problem and the underlying reasons for the problem. Obviously, these were partly already known to the company. However, a definition of the exact requirements of the proposed inland terminal for the shipping line, and thus for the terminal location, was not clear from the beginning. Therefore, the initial steps of the research were involved with defining the inland terminal location problem from the perspective of the shipping line, a point of view which is not very common in the contemporary literature on inland terminal location selection. By means of the four-layer model as adapted in the system development part of this research, the position of the inland terminal within the shipping line's inland transport chain could be clarified. This helped in defining the relevant stakeholders, objectives and possible methodologies to encounter the problem.

Reflection on literature review

The problem definition and the identified complexity due to the varying stakeholders and objectives involved lead to looking into literature on MCDM. The body of reviewed literature provided multiple comparable inland terminal location selection studies which were executed by making use of MCDM techniques. First of all, this gave insight in the various factors taken into account in the different studies, which vary considerably based on the included study settings and stakeholders. Secondly, this provided knowledge on the possible methodologies. The observations led to identifying a research gap based on the fact that most studies apply fixed criteria sets for the different stakeholders involved in the MCDM study. The conclusion was made to specifically consider actor-specific criteria sets in order to take into account the most relevant preferences of all stakeholders. Therefore, literature on the MAMCA methodology was further examined, which provided a useful basis for the methodology framework used in this study. Next to that, by including BWM in the MAMCA framework, the possibilities to successfully involve the stakeholder preferences coming from the actor-specific criteria sets were enlarged based on the multi-optimality properties as provided by the non-linear BWM model.

Reflection on methodology

As mentioned previously, the research methodology was largely built on the principles of the MAMCA framework, although adapted to fit with the particular inland terminal location selection problem for the shipping line. Due to this, not all elements regarded as essential in the MAMCA framework were included completely. For example, whereas an extensive stakeholder analysis is an important part of the original MAMCA framework, it was chosen to let this only be a minor part of the study methodology. This choice was made mostly due to time limitations and a lack of sufficient access to all relevant stakeholders involved in the inland terminal location selection process. Therefore, the stakeholders included in this research might have more passive roles with regards to the study outcomes rather than being actively involved. Next to that, because of the same reasons concerned with time and accessibility, surveys were used to determine final decision criteria and preference statements. Although this was time-efficient, using surveys might not result in entirely the same answers as questioning respondents in a more interactive way (e.g. by means of personal conversations). For example, survey questions as well as the topics being surveyed about might be misunderstood, or surveys might be filled out in a hurry leading to inaccurate statements. On the other hand, on a more theoretical level, the applied BWM methodology to determine the criteria weights as well as the use of utility aggregation to calculate final utility scores was a way to extract the stakeholders' preferences in an efficient way. In that sense, individual preferences have been taken into account as much as possible.

Reflection on study outcomes

The weights calculated based on the respondents' preference statements overall lead to logical figures. Not all findings were exactly in line with the observations from the literature review, but it might be argued that a possible reason for this is the fact that location selection problems such as these are rather geographically specific and reliant on the particular experts and their backgrounds involved in the process, which might differ per case study. The final utility scores (partially) based on these weights are in line with initial expectation: high utilities for the locations with relatively large amounts of container volume potentials and lower scores for locations with less market potential. The sensitivity analyses provided valuable insights in changing dynamics within the process. With regards to the initial problem and goal of the case shipping line, relevant recommendations could be made based on these study outcomes. Next to that, the study results have shown that using BWM to determine weight intervals and utility aggregation to determine the final utility scores is an effective way of incorporating stakeholders' preferences based on relevant specific criteria. In that regard, the study contributes to the literature as well as to the particular business needs.

Bibliography

Acciaro, M. and A. McKinnon, 2015. Efficient hinterland transport infrastructure and services for large container ports. *in Port Investment and Container Shipping Markets, OECD Publishing, Paris*.

Ahmadi, H. B., S. Kusi-Sarpong, and J. Rezaei, 2017. Assessing the social sustainability of supply chains using Best Worst Method. *Resources, Conservation and Recycling*, 126: 99–106.

Alireza, S. and S. Alagheband, 2011. 5-logistics parties. *Logistics Operations and Management*, pages 71–91.

Alumur, S. and B. Y. Kara, 2008. Network hub location problems: The state of the art. *European journal of operational research*, 190(1):1–21.

Ambrosino, D. and A. Sciomachen, 2014. Location of mid-range dry ports in multimodal logistic networks. *Procedia-Social and Behavioral Sciences*, 108:118–128.

APM Terminals, 2020. Inland services Romania, *https://www.apmterminals.com/en/romania*, retrieved on 15-01-2020.

Arnold, P., D. Peeters, and I. Thomas, 2004. Modelling a rail/road intermodal transportation system. *Transportation Research Part E: Logistics and Transportation Review*, 40(3):255–270.

Atieno, O. P., 2009. An analysis of the strengths and limitation of qualitative and quantitative research paradigms. *Problems of Education in the 21st Century*, 13(1):13–38.

Bergqvist, R. and J. Monios, 2014. The role of contracts in achieving effective governance of intermodal terminals. *World Review of Intermodal Transportation Research*, 5(1):18–38.

Brans, J.-P., P. Vincke, and B. Mareschal, 1986. How to select and how to rank projects: The PROMETHEE method. *European journal of operational research*, 24(2):228–238.

Brunelli, M. and J. Rezaei, 2019. A multiplicative best–worst method for multi-criteria decision making. *Operations Research Letters*, 47(1):12–15.

Calik, H., M. Labbé, and H. Yaman, 2015. p-center problems. In *Location Science*, pages 79–92. Springer.

Caris, A., C. Macharis, and G. K. Janssens, 2012. Corridor network design in hinterland transportation systems. *Flexible Services and Manufacturing Journal*, 24(3):294–319.

Çelen, A., 2014. Comparative analysis of normalization procedures in TOPSIS method: with an application to Turkish deposit banking market. *Informatica*, 25(2):185–208.

Daskin, M. S. and K. L. Maass, 2015. The p-median problem. In *Location science*, pages 21–45. Springer.

De Langen, P. W., J. C. Fransoo, and B. van Rooy, 2013. Business models and network design in hinterland transport. In *Handbook of Global Logistics*, pages 367–389. Springer.

De Langen, P. and A. Chouly, 2009. Strategies of terminal operating companies in changing environments. *International Journal of Logistics: Research and Applications*, 12(6):423–434.

de Villiers, G., 2015. Inland intermodal terminals and freight logistics hubs. *WIT Transactions on State-of-the-art in Science and Engineering*, 86:123–151.

Diaz, R., W. Talley, and M. Tulpule, 2011. Forecasting empty container volumes. *The Asian Journal of Shipping and Logistics*, 27(2):217–236.

Dobrota, M., D. Macura, and M. Šelmić, 2015. Multi criteria decision making for distribution center location selection-serbia case study. In *2nd Logistics International Conference*, pages 32–37.

Douma, A., 2008. *Aligning the operations of barges and terminals through distributed planning.* University of Twente, Enschede, Netherlands.

Ducruet, C. and T. Notteboom, 2012. Developing liner service networks in container shipping.

Farahani, R. Z. and N. Asgari, 2007. Combination of MCDM and covering techniques in a hierarchical model for facility location: A case study. *European Journal of Operational Research*, 176(3):1839–1858.

Farahani, R. Z., M. SteadieSeifi, and N. Asgari, 2010. Multiple criteria facility location problems: A survey. *Applied Mathematical Modelling*, 34(7):1689–1709.

Feng, C.-m. and H.-h. Huang, 2005. The economic evaluation of intercity intermodal logistics. *Journal of the Eastern Asia Society for Transportation Studies*, 6:2921–2936.

Fernández, E. and M. Landete, 2015. Fixed-charge facility location problems. In *Location science*, pages 47–77. Springer.

Franc, P. and M. Van der Horst, 2010. Understanding hinterland service integration by shipping lines and terminal operators: a theoretical and empirical analysis. *Journal of Transport Geography*, 18(4):557–566.

Frémont, A., 2009. Shipping lines and logistics. *Transport Reviews*, 29(4):537–554.

Garg, C. P. and A. Sharma, 2018. Sustainable outsourcing partner selection and evaluation using an integrated BWM-VIKOR framework. *Environment, Development and Sustainability*, pages 1–29.

Groenendijk, L., J. Rezaei, and G. Correia, 2018. Incorporating the travellers' experience value in assessing the quality of transit nodes: A Rotterdam case study. *Case Studies on Transport Policy*, 6(4):564–576.

Gupta, H. and M. K. Barua, 2018. A novel hybrid multi-criteria method for supplier selection among SMEs on the basis of innovation ability. *International Journal of Logistics Research and Applications*, 21(3):201–223.

Hafezalkotob, A., A. Hafezalkotob, H. Liao, and F. Herrera, 2019. Interval MULTIMOORA method integrating interval borda rule and interval best-worst-method-based weighting model: Case study on hybrid vehicle engine selection. *IEEE transactions on cybernetics.*

Ishfaq, R. and C. R. Sox, 2010. Intermodal logistics: The interplay of financial, operational and service issues. *Transportation Research Part E: Logistics and Transportation Review*, 46(6):926–949.

Ishfaq, R. and C. R. Sox, 2011. Hub location–allocation in intermodal logistic networks. *European Journal of Operational Research*, 210(2):213–230.

Jahan, A. and K. L. Edwards, 2015. A state-of-the-art survey on the influence of normalization techniques in ranking: Improving the materials selection process in engineering design. *Materials & Design (1980-2015)*, 65:335–342.

Jeong, S.-J., C.-G. Lee, and J. H. Bookbinder, 2007. The European freight railway system as a hub-and-spoke network. *Transportation Research Part A: Policy and Practice*, 41(6): 523–536.

Ka, B., 2011. Application of fuzzy AHP and ELECTRE to China dry port location selection. *The Asian Journal of Shipping and Logistics*, 27(2):331–353.

Karaşan, A. and C. Kahraman, 2019. A novel intuitionistic Fuzzy DEMATEL–ANP–TOPSIS integrated methodology for freight village location selection. *Journal of Intelligent & Fuzzy Systems*, (Preprint):1–18.

Kayikci, Y., 2010. A conceptual model for intermodal freight logistics centre location decisions. *Procedia-Social and Behavioral Sciences*, 2(3):6297–6311.

Keeney, R. L. and H. Raiffa, 1976. Decision analysis with multiple conflicting objectives. *Wiley& Sons, New York*.

Komchornrit, K., 2017. The selection of dry port location by a hybrid CFA-MACBETH-PROMETHEE method: A case study of southern Thailand. *The Asian Journal of Shipping and Logistics*, 33(3):141–153.

Lai, Y.-J., T.-Y. Liu, and C.-L. Hwang, 1994. Topsis for MODM. *European journal of operational research*, 76(3):486–500.

Laporte, G., S. Nickel, and F. S. da Gama, 2015. *Location science*, volume 528. Springer.

Li, F., X. Shi, and H. Hu, 2011. Location selection of dry port based on AP clustering-the case of southwest China. *Journal of System and Management Sciences Vol*, 1(5).

Liang, F., M. Brunelli, and J. Rezaei, 2019. Consistency Issues in the Best Worst Method: Measurements and Thresholds. *Omega*, page 102175.

Limbourg, S. and B. Jourquin, 2007. Rail-road terminal locations: aggregation errors and best potential locations on large networks. *European Journal of Transport and Infrastructure Research*, 7(4).

Limbourg, S. and B. Jourquin, 2009. Optimal rail-road container terminal locations on the European network. *Transportation Research Part E: Logistics and Transportation Review*, 45(4):551–563.

Limbourg, S. and B. Jourquin, 2010. Market area of intermodal rail-road container terminals embedded in a hub-and-spoke network. *Papers in Regional Science*, 89(1):135–154.

Long, S. and S. E. Grasman, 2012. A strategic decision model for evaluating inland freight hub locations. *Research in Transportation Business & Management*, 5:92–98.

Lv, R.-S. and C. Li, 2009. Analysis on location selection of dry ports based on ANP. In *2009 16th International Conference on Industrial Engineering and Engineering Management*, pages 638–641. IEEE.

Macharis, C. and B. Januarius, 2010. The Multi-Actor Multi-Criteria Analysis (MAMCA) for the evaluation of difficult transport projects: the case of the Oosterweel connection. *12th WCTR, July*, pages 11–15.

Macharis, C., 2005. The importance of stakeholder analysis in freight transport.

Macharis, C., A. Verbeke, and K. De Brucker, 2004. The strategic evaluation of new technologies through multicriteria analysis: the ADVISORS case. *Research in Transportation Economics*, 8:443–462.

Macharis, C., L. Turcksin, and K. Lebeau, 2012. Multi actor multi criteria analysis (MAMCA) as a tool to support sustainable decisions: State of use. *Decision Support Systems*, 54(1): 610–620.

Meers, D. and C. Macharis, 2014. Are additional intermodal terminals still desirable? an analysis for belgium. *European Journal of Transport and Infrastructure Research*, 14(2).

Mohammadi, M. and J. Rezaei, 2019. Bayesian best-worst method: A probabilistic group decision making model. *Omega*, page 102075.

Monios, J. and G. Wilmsmeier, 2012. Giving a direction to port regionalisation. *Transportation Research Part A: Policy and Practice*, 46(10):1551–1561.

Munda, G., 2002. Social multi-criteria evaluation (SMCE): methodological foundations and operational consecuences. Barcelona: Universitat Autónoma de Barcelona. 26 p. *Manuscript submitted to European Journal of Operational Research.*

Nguyen, L. C. and T. Notteboom, 2016. A multi-criteria approach to dry port location in developing economies with application to vietnam. *The Asian Journal of Shipping and Logistics*, 32(1):23–32.

Notteboom, T., 2011. An application of multi-criteria analysis to the location of a container hub port in south africa. *Maritime policy & management*, 38(1):51–79.

Notteboom, T. and J.-P. Rodrigue, 2017. Re-assessing port-hinterland relationships in the context of global commodity chains. In *Ports, cities, and global supply chains*, pages 67–82. Routledge.

Onstein, A. T., M. Ektesaby, J. Rezaei, L. A. Tavasszy, and D. A. van Damme, 2019. Importance of factors driving firms' decisions on spatial distribution structures. *International Journal of Logistics Research and Applications*, pages 1–20.

Opricovic, S. and G.-H. Tzeng, 2004. Compromise solution by MCDM methods: A comparative analysis of VIKOR and TOPSIS. *European journal of operational research*, 156(2): 445–455.

Özceylan, E., M. Erbaş, M. Tolon, M. Kabak, and T. Durğut, 2016. Evaluation of freight villages: A GIS-based multi-criteria decision analysis. *Computers in Industry*, 76:38–52.

Panayides, P. M. and R. Wiedmer, 2011. Strategic alliances in container liner shipping. *Research in Transportation Economics*, 32(1):25–38.

Patro, S. and K. K. Sahu, 2015. Normalization: A preprocessing stage. *http://arxiv.org/ftp/arxiv/papers/1503/1503.06462.pdf.*

Pekin, E., 2010. A GIS-based intermodal transport policy evaluation model. *PhD thesis, Vrije Universiteit Brussel, Brussels.*

Pekin, E., C. Macharis, D. Meers, and P. Rietveld, 2013. Location analysis model for belgian intermodal terminals: Importance of the value of time in the intermodal transport chain. *Computers in Industry*, 64(2):113–120.

Pramanik, S., S. Dalapati, and T. K. Roy, 2016. Logistics center location selection approach based on neutrosophic multi-criteria decision making. *New Trends in Neutrosophic Theories and Applications, Pons-Editions, Brussels*, pages 161–174.

Regmi, M. B. and S. Hanaoka, 2013. Location analysis of logistics centres in laos. *International Journal of Logistics Research and Applications*, 16(3):227–242.

Ren, J., 2018. Multi-criteria decision making for the prioritization of energy systems under uncertainties after life cycle sustainability assessment. *Sustainable Production and Consumption*, 16:45–57.

Rezaei, J., 2015. Best-worst multi-criteria decision-making method. *Omega*, 53:49–57.

Rezaei, J., 2016. Best-worst multi-criteria decision-making method: Some properties and a linear model. *Omega*, 64:126–130.

Rezaei, J., J. Wang, and L. Tavasszy, 2015. Linking supplier development to supplier segmentation using best worst method. *Expert Systems with Applications*, 42(23):9152–9164.

Rezaei, J., T. Nispeling, J. Sarkis, and L. Tavasszy, 2016. A supplier selection life cycle approach integrating traditional and environmental criteria using the best worst method. *Journal of Cleaner Production*, 135:577–588.

Rezaei, J., L. van Wulfften Palthe, L. Tavasszy, B. Wiegmans, and F. van der Laan, 2019. Port performance measurement in the context of port choice: an MCDA approach. *Management Decision*.

Rodrigue, J.-P. and T. Notteboom, 2009. The terminalization of supply chains: reassessing the role of terminals in port/hinterland logistical relationships. *Maritime Policy & Management*, 36(2):165–183.

Rodrigue, J.-P. and T. Notteboom, 2013. Containerized freight distribution in North America and Europe. In *Handbook of Global Logistics*, pages 219–246. Springer.

Rodrigue, J.-P., J. Debrie, A. Fremont, and E. Gouvernal, 2010. Functions and actors of inland ports: European and North American dynamics. *Journal of transport geography*, 18 (4):519–529.

Roso, V., N. Brnjac, and B. Abramovic, 2015. Inland intermodal terminals location criteria evaluation: the case of croatia. *Transportation journal*, 54(4):496–515.

Roy, B., 1990. The outranking approach and the foundations of electre methods. In *Readings in multiple criteria decision aid*, pages 155–183. Springer.

Rožić, T., D. Ogrizović, and M. Galić, 2016. Decision making background for the location of inland terminals. *Pomorstvo*, 30(2):141–150.

Saaty, T. L., 1990. How to make a decision: the analytic hierarchy process. *European journal of operational research*, 48(1):9–26.

Saaty, T. L., 2008. Decision making with the analytic hierarchy process. *International journal of services sciences*, 1(1):83–98.

Saaty, T. L., 2013. The modern science of multicriteria decision making and its practical applications: The AHP/ANP approach. *Operations Research*, 61(5):1101–1118.

Saaty, T. L., 1996. *Decision making with dependence and feedback: The analytic network process*, volume 4922. RWS Publ.

Simina, D., S. Patrick, C. Radu, et al., 2012. Economic benefits of developing intermodal transport in the european union. *Annals of Faculty of Economics*, 1(2):81–87.

Smeele, F., 2009. Bill of Lading Contracts Under European National Laws (Civil Law Approaches to Explaining the Legal Position of the Consignee Under Bills of Lading). *The evolving law and practice of voyage charterparties, Informa*, pages 251–280.

Song, D.-P. and J.-X. Dong, 2015. Empty container repositioning. In *Handbook of ocean container transport logistics*, pages 163–208. Springer.

Sörensen, K., C. Vanovermeire, and S. Busschaert, 2012. Efficient metaheuristics to solve the intermodal terminal location problem. *Computers & Operations Research*, 39(9):2079–2090.

Sun, H., Y. Zhang, Y. Wang, L. Li, and Y. Sheng, 2015. A social stakeholder support assessment of low-carbon transport policy based on multi-actor multi-criteria analysis: The case of Tianjin. *Transport Policy*, 41:103–116.

Theofanis, S. and M. Boile, 2009. Empty marine container logistics: facts, issues and management strategies. *GeoJournal*, 74(1):51.

Torabi, S. A., R. Giahi, and N. Sahebjamnia, 2016. An enhanced risk assessment framework for business continuity management systems. *Safety science*, 89:201–218.

Turcksin, L. and C. Macharis, 2009. Dedicated workshop for biofuel representatives in belgium on 4th of june 2009. *Vrije Universiteit Brussel*.

Turcksin, L., A. Bernardini, and C. Macharis, 2011. A combined ahp-promethee approach for selecting the most appropriate policy scenario to stimulate a clean vehicle fleet. *Procedia-Social and Behavioral Sciences*, 20:954–965.

Vafaei, N., R. A. Ribeiro, and L. M. Camarinha-Matos, 2016. Normalization techniques for multi-criteria decision making: analytical hierarchy process case study. In *doctoral conference on computing, electrical and industrial systems*, pages 261–269. Springer.

Vafaei, N., R. A. Ribeiro, and L. M. Camarinha-Matos, 2018a. Data normalisation techniques in decision making: case study with topsis method. *International Journal of Information and Decision Sciences*, 10(1):19–38.

Vafaei, N., R. A. Ribeiro, and L. M. Camarinha-Matos, 2018b. Selection of normalization technique for weighted average multi-criteria decision making. In *Doctoral Conference on Computing, Electrical and Industrial Systems*, pages 43–52. Springer.

Vafaei, N., R. A. Ribeiro, L. M. Camarinha-Matos, and L. R. Valera, 2019. Normalization techniques for collaborative networks. *Kybernetes*.

Van de Kaa, G., D. Scholten, J. Rezaei, and C. Milchram, 2017. The battle between battery and fuel cell powered electric vehicles: a BWM approach. *Energies*, 10(11):1707.

Van den Berg, R. and P. W. De Langen, 2015. Towards an ‘inland terminal centred’ value proposition. *Maritime Policy & Management*, 42(5):499–515.

Van Der Horst, M. R. and P. W. De Langen, 2008. Coordination in hinterland transport chains: a major challenge for the seaport community. *Maritime Economics & Logistics*, 10 (1-2):108–129.

Veenstra, A., R. Zuidwijk, and E. Van Asperen, 2012. The extended gate concept for container terminals: Expanding the notion of dry ports. *Maritime Economics & Logistics*, 14(1):14–32.

Wang, B., H. Xiong, and C. Jiang, 2014. A multicriteria decision making approach based on fuzzy theory and credibility mechanism for logistics center location selection. *The Scientific World Journal*, 2014.

Wei, J., A. Sun, and J. Zhuang, 2010. The selection of dry port location with the method of Fuzzy-ANP. In *Advances in Wireless Networks and Information Systems*, pages 265–273. Springer.

Weiner, E. and A. Brown, 1986. Stakeholder analysis for effective issues management. *Planning review*.

Wiegmans, B. and B. Behdani, 2018. A review and analysis of the investment in, and cost structure of, intermodal rail terminals. *Transport Reviews*, 38(1):33–51.

Wilmsmeier, G., J. Monios, and B. Lambert, 2011. The directional development of intermodal freight corridors in relation to inland terminals. *Journal of Transport Geography*, 19(6): 1379–1386.

Yıldırım, B. and E. Önder, 2014. Evaluating potential freight villages in istanbul using multi criteria decision making techniques. *Journal of Logistics Management*, 3(1):1–10.

Żak, J. and S. Węgliński, 2014. The selection of the logistics center location based on MCDM/A methodology. *Transportation Research Procedia*, 3:555–564.

Zavadskas, E. K., Z. Turskis, and S. Kildienė, 2014. State of art surveys of overviews on MCDM/MADM methods. *Technological and economic development of economy*, 20(1):165–179.

Zionts, S., 1979. MCDM—if not a roman numeral, then what? *Interfaces*, 9(4):94–101.

A

Factors observed in literature on inland terminal location selection

This Appendix contains the lists of factors relevant for inland terminal location selection, including their estimated (global) weight values as observed in the literature review. For each list, the factors are ordered hierarchically according to their importance derived from the respective weight factors. Furthermore, the involved decision-making experts, regions of application and used methods are indicated.

With regards to the eventual criteria determination survey used in this study, the gathered factors filtered from this survey and the corresponding reason for filtering is indicated. The properties for this prioritization procedure are:

- A minimum threshold value of two observations in literature is used to filter out infrequently mentioned factors.
- Factors that are not relevant with regards to this research's particular case study (see Chapter 4) are filtered out. These include:
  - factors that are not generically applicable because they are location-specific (e.g. criteria aimed at particular local legislation).
  - factors indicating *existing* properties/performances of a facility, not applicable because this study is specifically aimed at finding a location for a *new* inland terminal.
  - factors considered with conditions that are preliminarily taken into account when selecting alternative locations, thus not relevant to assess (e.g. connection to infrastructure network).
  - factors concerned with certain terminal functionalities not applicable to the *Load center* terminal type (see Section 2.2.3) considered in this study.

If factors *are* included in the criteria determination survey, they might be grouped under more comprehensive criteria denominations or otherwise alternative names. This is done in order to let the observed factors be clearly presented in the report as well as in the criteria determination survey. This is also indicated in the tables.

Weighted factors as observed in Ka (2011), presented in Table A.1

- Decision-makers: governmental professionals
- Country: China
- Used method(s): AHP + ELECTRE

Factor	(Global) weight	Filtered from survey	Alternative grouping/naming in survey
Transportation	0,22	No	*Total inland transport costs*
Trade level	0,21	No	*Market volume potential*
Cost	0,18	No	*Inland terminal CAPEX / Inland terminal OPEX*
Policy environment	0,15	No	*Governmental policy*
Economic level	0,14	No	*Regional economic development*
Infrastructure facilities	0,10	No	*Transport infrastructure network in area*

Table A.1: Weighted factors relevant for inland terminal location selection, as observed in Ka (2011).

Weighted factors as observed in Karaşan and Kahraman (2019), presented in Table A.2

- Decision-makers: Supply chain professionals and academics
- Country: Turkey
- Used method(s): ANP

Factor	(Global) weight	Filtered from survey	Reason for filtering	Alternative grouping/ naming in survey
Governmental incentive	0,23	No		*Governmental policy*
Investment attraction	0,13	No		*Market volume potential*[1]
International market location	0,12	Yes	The case study region is in the Schengen Area, thus border crossings are deemed irrelevant.	
Origin/ Destination proximities	0,08	No		*Market proximity*
Value-added services	0,08	No	The goal of the research is to find a location for a new inland terminal, thus existing performance indicators are not applicable.	
Suitability to extension of land	0,07	No		*Expansion possibilities*
Delivery time	0,06	No		*Market proximity*[2] + *Traffic congestion*[3]

[1] As *Investment attraction* is a broad characteristic interpretable in various manners. It is chosen to let this characteristic be represented by the more specified market characteristic of *Market volume potential*.

[2] Delivery time is considered to be directly related to the pre-/end-haulage distances between the alternative location and the customers, thus represented by Market proximity.

[3] Delivery time is influenced by local traffic congestion.

Average traffic speed	0,06	No		*Traffic congestion*[4]
Transportation & logistical competition level	0,06	No		*Regional transport/logistics competition*
Transportation and distribution systems	0,03	No		*Transport infrastructure network in area*
Intermodal operations and management	0,03	Yes	The goal of the research is to find a location for a new inland terminal, thus existing performance indicators are not applicable.	
Building cost	0,01	No		*Inland terminal CAPEX*
Integration	0,01	Yes	The goal of the research is to find a location for a new inland terminal, thus existing performance indicators are not applicable.	
Infrastructure	0,01	No		*Transport infrastructure network in area*
Workforce	0,00	No		*Local labor market*

Table A.2: Weighted factors relevant for inland terminal location selection, as observed in Karaşan and Kahraman (2019).

Weighted factors as observed in Kayikci (2010), presented in Table A.3

- Decision-makers: Transport service organizers
- Country: Austria
- Used method(s): Fuzzy-AHP

Factor	**(Global) weight**	**Filtered from survey**	**Reason for filtering**	**Alternative grouping/ naming in survey**
Spatial development	0,099	No		*Land use near location*
Socio-economic development	0,090	No		*Regional economic development*
Social stability	0,085	Yes	Less than threshold value of two observations in literature.	
Economic stability	0,076	Yes	Less than threshold value of two observations in literature.	
Political stability	0,069	Yes	Less than threshold value of two observations in literature.	

[4] It is chosen to let this local traffic characteristic be represented by *Traffic congestion*

Transshipment volume	0,066	No		*Market volume potential*
International manufacturing market	0,059	No		*Market volume potential*
Corridors	0,052	Yes	Less than threshold value of two observations in literature.	
Import/Export volumes	0,045	No		*Market volume potential*
Accessibility	0,043	No		*Transport infrastructure network in area*
Energy use	0,039	Yes	The goal of the research is to find a location for a new inland terminal, thus existing performance indicators are not applicable.	
International consumption market	0,038	No		*Market volume potential*
Congestion	0,038	No		*Traffic congestion*
Emissions	0,032	No		*Environmental effects*
Transport costs	0,030	No		
Land use	0,029	Yes	The case study alternatives are determined based on the preliminary condition of being available properties, thus currently not used for other economical activities.	
Coordination	0,029	Yes	The goal of the research is to find a location for a new inland terminal, thus existing performance indicators are not applicable.	
Customs	0,028	Yes	The goal of the research is to find a location for a new inland terminal, thus existing offered services are not applicable.	
IT infrastructure	0,027	Yes	Case study region is assumed to have a sufficient IT infrastructure network, thus factor is deemed irrelevant.	
Accident	0,025	Yes	The goal of the research is to find a location for a new inland terminal, thus existing performance indicators are not applicable.	

Transport time	0,025	Yes	Proposed inland terminal is of the Load Center type, for which the distance to the hinterland location has limited relevance (see Section 2.2.3). Therefore, total transport times between seaports and customer locations are also deemed irrelevant. Pre-/end-haulage transport times are covered by measurements on distances between the alternative location and customer locations.	
Service availability	0,025	Yes	The goal of the research is to find a location for a new inland terminal, thus existing offered services are not applicable.	
Quality	0,025	Yes	The goal of the research is to find a location for a new inland terminal, thus existing performance indicators are not applicable.	
Border crossing	0,024	Yes	The case study region is in the Schengen Area, thus border crossings are deemed irrelevant.	
Connectivity	0,017	Yes	The case study alternatives are determined based on the preliminary condition of being connected to relevant transport infrastructure networks.	
Hazardous materials	0,014	No		*Environmental effects*
Interoperability	0,013	Yes	The goal of the research is to find a location for a new inland terminal, thus existing performance indicators are not applicable.	
Mobility	0,000	Yes	The goal of the research is to find a location for a new inland terminal, thus existing performance indicators are not applicable.	

Table A.3: Weighted factors relevant for inland terminal location selection to transport service organizers, as observed in Kayikci (2010).

Weighted factors as observed in Kayikci (2010), presented in Table A.4

- Decision-makers: Transport operators
- Country: Austria
- Used method(s): Fuzzy-AHP

Factor	**(Global) weight**	**Filtered from survey**	**Reason for filtering**	**Alternative grouping/ naming in survey**
Political stability	0,095	Yes	Less than threshold value of two observations in literature..	
Social stability	0,080	Yes	Less than threshold value of two observations in literature.	
Economic stability	0,075	Yes	Less than threshold value of two observations in literature.	
Transshipment volume	0,057	No		*Market volume potential*
Accident	0,055	Yes	The goal of the research is to find a location for a new inland terminal, thus existing performance indicators are not applicable.	
Accessibility	0,051	No		*Transport infrastructure network in area*
Import/Export volumes	0,048	No		*Market volume potential*
Socio-economic development	0,044	No		*Regional economic development*
Spatial development	0,042	No		*Land use near location*
Transport time	0,042	Yes	Inland terminal is of the Load Center type, for which the distance to the hinterland location has limited relevance (see Section 2.2.3). Therefore, total transport times between seaports and customer locations are also deemed irrelevant. Pre-/end-haulage transport times are covered by measurements on distances between the alternative location and customer locations.	
Congestion	0,042	No		*Traffic congestion*
Emissions	0,042	No		*Environmental effects*
Hazardous materials	0,042	No		*Environmental effects*
International manufacturing market	0,040	No		*Market volume potential*
International consumption market	0,039	No		*Market volume potential*
Corridors	0,038	Yes	Not deemed relevant to case study, since alternative locations are all on the same corridor.	

Energy use	0,036	Yes	The goal of the research is to find a location for a new inland terminal, thus existing performance indicators are not applicable.
IT infrastructure	0,036	Yes	Case study region is assumed to have a sufficient IT infrastructure network, thus factor is deemed irrelevant.
Transport costs	0,034	No	
Border crossing	0,031	Yes	The case study region is in the Schengen Area, thus border crossings are deemed irrelevant.
Customs	0,031	Yes	The goal of the research is to find a location for a new inland terminal, thus existing offered services are not applicable.
Interoperability	0,029	Yes	The goal of the research is to find a location for a new inland terminal, thus existing performance indicators are not applicable.
Quality	0,023	Yes	The goal of the research is to find a location for a new inland terminal, thus existing performance indicators are not applicable.
Connectivity	0,021	Yes	The case study alternatives are determined based on the preliminary condition of being connected to relevant transport infrastructure networks.
Mobility	0,019	Yes	The goal of the research is to find a location for a new inland terminal, thus existing performance indicators are not applicable.
Land use	0,015	Yes	The case study alternatives are determined based on the preliminary condition of being available properties, thus currently not used for other economical activities.
Service availability	0,015	Yes	The goal of the research is to find a location for a new inland terminal, thus existing offered services are not applicable.
Coordination	0,011	Yes	The goal of the research is to find a location for a new inland terminal, thus existing performance indicators are not applicable.

Table A.4: Weighted factors relevant for inland terminal location selection to terminal users, as observed in Kayikci (2010).

Weighted factors as observed in Kayikci (2010), presented in Table A.5

- Decision-makers: Terminal operators
- Country: Austria
- Used method(s): Fuzzy-AHP

Factor	**(Global) weight**	**Filtered from survey**	**Reason for filtering**	**Alternative grouping/ naming in survey**
Accessibility	0,106	No		*Transport infrastructure network in area*
International manufacturing market	0,077	No		*Market volume potential*
Border crossing	0,074	Yes	The case study region is in the Schengen Area, thus border crossings are deemed irrelevant.	
Accident	0,061	Yes	The goal of the research is to find a location for a new inland terminal, thus existing performance indicators are not applicable.	
Political stability	0,059	Yes	Less than threshold value of two observations in literature.	
International consumption market	0,058	No		*Market volume potential*
Corridors	0,058	Yes	Not deemed relevant to case study, since alternative locations are all on the same corridor.	
Social stability	0,053	Yes	Less than threshold value of two observations in literature.	
Energy use	0,051	Yes	The goal of the research is to find a location for a new inland terminal, thus existing performance indicators are not applicable.	
Congestion	0,049	No		*Traffic congestion*
Economic stability	0,048	Yes	Less than threshold value of two observations in literature.	
IT infrastructure	0,047	Yes	Case study region is assumed to have a sufficient IT infrastructure network, thus factor is deemed irrelevant.	

Interoperability	0,047	Yes	The goal of the research is to find a location for a new inland terminal, thus existing performance indicators are not applicable.	
Customs	0,046	Yes	The goal of the research is to find a location for a new inland terminal, thus existing offered services are not applicable.	
Emissions	0,044	No		*Environmental effects*
Import/Export volumes	0,042	No		*Market volume potential*
Transport costs	0,042	No		
Connectivity	0,042	Yes	The case study alternatives are determined based on the preliminary condition of being connected to relevant transport infrastructure networks.	
Quality	0,036	Yes	The goal of the research is to find a location for a new inland terminal, thus existing performance indicators are not applicable.	
Socio-economic development	0,034	No		*Regional economic development*
Land use	0,032	Yes	The case study alternatives are determined based on the preliminary condition of being available properties, thus currently not used for other economical activities.	
Transshipment volume	0,032	No		*Market volume potential*
Service availability	0,031	Yes	The goal of the research is to find a location for a new inland terminal, thus existing offered services are not applicable.	
Spatial development	0,029	No		*Land use near location*
Mobility	0,024	Yes	The goal of the research is to find a location for a new inland terminal, thus existing performance indicators are not applicable.	

Transport time	0,016	Yes	Inland terminal is of the Load Center type, for which the distance to the hinterland location has limited relevance (see Section 2.2.3). Therefore, total transport times between seaports and customer locations are also deemed irrelevant. Pre-/end-haulage transport times are covered by measurements on distances between the alternative location and customer locations.	
Coordination	0,016	Yes	The goal of the research is to find a location for a new inland terminal, thus existing performance indicators are not applicable.	
Hazardous materials	0,000	No		*Environmental effects*

Table A.5: Weighted factors relevant for inland terminal location selection to terminal operators, as observed in Kayikci (2010).

Weighted factors as observed in Komchornrit (2017), presented in Table A.6

- Decision-makers: Logistics experts
- Country: Thailand
- Used method(s): MACBETH

Factor	**(Global) weight**	**Filter from survey**	**Reason for filtering**	**Alternative grouping/ naming in survey**
Seaport	0,22	Yes	Proposed inland terminal is of the Load Center type, for which the distance to the hinterland location has limited relevance (see Section 2.2.3).	
Airport	0,20	Yes	The focus of this study is on container transport, which is not directly related to air freight and affiliated factors.	
Highway	0,18	No		*Transport infrastructure network in area*
Industrial area	0,17	No		*Land use near location*
Cross-border market	0,15	No		*Market volume potential*
Regional market	0,08	No		*Market volume potential*
Local market	0,06	No		*Market volume potential*

Table A.6: Weighted factors relevant for inland terminal location selection, as observed in Komchornrit (2017).

Weighted factors as observed in Nguyen and Notteboom (2016), presented in Table A.7

- Decision-makers: Terminal users
- Country: Vietnam
- Used method(s): AHP

Factor	**(Global) weight**	**Filtered from survey**	**Reason for filtering**	**Alternative grouping/ naming in survey**
Reduction of transport costs	0,157	No		*Total inland transport costs*
Reduction of transport time	0,152	Yes	Proposed inland terminal is of the Load Center type, for which the distance to the hinterland location has limited relevance (see Section 2.2.3). Therefore, total transport times between seaports and customer locations are also deemed irrelevant. Pre-/end-haulage transport times are covered by measurements on distances between the alternative location and customer locations.	
Range of services	0,145	Yes	The goal of the research is to find a location for a new inland terminal, thus existing offered services are not applicable.	
Accessibility to road	0,138	Yes	The case study alternatives are determined based on the preliminary condition of being connected to relevant transport infrastructure networks.	
Accessibility to rail	0,138	Yes	The case study alternatives are determined based on the preliminary condition of being connected to relevant transport infrastructure networks.	
Proximity to the production base	0,136	No		*Market proximity*
Accessibility to inland waterway	0,133	Yes	The case study alternatives are determined based on the preliminary condition of being connected to relevant transport infrastructure networks.	

Table A.7: Weighted factors relevant for inland terminal location selection to terminal users, as observed in Nguyen and Notteboom (2016).

Weighted factors as observed in Nguyen and Notteboom (2016), presented in Table A.8

- Decision-makers: Terminal operators
- Country: Vietnam
- Used method(s): AHP

Factor	(Global) weight	Filtered from survey	Alternative grouping/naming in survey
Market demand	0,363	No	*Market volume potential*
Cost	0,318	No	*Inland terminal CAPEX / Inland terminal OPEX*
Room for expansion	0,175	No	*Expansion possibilities*
Investment atmosphere	0,144	No	*Governmental policy*

Table A.8: Weighted factors relevant for inland terminal location selection to terminal operators, as observed in Nguyen and Notteboom (2016).

Weighted factors as observed in Nguyen and Notteboom (2016), presented in Table A.9

- Decision-makers: Community representatives
- Country: Vietnam
- Used method(s): AHP

Factor	(Global) weight	Filter from survey	Reason for filtering	Alternative grouping/ naming in survey
Complement with other transport planning	0,227	No		*Governmental policy*[5]
Maximizing value added services and return to government	0,148	Yes	Less than threshold value of two observations in literature	
Minimizing road congestion	0,136	No		*Traffic congestion*
Employment generation	0,131	No		*Local labor market*
Dry port related pollution	0,114	No		*Environmental effects*

[5] As other transport planning is assumed to be performed by governmental institutions, the inland terminal planning is ought to be in line with their policies as represented by this factor.

Contribution to land use reorganization	0,102	No		*Land use near location*
Minimizing pollution per route	0,097	No		*Environmental effects*
Minimizing visual intrusion	0,045	No		*Environmental effects*

Table A.9: Weighted factors relevant for inland terminal location selection to the local community, as observed in Nguyen and Notteboom (2016).

Weighted factors as observed in Özceylan et al. (2016), presented in Table A.10

- Decision-makers: Governmental professionals and academics
- Country: Turkey
- Used method(s): ANP-TOPSIS

Factor	**(Global) weight**	**Filtered from survey**	**Reason for filtering**	**Alternative grouping/ naming in survey**
Land costs	0,160	No		*Inland terminal CAPEX*
Proximity to population density	0,128	Yes	Less than threshold value of two observations in literature.	
Proximity to highway system	0,103	Yes	The case study alternatives are determined based on the preliminary condition of being connected to relevant transport infrastructure networks.	
Proximity to industrial zone	0,097	No		*Market proximity*
Acreage of land & Opportunities for possible site expansion	0,084	No		*Expansion possibilities*
Distance to rivers	0,082	No		*Environmental effects*
Distance to lakes	0,075	No		*Environmental effects*
Proximity to railroad system	0,069	Yes	The case study alternatives are determined based on the preliminary condition of being connected to relevant transport infrastructure networks.	
Distance to forest zone	0,066	No		*Environmental effects*

Slope of land	0,049	Yes	The case study alternatives are determined based on the preliminary condition of being available properties suitable specifically for inland terminal development, thus surface conditions are assumed to be sufficient already.	
Proximity to airport	0,036	Yes	The focus of this study is on container transport, which is not directly related to air freight and affiliated factors.	
Distance to earthquakes	0,026	Yes	Factor is excluded since earthquakes do not naturally occur in case study region.	
Height difference to railway	0,024	Yes	The case study alternatives are determined based on the preliminary condition of being available properties suitable specifically for inland terminal development, thus surface conditions are assumed to be sufficient already.	

Table A.10: Weighted factors relevant for inland terminal location selection, as observed in Özceylan et al. (2016).

Weighted factors as observed in Regmi and Hanaoka (2013), presented in Table A.11

- Decision-makers: Governmental professionals, freight forwarder professionals, general business professionals (local chambers of commerce)
- Country: Laos
- Used method(s): ANP-TOPSIS

Factor	**(Global) weight**	**Filter from survey**	**Reason for filtering**	**Alternative grouping/ naming in survey**
Total transport time from seaport	0,133	Yes	Proposed inland terminal is of the Load Center type, for which the distance to the hinterland location has limited relevance (see Section 2.2.3).	
Government policies to develop special economic zone or free trade area nearby	0,112	No		*Governmental policies*
Impacts from construction	0,110	No		*Environmental effects*
Impacts from transport operation	0,099	No		*Environmental effects*

Transportation costs	0,089	No		*Total inland transport costs*
Proximity to market, production centers and consumers	0,087	No		*Market proximity*
Highways	0,073	No		*Transport infrastructure network in area*
Railways	0,071	No		*Transport infrastructure network in area*
Construction costs	0,057	No		*Inland terminal CAPEX*
Freight demand	0,057	No		*Market volume potential*
Land acquisition costs	0,056	No		*Inland terminal CAPEX*
Inland waterways	0,034	No		*Transport infrastructure network in area*
Seaports	0,023	Yes	Proposed inland terminal is of the Load Center type, for which the distance to the hinterland location has limited relevance (see Section 2.2.3).	

Table A.11: Weighted factors relevant for inland terminal location selection, as observed in Regmi and Hanaoka (2013).

Weighted factors as observed in Roso et al. (2015), presented in Table A.12

- Decision-makers: Governmental professionals, intermodal logistics professionals, terminal operator professionals, port authority professionals, shipping line professionals
- Country: Croatia
- Used method(s): AHP

Factor	**(Global) weight**	**Filtered from survey**	**Reason for filtering**	**Alternative grouping/ naming in survey**
Goods flows in the catchment area of the terminal	0,112	No		*Market volume potential*
Power of the economic sector in the catchment area of the terminal	0,102	No		*Regional economic development*

International freight flows that pass through the area of the terminal (tonnes per year)	0,092	Yes	The case study region is in the Schengen Area, thus border crossings are deemed irrelevant.	
Future goods flows in the catchment area of the terminal	0,058	No		*Market volume potential*
Distance from main industrial zones (km)	0,051	No		*Market proximity*
Distance from railway stations	0,049	Yes	Less than threshold value of two observations in literature.	
Distance from seaports	0,046	Yes	Proposed inland terminal is of the Load Center type, for which the distance to the hinterland location has limited relevance (see Section 2.2.3).	
Terminal connections	0,045	Yes	The case study alternatives are determined based on the preliminary condition of being connected to relevant transport infrastructure networks.	
Possibility of expanding the area considering future requirements	0,039	No		*Expansion possibilities*
Possibility of getting a major status in the network	0,034	Yes	Proposed inland terminal is of the Load Center type, for which the network function of the inland terminal has limited relevance (see Section 2.2.3).	
Flows that are created in the catchment area of the terminal	0,034	No		*Market volume potential*
Ratio of total flows rail / road	0,034	Yes	Less than threshold value of two observations in literature.	
Free zones (SZ) in the catchment area of the terminal	0,034	Yes	Not applicable to case study, since this factor is specifically considered with Croatian public administration.	

Safety of planning (SZ) – planning (is it approved for implementation, and in compliance with national and regional planning?)	0,034	Yes		*Governmental policy*
Ownership status / availability (public or private, one or several owners)	0,034	Yes	The case study alternatives are determined based on the preliminary condition of being available properties.	
Distance from transport and rail companies	0,034	No		*Market proximity*
Rail network characteristics	0,032	No		*Transport infrastructure network in area*
Terminal performance indicators	0,026	Yes	The goal of the research is to find a location for a new inland terminal, thus existing performance indicators are not applicable.	
Distance from river ports (km)	0,019	Yes	The case study does not involve barge transport (related) operations (see Section 4.1), thus barge transport (related) factors are not applicable.	
Accessibility to municipal and commercial centers	0,019	No		*Market proximity*[6]
Distance from agricultural centers	0,019	No		*Market proximity*[6]
IWW network characteristics	0,017	No		*Transport infrastructure network in area*
Quality indicators	0,015	Yes	The goal of the research is to find a location for a new inland terminal, thus existing performance indicators are not applicable.	
Equipment and activities at terminal	0,010	Yes	The goal of the research is to find a location for a new inland terminal, thus existing performance indicators are not applicable.	

[6]*Accessibility to municipal and commercial centers* and *Distance from agricultural centers* are combined grouped into *Market proximity*

Distance from airports	0,007	Yes	The focus of this study is on container transport, which is not directly related to air freight and affiliated factors.	
Development of logistics structures	0,006	Yes	Less than threshold value of two observations in literature.	

Table A.12: Weighted factors relevant for inland terminal location selection, as observed in Roso et al. (2015).

Weighted factors as observed in Rožić et al. (2016), presented in Table A.13

- Decision-makers: Undefined
- Country: Undefined
- Used method(s): AHP + ELECTRE + PROMETHEE

Factor	**Final weight result**	**Filtered from survey**	**Reason for filtering**	**Alternative grouping/ naming in survey**
Goods flow	9	No		*Market volume potential*
City logistics	8	Yes	Less than threshold value of two observations in literature.	
Infrastructure	7	No		*Transport infrastructure network in area*
Port influence	6	Yes	Proposed inland terminal is of the Load Center type, for which the relation with the seaport has less relevance (see Section 2.2.3).	
Labour market	5	No		*Local labor market*

Table A.13: Weighted factors relevant for inland terminal location selection, as observed in Rožić et al. (2016).

Weighted factors as observed in Wei et al. (2010), presented in Table A.14

- Decision-makers: Undefined
- Country: China
- Used method(s): Fuzzy-ANP

Factor	**(Global) weight**	**Filtered from survey**	**Reason for filtering**	**Alternative grouping/ naming in survey**
Traffic	0,167	No		*Traffic congestion*
Information infrastructure	0,145	Yes	Case study region is assumed to have a sufficient IT infrastructure network, thus factor is deemed irrelevant.	

Distribution and quantity of goods	0,129	No		*Market volume potential*
Customer conditions	0,129	Yes	Less than threshold value of two observations in literature.	
Transport costs	0,107	No		*Total inland transport costs*
Local labor wage level	0,096	Yes	Less than threshold value of two observations in literature.	
Environment protection costs	0,087	Yes	Less than threshold value of two observations in literature.	
Labor conditions	0,081	No		*Local labor market*
State of public facilities	0,058	No		*Transport infrastructure network in area*[7]

Table A.14: Weighted factors relevant for inland terminal location selection, as observed in Wei et al. (2010).

Weighted factors as observed in Yıldırım and Önder (2014), presented in Table A.15

- Decision-makers: Governmental professionals, logistics firm professionals, customer firm professionals, academics
- Country: Turkey
- Used method(s): AHP

Factor	**(Global) weight**	**Filtered from survey**	**Reason for filtering**	**Alternative grouping/ naming in survey**
Proximity to highway system	0,19	Yes	The case study alternatives are determined based on the preliminary condition of being connected to relevant transport infrastructure networks.	
Cost of land	0,18	No		*Inland terminal CAPEX*
Opportunities for possible site expansion	0,17	No		*Expansion possibilities*
Proximity to harbor	0,17	Yes	Proposed inland terminal is of the Load Center type, for which the distance to the hinterland location has limited relevance (see Section 2.2.3).	

[7] Public facilities is grouped under the transport infrastructure criterion since this encompasses the publicly accessible infrastructure in the area.

Proximity to railroad system	0,17	Yes	Proposed inland terminal is of the Load Center type, for which the distance to the hinterland location has limited relevance (see Section 2.2.3).	
Proximity to industrial zone	0,08	No		*Market proximity*
Proximity to airport	0,04	Yes	The focus of this study is on container transport, which is not directly related to air freight and affiliated factors.	

Table A.15: Weighted factors relevant for inland terminal location selection, as observed in Yıldırım and Önder (2014).

Factors as observed in Li et al. (2011) and Long and Grasman (2012), presented in Table A.16. Weight values are not indicated in the papers, thus not present in the overview either.

Factor	**Filter from survey**	**Reason for filtering**	**Alternative grouping/ naming in survey**
Li et al. (2011) Country: China			
Environmental protection climate - numbers of sustainability measures by governments	No		*Governmental policy*[8]
Environmental protection climate - percentage of investment in sustainability measures compared to total governmental expenses	No		*Governmental policy*[8]
Gross Regional Product per capita	No		*Regional economic development*
Monetary value of fixed transport related assets	No		*Inland terminal CAPEX*
Total freight infrastructure length	No		*Transport infrastructure in area*
Total freight volumes	No		*Market volume potential*
Total import and export value	No		*Market volume potential*[9]

[8]Although only focused on environmental protection, the original factor is regarded as an investment climate indicator based on governmental policies

[9]Market characteristics are expressed in volumes rather than monetary units.

Long and Grasman (2012) Country: United States of America			
Infrastructure	No		*Transport infrastructure in area*
Proximity to market	No		*Market proximity*
Land availability	Yes	The case study alternatives are determined based on the preliminary condition of being available properties.	
Government and industry support	No		*Governmental policy*
Labor supply	No		*Local labor market*
Origin/destination distances	No		*Market proximity*
Congestion	No		*Traffic congestion*

Table A.16: Factors relevant for inland terminal location selection, as observed in Li et al. (2011); Long and Grasman (2012) (no weight values observed).

B

Criteria determination survey template

Q1. Next, you see a list of factors gathered through reviewing earlier performed studies and other kinds of literature. From this list, could you indicate (by ticking the box(es)) the most important factors for evaluating the location of an inland terminal? In other words, which factors would you use to determine if an inland terminal is located good, bad, moderate, etc.? Please select as few or many criteria as you would like up to a maximum of 8 (ranking them is not needed).

Factor	*Explanation*	Important
Market volume potential	*Amount of container volumes forecasted to be generated in and/or attracted to the area*	☐
Market proximity	*Distance to volume potentials*	☐
Transport infrastructure network in area	*Characteristics of transport infrastructure network (e.g. lengths, density) in area*	☐
Total inland transport costs	*Overall costs for inland transport, including trucking costs, rail/barge costs and inland terminal handling costs.*	☐
Inland terminal CAPEX	*Investment costs of inland terminal*	☐
Inland terminal OPEX	*Costs for operating inland terminal and related activities (e.g. handling)*	☐
Terminal market profitability	*Local market margins gained from inland terminal handlings and storage*	☐
Intermodal market profitability	*Local market margins gained from intermodal services via inland terminal*	☐
Local labor market	*Local supply of sufficiently skilled labor for inland terminal related activities.*	☐
Governmental policy	*Local/regional political, administrational and regulatory circumstances with regards to inland terminal (related) developments/activities*	☐
Local environmental effects	*Environmental effects of inland terminal operations on surrounding area (e.g. noise pollution, particulars, emissions, reduction of emissions due to intermodal transport, etc.)*	☐
Global environmental effects	*Environmental effects of inland terminal operations on broader transportation level (e.g. emissions, reduction of emissions due to intermodal transport)).*	☐
Expansion possibilities	*Available land which could potentially be used to physically expand inland terminal*	☐
Traffic congestion	*Local congested infrastructure causing delays in transport flows*	☐
Regional economic development	*Economical character of region, e.g. indicated by Regional Gross Domestic Product per capita.*	☐
Regional transport/logistics competition	*Amount of companies involved in inland terminal (related) activities in area*	☐
Land use near location	*Land use at sites neighboring the inland terminal location*	☐

Q2. Are there factors you find important for evaluating the location of an inland terminal, but not present in the list? If not, you can skip this question. If so, please indicate accordingly (and further explain if necessary):

____

Q3. Do you have any other remarks on the above list and your selection of criteria important for evaluating the location of an inland terminal? If not, you can skip this question. If so, please indicate below:

____

End of questionnaire. Thank you very much for your participation. If you would be interested in receiving (non-confidential) research results after completion of this study, please feel free to reach out.

C
Data gathering methods per criterion

Content cannot be displayed due to confidentiality reasons.

D

Preference statement survey template

D.1. Survey for shipping line experts

The following main factors and sub factors were identified as most important for evaluating the location of an inland terminal:

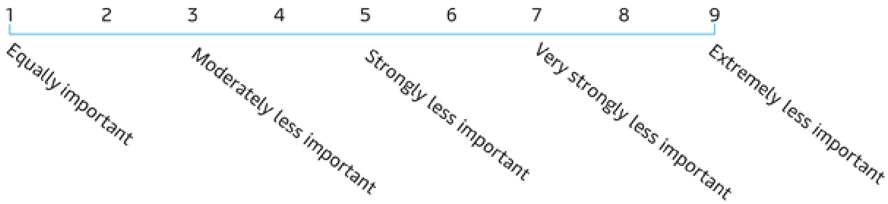
Main factor	Sub factor	*Explanation*
Costs and benefits	Inland terminal CAPEX	*Investment (realization) costs of inland terminal*
	Intermodal market profitability	*Local market margins gained from intermodal services via inland terminal*
	Total inland transport costs	*Overall costs for inland transport, including trucking costs, rail/barge costs and inland terminal handling costs.*
Local market characteristics	Market volume potential	*Companies generating/attracting container volumes (e.g. manufacturing or retail) in area.*
	Market proximity	*Distance to volume potentials*
	Regional transport/logistics competition	*Amount of companies offering transport and logistics services in area*
	Governmental policy	*Attitude of local/regional/national/European governmental organizations towards inland terminal operations/developments.*
Technical characteristics	Expansion possibilities	*Amount of land available which could be used to expand an existing inland terminal*
	Transport infrastructure network in area	*Local transport infrastructure characteristics, e.g. highway, railway and waterway network.*
	Local depot capacity	*Existing depot capacity in area*

The first question consists of scoring the main factors:

Q1a. Could you indicate which one of the main factors you find the MOST important for evaluating the location of an inland terminal?

____

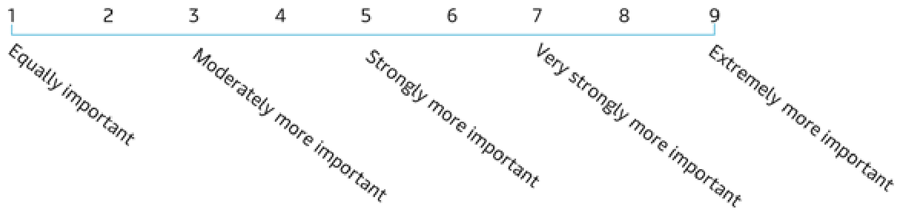
Q1b. Could you indicate how much you consider the other main factors to be LESS important than what you selected? Use a number from the scale 1 – 9, as follows;



Main factor	*Score relative to MOST IMPORTANT main factor*
Costs and benefits	Choose an item.
Local market characteristics	Choose an item.
Technical characteristics	Choose an item.

Q1c. Could you indicate which one of the main factors you find the LEAST important for evaluating the location of an inland terminal?

Q1d. Could you indicate how much you consider the other main factors to be MORE important than what you selected? Use a number from the scale 1 – 9, as follows;



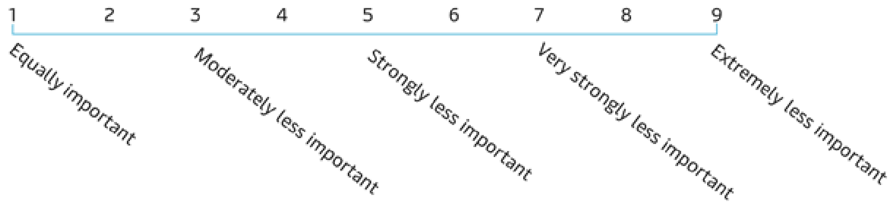
Main factor	*Score relative to LEAST IMPORTANT main factor*
Costs and benefits	Choose an item.
Local market characteristics	Choose an item.
Technical characteristics	Choose an item.

The next part consists of scoring the sub factors:

Costs and benefits

Q2a. Could you indicate which one of these costs and benefits factors you find the MOST important for evaluating the location of an inland terminal?

Q2b. Could you indicate how much you consider the other factors to be LESS important than what you selected? Use a number from the scale 1 – 9, as follows;

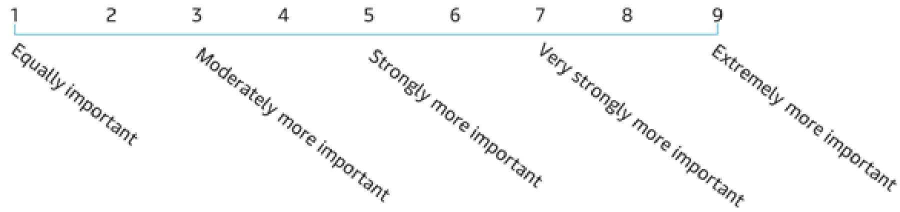


Factor	Score relative to MOST IMPORTANT factor
Intermodal market profitability	Choose an item.
Total inland transport costs	Choose an item.
Inland terminal CAPEX	Choose an item.

Q2c. Could you indicate which one of these costs and benefits factors you find the LEAST important for evaluating the location of an inland terminal?

____

Q2d. Could you indicate how much you consider the other factors to be MORE important than what you selected? Use a number from the scale 1 – 9, as follows;



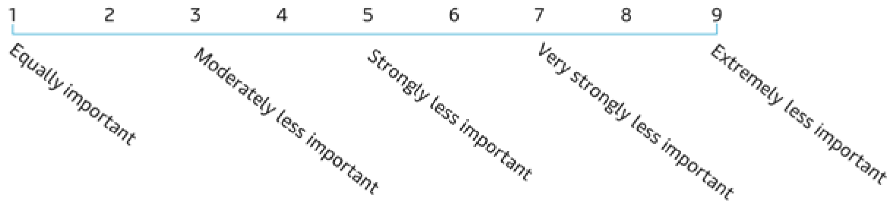
Factor	Score relative to LEAST IMPORTANT factor
Intermodal market profitability	Choose an item.
Total inland transport costs	Choose an item.
Inland terminal CAPEX	Choose an item.

Local market characteristics

Q3a. Could you indicate which one of these local market characteristics factors you find the MOST important for evaluating the location of an inland terminal?

____

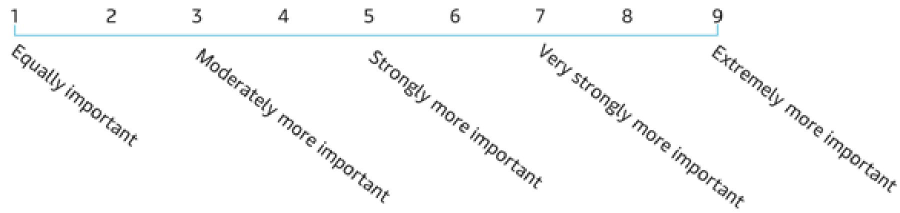
Q3b. Could you indicate how much you consider the other factors to be LESS important than what you selected? Use a number from the scale 1 – 9, as follows;



Factor	Score relative to MOST IMPORTANT factor
Market volume potential	Choose an item.
Market proximity	Choose an item.
Regional transport/logistics competition	Choose an item.
Governmental policy	Choose an item.

Q3c. Could you indicate which one of these local market characteristics factors you find the LEAST important for evaluating the location of an inland terminal?

Q3d. Could you indicate how much you consider the other factors to be MORE important than what you selected? Use a number from the scale 1 – 9, as follows;

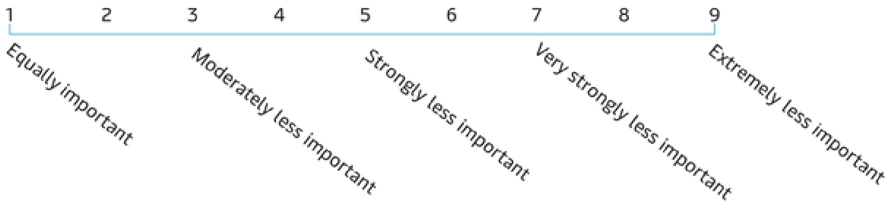


Factor	Score relative to LEAST IMPORTANT factor
Market volume potential	Choose an item.
Market proximity	Choose an item.
Regional transport/logistics competition	Choose an item.
Governmental policy	Choose an item.

Technical characteristics

Q4a. Could you indicate which one of these technical characteristics factors you find the MOST important for evaluating the location of an inland terminal?

Q4b. Could you indicate how much you consider the other factors to be LESS important than what you selected? Use a number from the scale 1 – 9, as follows;

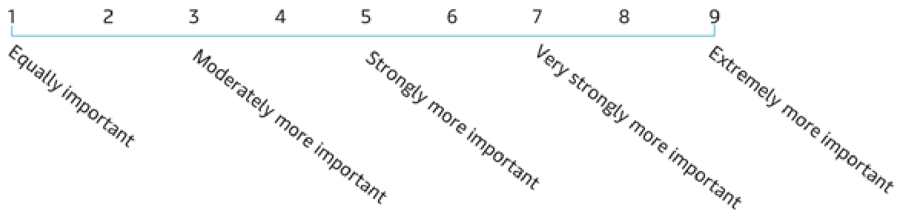


Factor	Score relative to MOST IMPORTANT factor
Transport infrastructure network in area	Choose an item.
Local depot capacity	Choose an item.
Expansion possibilities	Choose an item.

Q4c. Could you indicate which one of these technical characteristics factors you find the LEAST important for evaluating the location of an inland terminal?

____

Q4d. Could you indicate how much you consider the other factors to be MORE important than what you selected? Use a number from the scale 1 – 9, as follows;



Factor	Score relative to LEAST IMPORTANT factor
Transport infrastructure network in area	Choose an item.
Local depot capacity	Choose an item.
Expansion possibilities	Choose an item.

D.2. Survey for terminal operator experts

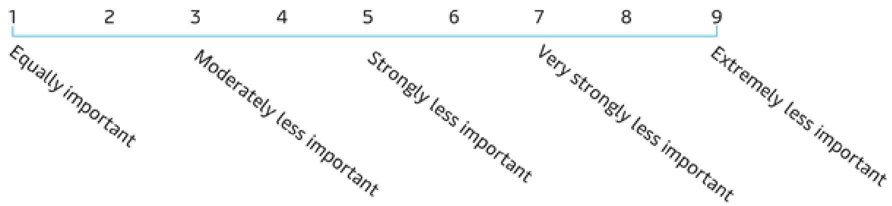
The following factors were identified as most important for evaluating the location of an inland terminal:

Factor	***Explanation***
Market volume potential	*Companies generating/attracting container volumes (e.g. manufacturing or retail) in area.*
Transport infrastructure network in area	*Local transport infrastructure characteristics, e.g. highway, railway and waterway network.*
Total inland transport costs	*Overall costs for inland transport, including trucking costs, rail/barge costs and inland terminal handling costs.*
Inland terminal CAPEX	*Investment (realization) costs of inland terminal*
Regional transport/logistics competition	*Amount of companies offering transport, logistics and terminal services in area*
Modality shift	*Enabling a shift from truck transport to intermodal transport via inland terminal*
Anchor customer proximity	*Proximity of inland terminal location to anchor customer*
Regional economic development	*Economical character of region, e.g. indicated by Regional Gross Domestic Product per capita.*

Q1. Could you indicate which one of these factors you find the MOST important for evaluating the location of an inland terminal?

____

Q2. Could you indicate how much you consider the other factors to be LESS important than what you selected? Use a number from the scale 1 – 9, as follows;

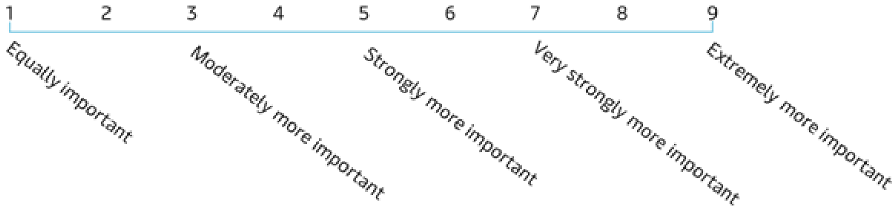


Factor	***Score relative to MOST IMPORTANT factor***
Market volume potential	Choose an item.
Transport infrastructure network in area	Choose an item.
Total inland transport costs	Choose an item.
Inland terminal CAPEX	Choose an item.
Regional transport/logistics competition	Choose an item.
Modality shift	Choose an item.
Anchor customer proximity	Choose an item.
Regional economic development	Choose an item.

Q3. Could you indicate which one of these factors you find the LEAST important for evaluating the location of an inland terminal?

____

Q4. Could you indicate how much you consider the other factors to be MORE important than what you selected? Use a number from the scale 1 – 9, as follows;



Factor	Score relative to LEAST IMPORTANT factor
Market volume potential	Choose an item.
Transport infrastructure network in area	Choose an item.
Total inland transport costs	Choose an item.
Inland terminal CAPEX	Choose an item.
Regional transport/logistics competition	Choose an item.
Modality shift	Choose an item.
Anchor customer proximity	Choose an item.
Regional economic development	Choose an item.

D.3. Survey for terminal user experts

D.3.1. Survey for intermodal transport operator experts

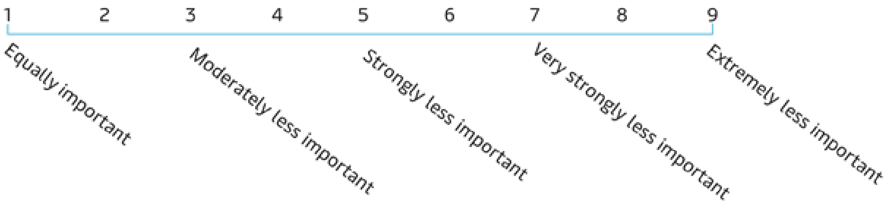
The following factors were identified as most important for evaluating the location of an inland terminal:

Factor	*Explanation*
Market volume potential	*Companies generating/attracting container volumes (e.g. manufacturing or retail) in area.*
Market proximity	*Distance to volume potentials*
Transport infrastructure network in area	*Local transport infrastructure characteristics, e.g. highway, railway and waterway network.*
Inland terminal CAPEX	*Investment (realization) costs of inland terminal*
Expansion possibilities	*Amount of land available which could be used to expand an existing inland terminal*

Q1. Could you indicate which one of these factors you find the MOST important for evaluating the location of an inland terminal?

____

Q2. Could you indicate how much you consider the other factors to be LESS important than what you selected? Use a number from the scale 1 – 9, as follows;

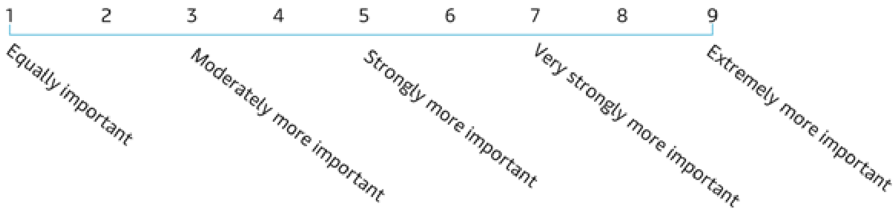


Factor	*Score relative to MOST IMPORTANT factor*
Market volume potential	Choose an item.
Market proximity	Choose an item.
Transport infrastructure network in area	Choose an item.
Inland terminal CAPEX	Choose an item.
Expansion possibilities	Choose an item.

Q3. Could you indicate which one of these factors you find the LEAST important for evaluating the location of an inland terminal?

____

Q4. Could you indicate how much you consider the other factors to be MORE important than what you selected? Use a number from the scale 1 – 9, as follows;



Factor	*Score relative to LEAST IMPORTANT factor*
Market volume potential	Choose an item.
Market proximity	Choose an item.
Transport infrastructure network in area	Choose an item.
Inland terminal CAPEX	Choose an item.
Expansion possibilities	Choose an item.

D.3.2. Survey for truck transport operator experts

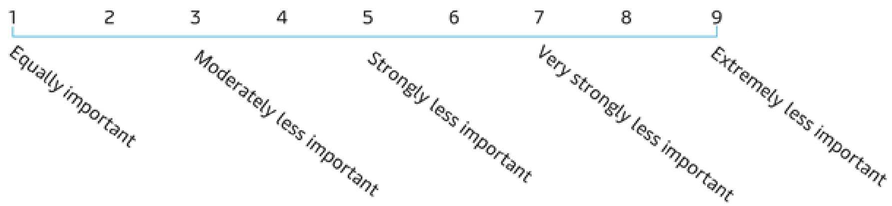
The following factors were identified as most important for evaluating the location of an inland terminal:

Factor	*Explanation*
Market volume potential	*Companies generating/attracting container volumes (e.g. manufacturing or retail) in area.*
Market proximity	*Distance to volume potentials*
Regional transport/logistics competition	*Amount of companies offering transport, logistics and terminal services in area*
Transport infrastructure network in area	*Local transport infrastructure characteristics, e.g. highway, railway and waterway network.*
Total inland transport costs	*Overall costs for inland transport, including trucking costs, rail/barge costs and inland terminal handling costs.*
Intermodal market profitability	*Local market margins gained from intermodal services via inland terminal*
Terminal market profitability	*Local market margins gained from inland terminal handlings and storage*
Land use near location	*Land use (e.g. industrial, residential, etc.) of sites neighboring inland terminal*
Expansion possibilities	*Amount of land available which could be used to expand an existing inland terminal*

Q1. Could you indicate which one of these factors you find the MOST important for evaluating the location of an inland terminal?

____

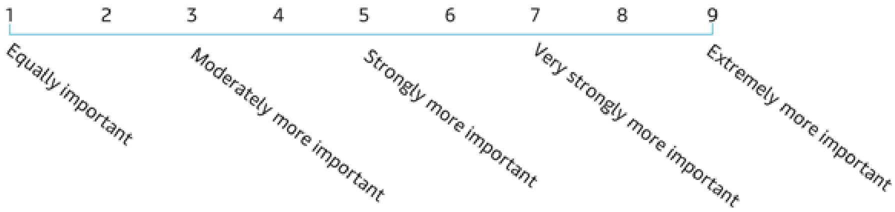
Q2. Could you indicate how much you consider the other factors to be LESS important than what you selected? Use a number from the scale 1 – 9, as follows;



Factor	***Score relative to MOST IMPORTANT factor***
Market volume potential	Choose an item.
Market proximity	Choose an item.
Regional transport/logistics competition	Choose an item.
Transport infrastructure network in area	Choose an item.
Total inland transport costs	Choose an item.
Intermodal market profitability	Choose an item.
Terminal market profitability	Choose an item.
Land use near location	Choose an item.
Expansion possibilities	Choose an item.

Q3. Could you indicate which one of these factors you find the LEAST important for evaluating the location of an inland terminal?

Q4. Could you indicate how much you consider the other factors to be MORE important than what you selected? Use a number from the scale 1 – 9, as follows;



Factor	***Score relative to LEAST IMPORTANT factor***
Market volume potential	Choose an item.
Market proximity	Choose an item.
Regional transport/logistics competition	Choose an item.
Transport infrastructure network in area	Choose an item.
Total inland transport costs	Choose an item.
Intermodal market profitability	Choose an item.
Terminal market profitability	Choose an item.
Land use near location	Choose an item.
Expansion possibilities	Choose an item.

E

Model verification

E.1. Non-linear Weight Interval Determination Models

The following constraints are checked to verify Models 3.4 and 3.5:

$$\left|\frac{w_B}{w_j} - a_{Bj}\right| \leq \xi^*, \forall j$$

$$\left|\frac{w_j}{w_W} - a_{jW}\right| \leq \xi^*, \forall j$$

$$\sum_j w_j = 1$$

$$w_j \geq 0, \forall j$$

Shipping line 1 (global)							
a_{Bj}			2	1	8		
a_{jW}			6	8	1	Σ	
w_j			0,3687	0,5646	0,0667	1,0000	✓
w_B	0,5646	$\|(w_B/w_j-a_{Bj})\|$	0,4689	0,0000	0,4689		
w_W	0,0667	$\|(w_j/w_W-a_{jW})\|$	0,4689	0,4689	0,0000		
ξ*	0,4689	≥	✓	✓	✓		

Shipping line 1 (local cost and benefit factors)							
a_{Bj}			7	1	1		
a_{jW}			1	7	6	Σ	
w_j			0,0667	0,5000	0,4333	1,0000	✓
w_B	0,5000	$\|(w_B/w_j-a_{Bj}$	0,5000	0,0000	0,1538		
w_W	0,0667	$\|(w_j/w_W-a_{jW}$	0,0000	0,5000	0,5000		
ξ*	0,5000	≥	✓	✓	✓		

Shipping line 1 (local market factors)								
a_{Bj}			8	1	1	5		
a_{jW}			1	8	8	4	Σ	
w_j			0,0447	0,4195	0,4195	0,1163	1,0000	✓
w_B	0,4195	$\|(w_B/w_j-a_{Bj})\|$	1,3944	0,0000	0,0000	1,3944		
w_W	0,0447	$\|(w_j/w_W-a_{jW})\|$	0,0000	1,3944	1,3944	1,3944		
ξ*	1,3944	≥	✓	✓	✓	✓		

Shipping line 1 (local technical factors)							
a_{Bj}			8	3	1		
a_{jW}			1	5	8	Σ	
w_j			0,0714	0,2957	0,6329	1,0000	✓
w_B	0,6329	$\lvert(w_B/w_j-a_{Bj})\rvert$	0,8599	0,8599	0,0000		
w_W	0,0714	$\lvert(w_j/w_W-a_{jW})\rvert$	0,0000	0,8599	0,8599		
ξ*	0,8599	≥	✓	✓	✓		

Shipping line 2 (global)							
a_{Bj}			1	3	9		
a_{jW}			9	6	1	Σ	
w_j			0,6250	0,3125	0,0625	1,0000	✓
w_B	0,6250	$\lvert(w_B/w_j-a_{Bj})\rvert$	0,0000	1,0000	1,0000		
w_W	0,0625	$\lvert(w_j/w_W-a_{jW})\rvert$	1,0000	1,0000	0,0000		
ξ*	1,0000	≥	✓	✓	✓		

Shipping line 2 (local cost and benefit factors)							
a_{Bj}			3	1	7		
a_{jW}			4	7	1	Σ	
w_j			0,2764	0,6403	0,0833	1,0000	✓
w_B	0,6403	$\lvert(w_B/w_j-a_{Bj})\rvert$	0,6834	0,0000	0,6834		
w_W	0,0833	$\lvert(w_j/w_W-a_{jW})\rvert$	0,6834	0,6834	0,0000		
ξ*	0,6834	≥	✓	✓	✓		

Shipping line 2 (local market factors)								
a_{Bj}			9	8	1	3		
a_{jW}			1	3	9	5	Σ	
w_j			0,0567	0,0897	0,5902	0,2635	1,0000	✓
w_B	0,5902	$\lvert(w_B/w_j-a_{Bj})\rvert$	1,4174	1,4174	0,0000	0,7598		
w_W	0,0567	$\lvert(w_j/w_W-a_{jW})\rvert$	0,0000	1,4174	1,4174	0,3497		
ξ*	1,4174	≥	✓	✓	✓	✓		

Shipping line 2 (local technical factors)							
a_{Bj}			9	3	1		
a_{jW}			1	6	9	Σ	
w_j			0,0625	0,3125	0,6250	1,0000	✓
w_B	0,6250	$\lvert(w_B/w_j-a_{Bj})\rvert$	1,0000	1,0000	0,0000		
w_W	0,0625	$\lvert(w_j/w_W-a_{jW})\rvert$	0,0000	1,0000	1,0000		
ξ*	1,0000	≥	✓	✓	✓		

Shipping line 3 (global)							
a_{Bj}			2	1	5		
a_{jW}			2	5	1	Σ	
w_j			0,2741	0,6009	0,1250	1,0000	✓
w_B	0,6009	$\lvert(w_B/w_j-a_{Bj})\rvert$	0,1926	0,0000	0,1926		
w_W	0,1250	$\lvert(w_j/w_W-a_{jW})\rvert$	0,1926	0,1926	0,0000		
ξ*	0,1926	≥	✓	✓	✓		

Shipping line 3 (local cost and benefit factors)							
a_{Bj}			4	1	9		
a_{jW}			4	9	1	Σ	
w_j			0,2243	0,7043	0,0714	1,0000	✓
w_B	0,7043	$\lvert(w_B/w_j-a_{Bj})\rvert$	0,8599	0,0000	0,8599		
w_W	0,0714	$\lvert(w_j/w_W-a_{jW})\rvert$	0,8599	0,8599	0,0000		
ξ*	0,8599	≥	✓	✓	✓		

Shipping line 3 (local market factors)								
a_{Bj}			4	1	2	3		
a_{jW}			1	4	3	2	Σ	
w_j			0,1037	0,4514	0,2743	0,1706	1,0000	✓
w_B	0,4514	$\|(w_B/w_j-a_{}$	0,3542	0,0000	0,3542	0,3542		
w_W	0,1037	$\|(w_j/w_W-a$	0,0000	0,3542	0,3542	0,3542		
ξ*	0,3542	≥	✓	✓	✓	✓		

Shipping line 3 (local technical factors)							
a_{Bj}			1	2	5		
a_{jW}			5	2	1	Σ	
w_j			0,6009	0,2741	0,1250	1,0000	✓
w_B	0,6009	$\|(w_B/w_j-a_{}$	0,0000	0,1926	0,1926		
w_W	0,1250	$\|(w_j/w_W-a$	0,1926	0,1926	0,0000		
ξ*	0,1926	≥	✓	✓	✓		

Rail operator 1									
a_{Bj}			8	4	5	1	3		
a_{jW}			1	6	4	8	7	Σ	
w_j			0,0430	0,1839	0,1277	0,4184	0,2269	*1,0000*	✓
w_B	0,4184	$\|(w_B/w_j-a_{Bj})\|$	1,7251	1,7251	1,7246	0,0000	1,1564		
w_W	0,0430	$\|(w_j/w_W-a_{jW})\|$	0,0000	1,7251	1,0308	1,7251	1,7251		
ξ*	1,7251	≥	✓	✓	✓	✓	✓		

Rail operator 2									
a_{Bj}			4	4	6	1	1		
a_{jW}			3	3	1	6	6	Σ	
w_j			0,1138	0,1138	0,0526	0,3599	0,3599	*1,0000*	✓
w_B	0,3599	$\|(w_B/w_j-a_{Bj})\|$	0,8377	0,8377	0,8377	0,0000	0,0000		
w_W	0,0526	$\|(w_j/w_W-a_{jW})\|$	0,8377	0,8377	0,0000	0,8377	0,8377		
ξ*	0,8377	≥	✓	✓	✓	✓	✓		

Truck transport operator													
a_{Bj}			8	3	9	2	1	6	5	4	7		
a_{jW}			2	7	1	8	9	4	5	6	3	Σ	
w_j			0,0301	0,1599	0,0262	0,1988	0,2813	0,0608	0,0859	0,1235	0,0334	*1,0000*	✓
w_B	0,2813	$\|(w_B/w_j-a_{Bj})\|$	1,3289	1,2407	1,7251	0,5855	0,0000	1,3770	1,7251	1,7224	1,4124		
w_W	0,0262	$\|(w_j/w_W-a_{jW})\|$	0,8503	0,9038	0,0000	0,4178	1,7251	1,6800	1,7251	1,2911	1,7251		
ξ*	1,7251	≥	✓	✓	✓	✓	✓	✓	✓	✓	✓		

Terminal operator 1												
a_{Bj}			2	4	7	2	1	4	3	3		
a_{jW}			4	4	1	5	7	3	4	5	Σ	
w_j			0,1521	0,0846	0,0296	0,1821	0,2414	0,0549	0,1268	0,1285	*1,0000*	✓
w_B	0,2414	$\|(w_B/w_j-a_{Bj})\|$	0,4124	1,1459	1,1459	0,6746	0,0000	0,3934	1,0955	1,1212		
w_W	0,0296	$\|(w_j/w_W-a_{jW})\|$	1,1309	1,1459	0,0000	1,1459	1,1459	1,1459	0,2772	0,6643		
ξ*	1,1459	≥	✓	✓	✓	✓	✓	✓	✓	✓		

Terminal operator 2												
a_{Bj}			3	7	4	1	3	3	6	5		
a_{jW}			5	1	4	7	5	5	2	3	Σ	
w_j			0,1409	0,0363	0,1036	0,2956	0,1479	0,1456	0,0578	0,0722	*1,0000*	✓
w_B	0,2956	$\lvert(w_B/w_j-a_{Bj})\rvert$	0,9025	1,1459	1,1459	0,0000	1,0018	0,9703	0,8864	0,9063		
w_W	0,0363	$\lvert(w_j/w_W-a_{jW})\rvert$	1,1165	0,0000	1,1459	1,1459	0,9233	0,9866	0,4070	1,0101		
ξ*	1,1459	≥	✓	✓	✓	✓	✓	✓	✓	✓		

Terminal operator 3												
a_{Bj}			1	7	5	4	9	4	1	9		
a_{jW}			9	2	5	7	1	7	9	2	Σ	
w_j			0,2835	0,0319	0,0818	0,1335	0,0261	0,1335	0,2835	0,0261	*1,0000*	✓
w_B	0,2835	$\lvert(w_B/w_j-a_{Bj})\rvert$	0,0000	1,8769	1,5338	1,8769	1,8769	1,8769	0,0000	1,8769		
w_W	0,0261	$\lvert(w_j/w_W-a_{jW})\rvert$	1,8769	0,7747	1,8620	1,8769	0,0000	1,8769	1,8769	1,0000		
ξ*	1,8769	≥	✓	✓	✓	✓	✓	✓	✓	✓		

E.2. Weight Aggregation Model

The following constraints are checked to verify Model 3.7:

$$\left|w_j^{agg} - w_j^k\right| \leq \omega, \forall j, k$$
$$w_j^{min} \leq w_j^k \leq w_j^{max}, \forall i, k$$

Shipping line		c_1	c_2	c_3	c_4	c_5	c_6	c_7	c_8	c_9	c_{10}
w^{agg}		0,0995	0,2923	0,0897	0,0243	0,1072	0,2052	0,0890	0,1903	0,1323	0,2162
$w^{min,1}$	≥	0,0246	0,1712	0,1598	0,0165	0,1547	0,1547	0,0429	0,0403	0,1670	0,3573
w_j^1	=	0,0263	0,1844	0,1598	0,0165	0,1547	0,1547	0,0429	0,0403	0,1670	0,3573
$w^{max,1}$	≤	0,0263	0,1844	0,1712	0,0165	0,1547	0,1547	0,0429	0,0403	0,1670	0,3573
$w^{min,2}$	≥	0,1727	0,4002	0,0521	0,0322	0,0509	0,3353	0,1350	0,0195	0,0977	0,1953
w_j^2	=	0,1727	0,4002	0,0521	0,0322	0,0596	0,3353	0,1350	0,0195	0,0977	0,1953
$w^{max,2}$	≤	0,1727	0,4002	0,0521	0,0377	0,0596	0,3926	0,2066	0,0195	0,0977	0,1953
$w^{min,3}$	≥	0,0615	0,1930	0,0196	0,0284	0,1237	0,0752	0,0468	0,3611	0,1647	0,0751
w_j^3	=	0,0615	0,1930	0,0196	0,0284	0,1237	0,0752	0,0468	0,3611	0,1647	0,0751
$w^{max,3}$	≤	0,0615	0,1930	0,0196	0,0284	0,1237	0,0752	0,0468	0,3611	0,1647	0,0751
$\lvert w^{agg} - w_j^1\rvert$	=	0,0732	0,1079	0,0701	0,0079	0,0475	0,0506	0,0461	0,1500	0,0347	0,1411
$\lvert w^{agg} - w_j^2\rvert$	=	0,0732	0,1079	0,0376	0,0079	0,0475	0,1301	0,0461	0,1708	0,0347	0,0209
$\lvert w^{agg} - w_j^3\rvert$	=	0,0381	0,0992	0,0701	0,0041	0,0166	0,1301	0,0422	0,1708	0,0324	0,1411
		≤	≤	≤	≤	≤	≤	≤	≤	≤	≤
ω	=	*0,0732*	*0,1079*	*0,0701*	*0,0079*	*0,0475*	*0,1301*	*0,0461*	*0,1708*	*0,0347*	*0,1411*
		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Rail transport operator		c_1	c_2	c_3	c_4	c_5
w^{agg}		0,0791	0,1404	0,0720	0,3699	0,3331
$w^{min,1}$	≥	0,0391	0,1670	0,0914	0,3799	0,2269
w_j^1	=	0,0443	0,1670	0,0914	0,3799	0,3063
$w^{max,1}$	≤	0,0443	0,1896	0,1278	0,4313	0,3063
$w^{min,2}$	≥	0,1138	0,1138	0,0526	0,3599	0,3599
w_j^2	=	0,1138	0,1138	0,0526	0,3599	0,3599
$w^{max,2}$	≤	0,1138	0,1138	0,0526	0,3599	0,3599
$\lvert w^{agg} - w_j^1\rvert$	=	0,0347	0,0266	0,0194	0,0100	0,0268
$\lvert w^{agg} - w_j^2\rvert$	=	0,0347	0,0266	0,0194	0,0100	0,0268
		≤	≤	≤	≤	≤
ω	=	*0,0347*	*0,0266*	*0,0194*	*0,0100*	*0,0268*
		✓	✓	✓	✓	✓

Terminal operator		c_1	c_2	c_3	c_4	c_5	c_6	c_7	c_8
w^{agg}		0,2166	0,0597	0,0676	0,2074	0,1296	0,1183	0,1665	0,0757
$w^{min,1}$	≥	0,0874	0,0817	0,0286	0,1181	0,2332	0,0546	0,0855	0,1121
w_j^1	=	0,1621	0,0817	0,0367	0,1336	0,2332	0,1010	0,0855	0,1121
$w^{max,1}$	≤	0,1741	0,1047	0,0367	0,2079	0,2987	0,1010	0,1525	0,1580
$w^{min,2}$	≥	0,1356	0,0345	0,0985	0,2812	0,1356	0,1356	0,0401	0,0646
w_j^2	=	0,1621	0,0377	0,0985	0,2812	0,1356	0,1356	0,0619	0,0646
$w^{max,2}$	≤	0,1621	0,0377	0,1075	0,3067	0,1621	0,1621	0,0619	0,0788
$w^{min,3}$	≥	0,2710	0,0312	0,0785	0,1277	0,0249	0,1277	0,2710	0,0252
w_j^3	=	0,2710	0,0377	0,0785	0,1336	0,0261	0,1277	0,2710	0,0393
$w^{max,3}$	≤	0,2836	0,0541	0,0900	0,1336	0,0261	0,1336	0,2836	0,0393
$\lvert w^{agg} - w_j^1 \rvert$	=	0,0544	0,0220	0,0309	0,0738	0,1036	0,0173	0,0810	0,0364
$\lvert w^{agg} - w_j^2 \rvert$	=	0,0544	0,0220	0,0309	0,0738	0,0059	0,0173	0,1045	0,0111
$\lvert w^{agg} - w_j^3 \rvert$	=	0,0544	0,0220	0,0109	0,0738	0,1036	0,0094	0,1045	0,0364
		≤	≤	≤	≤	≤	≤	≤	≤
ω	=	*0,0544*	*0,0220*	*0,0309*	*0,0738*	*0,1036*	*0,0173*	*0,1045*	*0,0364*
		✓	✓	✓	✓	✓	✓	✓	✓

E.3. Utility Aggregation Model

The following constraints are checked to verify Model 3.12:

$$\left|V_i^{agg} - V_i^k\right| \leq \zeta, \forall i, k$$
$$V_i^{min} \leq V_i^k \leq V_i^{max}, \forall i, k$$

		A_1	A_2	A_3	A_4	A_5	A_6
V^{agg}		0,7338	0,6044	0,3960	0,3694	0,5380	0,5608
$V^{min,1}$	≥	0,6207	0,5861	0,1732	0,1119	0,3962	0,4283
V_j^1	=	0,6207	0,5861	0,1732	0,1134	0,3962	0,4283
$V^{max,1}$	≤	0,7535	0,7067	0,1977	0,1336	0,4985	0,5341
$V^{min,2}$	≥	0,7008	0,5580	0,2047	0,1134	0,4884	0,5038
V_j^2	=	0,7008	0,5580	0,2047	0,1134	0,4884	0,5038
$V^{max,2}$	≤	0,7008	0,5580	0,2047	0,1134	0,4884	0,5038
$V^{min,3}$	≥	0,6075	0,5986	0,1418	0,1721	0,2817	0,2862
V_j^3	=	0,6111	0,5986	0,1418	0,1721	0,2817	0,2862
$V^{max,3}$	≤	0,8456	0,8290	0,2310	0,2821	0,4292	0,4308
$V^{min,4}$	≥	0,7201	0,6910	0,1787	0,1986	0,1862	0,1951
V_j^4	=	0,7201	0,6910	0,1787	0,1986	0,2186	0,2463
$V^{max,4}$	≤	1,1215	1,0744	0,2384	0,2741	0,2756	0,2891
$V^{min,5}$	≥	0,7972	0,7886	0,1900	0,1733	0,1849	0,2107
V_j^5	=	0,7972	0,7886	0,1900	0,1733	0,2186	0,2463
$V^{max,5}$	≤	0,9346	0,9231	0,2192	0,2054	0,2186	0,2463
$V^{min,6}$	≥	0,8565	0,8563	0,1166	0,1464	0,2287	0,2403
V_j^6	=	0,8565	0,8563	0,1281	0,1464	0,2287	0,2463
$V^{max,6}$	≤	0,9250	0,9235	0,1281	0,1581	0,2600	0,2735
$V^{min,7}$	≥	0,7390	0,6692	0,2912	0,3876	0,7898	0,7827
V_j^7	=	0,7390	0,6692	0,2912	0,3876	0,7898	0,7827
$V^{max,7}$	≤	0,7499	0,6823	0,3006	0,4037	0,8088	0,8013
$V^{min,8}$	≥	0,7236	0,7468	0,5105	0,6255	0,8574	0,8753
V_j^8	=	0,7236	0,7468	0,5105	0,6255	0,8574	0,8753
$V^{max,8}$	≤	0,8658	0,8866	0,5274	0,6427	0,8600	0,8810
$V^{min,9}$	≥	0,6111	0,3526	0,6638	0,4309	0,5210	0,4881
V_j^9	=	0,6111	0,3526	0,6638	0,4309	0,5210	0,4881
$V^{max,9}$	≤	0,6111	0,3526	0,6638	0,4309	0,5210	0,4881
$\lvert V^{agg} - V_j^1 \rvert$	=	0,1131	0,0183	0,2228	0,2560	0,1418	0,1325
$\lvert V^{agg} - V_j^2 \rvert$	=	0,0330	0,0464	0,1912	0,2560	0,0496	0,0570
$\lvert V^{agg} - V_j^3 \rvert$	=	0,1227	0,0059	0,2542	0,1974	0,2563	0,2746
$\lvert V^{agg} - V_j^4 \rvert$	=	0,0137	0,0865	0,2172	0,1709	0,3194	0,3145
$\lvert V^{agg} - V_j^5 \rvert$	=	0,0634	0,1842	0,2059	0,1961	0,3194	0,3145
$\lvert V^{agg} - V_j^6 \rvert$	=	0,1227	0,2518	0,2679	0,2231	0,3093	0,3145
$\lvert V^{agg} - V_j^7 \rvert$	=	0,0052	0,0648	0,1048	0,0181	0,2518	0,2219
$\lvert V^{agg} - V_j^8 \rvert$	=	0,0101	0,1423	0,1145	0,2560	0,3194	0,3145
$\lvert V^{agg} - V_j^9 \rvert$	=	0,1227	0,2518	0,2679	0,0614	0,0170	0,0726
		≤	≤	≤	≤	≤	≤
ζ	=	*0,1227*	*0,2518*	*0,2679*	*0,2560*	*0,3194*	*0,3145*
		✓	✓	✓	✓	✓	✓

F
Model validation

F.1. Non-linear Weight Interval Determination Models

The following model outputs support the validation of Models 3.4 and 3.5:

Criterion	Model input		*Expected rank*	Model output		*Compliance*
	BO	OW		w	Actual rank	
c_1	1	9	*1*	0,5100	1	*Yes*
c_2	3	6	*2*	0,2357	2	*Yes*
c_3	5	4	*3*	0,1363	3	*Yes*
c_4	7	2	*4*	0,0683	4	*Yes*
c_5	9	1	*5*	0,0497	5	*Yes*

Table F.1: Validation of Models 3.4 and 3.5: Expected criteria ranking versus actual criteria ranking.

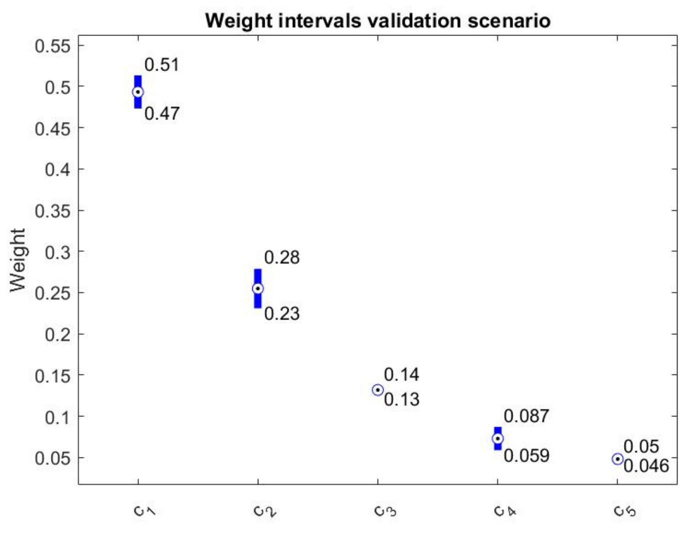


Figure F.1: Weight intervals of criteria weight determination problem for validation

As the expected criteria weight ranks comply with the actual criteria weight ranks and the model produces intervals rather than discrete values, Models 3.4 and 3.5 are successfully validated.

F.2. Weight Aggregation Model and Utility Aggregation Model

The following model outputs support the validation of Models 3.7 and 3.12:

Criterion	Model input				Expected weight range	Model output	*Comp-liance*
	$w_j^{min,1}$	$w_j^{max,1}$	$w_j^{min,2}$	$w_j^{max,2}$		w^{agg}	
c1	0,4732	0,5133	0,9465	1,027	$0,5133 \leq w^{agg} \leq 0,9465$	0,7299	*Yes*
c2	0,2310	0,2787	0,4620	0,5574	$0,2787 \leq w^{agg} \leq 0,4620$	0,3703	*Yes*
c3	0,1265	0,1372	0,2530	0,2744	$0,1372 \leq w^{agg} \leq 0,2530$	0,1951	*Yes*
c4	0,0588	0,0870	0,1176	0,1741	$0,0870 \leq w^{agg} \leq 0,1176$	0,1023	*Yes*
c5	0,0461	0,0500	0,0923	0,1001	$0,0500 \leq w^{agg} \leq 0,0923$	0,0712	*Yes*

Table F.2: Validation of Models 3.7 and 3.12: Expected aggregated criteria weights versus actual aggregated criteria weights.

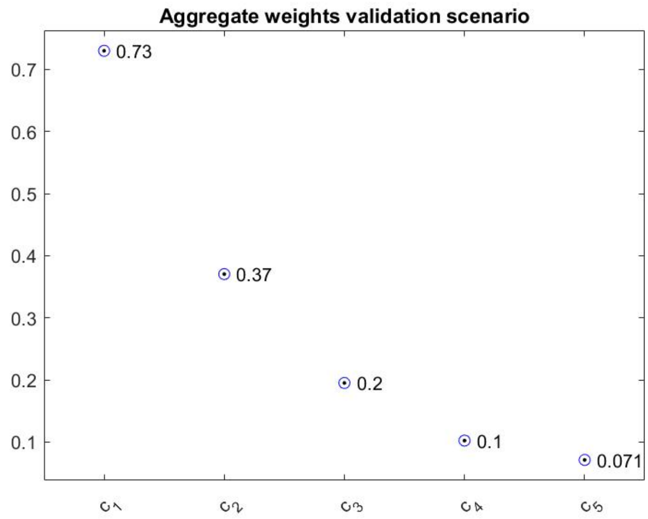


Figure F.2: Aggregate weights of weight aggregation problem for validation

As the expected aggregated weight values comply with the actual aggregated weight values and the aggregate weight ranking is the same as the ranking of the initial weight intervals, Models 3.7 and 3.12 are successfully validated[1].

[1]Note that weights w_j^2 are duplicates of weights w_j^1 purely in order to conduct this validation exercise. Theoretically, weights cannot be calculated by multiplying initial weight factors with themselves/other weight values.

G

Results of criteria determination surveys

The criteria selection survey produces two outcomes. First of all, it produces the outcome of the examination of criteria gathered in the literature review by the industry expert. The selections of the most important literature criteria are presented in Table G.1.

Stakeholder	**Shipping line**	**Terminal user** **Intermodal operator**	 **Truck operator**	**Terminal operator**	
Criterion		**Times mentioned**			***Total***
Transport infrastructure network in area	5	1	2	2	*10*
Market volume potential	4	1	1	2	*8*
Expansion possibilities	4	1	2	-	*7*
Market proximity	4	1	1	-	*6*
Total inland transport costs	2	-	2	1	*5*
Regional transport/logistics competition	2	-	1	1	*4*
Inland terminal CAPEX	2	1	-	1	*4*
Intermodal market profitability	2	-	1	-	*3*
Local environmental effects	1	1	-	1	*3*
Governmental policy	2	-	-	-	*2*
Terminal market profitability	1	-	1	-	*2*
Land use near location	1	-	1	-	*2*
Regional economic development	-	-	-	2	*2*
Inland terminal OPEX	1	-	-	-	*1*
Traffic congestion	1	-	-	-	*1*
Local labor market	-	-	-	-	-
Local average wage level	-	-	-	-	-
Global environmental effects	-	-	-	-	-

Table G.1: Criteria selection survey results: Numbers of selections by experts.

Secondly, the survey gains insight in factors not observed in the literature but still considered to be important by industry experts. These additionally mentioned criteria are presented in Table G.2.

Stakeholder	Shipping line	Terminal user Intermodal operator	 Truck operator	Terminal operator	
Criterion		**Times mentioned**			***Total***
Local depot capacity	1	-	-	-	*1*
Uniqueness	1	-	-	-	*1*
Customer demand	-	-	-	1	*1*
Enabling modality shift	-	-	-	1	*1*
Anchor customer proximity	-	-	-	1	*1*
Development of supply-demand over time	-	-	-	1	*1*
Ability to offer ancillary services	-	-	-	1	*1*

Table G.2: Criteria selection survey results: Numbers of additional mentions by experts.

H Results of preference statement surveys

In this appendix the results of the preference statement survey are presented for each respondent. The tables display the *Best-to-Others (BO)* scores as well as the *Others-to-Worst (OW)* scores.

Shipping line respondent 1

Main criterion	**BO**	**OW**	**Subcriterion**	**BO**	**OW**
Cost and benefits	2	6	Inland terminal CAPEX	7	1
			Intermodal market profitability	1	7
			Total inland transport costs	1	6
Local market characteristics	1	8	Governmental policy	8	1
			Market proximity	1	8
			Market volume potential	1	8
			Regional transport/logistics competition	5	4
Technical characteristics	8	1	Expansion possibilities	8	1
			Local depot capacity	3	5
			Transport infrastructure network in area	1	8

Table H.1: Preference statement survey results: Shipping line 1

Shipping line respondent 2

Main criterion	**BO**	**OW**	**Subcriterion**	**BO**	**OW**
Cost and benefits	1	9	Inland terminal CAPEX	3	4
			Intermodal market profitability	1	7
			Total inland transport costs	7	1
Local market characteristics	3	6	Governmental policy	9	1
			Market proximity	8	3
			Market volume potential	1	9
			Regional transport/logistics competition	3	5
Technical characteristics	9	1	Expansion possibilities	9	1
			Local depot capacity	3	6
			Transport infrastructure network in area	1	9

Table H.2: Preference statement survey results: Shipping line 2

Shipping line respondent 3

Main criterion	BO	OW	Subcriterion	BO	OW
Cost and benefits	2	2	Inland terminal CAPEX	4	4
			Intermodal market profitability	1	9
			Total inland transport costs	9	1
Local market characteristics	1	5	Governmental policy	4	1
			Market proximity	1	4
			Market volume potential	2	3
			Regional transport/logistics competition	3	2
Technical characteristics	5	1	Expansion possibilities	1	5
			Local depot capacity	2	2
			Transport infrastructure network in area	5	1

Table H.3: Preference statement survey results: Shipping line 3

Terminal operator respondents 1, 2 and 3

Criterion	Respondent 1		Respondent 2		Respondent 3	
	BO	OW	BO	OW	BO	OW
Anchor customer proximity	2	4	3	5	1	9
Enabling modality shift	4	4	7	1	7	2
Inland terminal CAPEX	7	1	4	4	5	5
Market volume potential	2	5	1	7	4	7
Regional economic development	1	7	3	5	9	1
Regional transport/logistics competition	4	3	3	5	4	7
Total inland transport costs	3	4	6	2	1	9
Transport infrastructure network in area	3	5	5	3	9	2

Table H.4: Preference statement survey results: Terminal operators

Rail transport operator respondent 1 and 2

Criterion	Respondent 1		Respondent 2	
	BO	OW	BO	OW
Expansion possibilities	8	1	4	3
Inland terminal CAPEX	4	6	4	3
Market proximity	5	4	6	1
Market volume potential	1	8	1	6
Transport infrastructure network in area	3	7	1	6

Table H.5: Preference statement survey results: Rail transport operators

Truck transport operator respondent

Criterion	**BO**	**OW**
Expansion possibilities	8	2
Intermodal market profitability	3	7
Land use near location	9	1
Market proximity	2	8
Market volume potential	1	9
Regional transport/logistics competition	6	4
Terminal market profitability	5	5
Total inland transport costs	4	6

Table H.6: Preference statement survey results: Truck transport operator

I Consistency of comparisons

Although BWM always results in consistent comparisons, they are not always *fully* consistent (Rezaei, 2015). Therefore, Consistency Ratio threshold values from the study of Liang et al. (2019) are used to check the levels of consistency of the several comparisons made in this study. These threshold values are based on two parameters:

- Number of criteria considered in comparison
- Corresponding value of a_{BW}

The threshold values are displayed in Table I.1.

	Number of criteria						
a_{BW}	**3**	**4**	**5**	**6**	**7**	**8**	**9**
3	0,2087	0,2087	0,2087	0,2087	0,2087	0,2087	0,2087
4	0,1581	0,2352	0,2738	0,2928	0,3102	0,3154	0,3273
5	0,2111	0,2848	0,3019	0,3309	0,3479	0,3611	0,3741
6	0,2164	0,2922	0,3565	0,3924	0,4061	0,4168	0,4225
7	0,2090	0,3313	0,3734	0,3931	0,4035	0,4108	0,4298
8	0,2267	0,3409	0,4029	0,4230	0,4379	0,4543	0,4599
9	0,2122	0,3653	0,4055	0,4225	0,4445	0,4587	0,4747

Table I.1: Consistency Ratio thresholds for different combinations of numbers of criteria and a_{BW} (from Liang et al., 2019)

A comparison is considered to be consistent if the Consistency Ratio does not exceed the corresponding consistency threshold value. If the Consistency Ratio is larger than the corresponding consistency threshold value, the comparison is not consistent. In general, the closer the Consistency Ratio value is to 0, the more consistent the comparison is.

Table I.2 shows the Consistency Ratio value of the separate comparisons considered by each actor in this study. Corresponding threshold values and consistency based on (the violation of) these thresholds are also included.

Comparison by actor	$n_{criteria}$	a_{BW}	Threshold	CR	Consistency check
Shipping line 1 (global)	3	6	0,2164	0,1049	Consistent
Shipping line 1 (local c&b)	3	7	0,2090	0,1340	Consistent
Shipping line 1 (local market)	4	8	0,3409	0,3120	Consistent
Shipping line 1 (local technical)	3	8	0,2267	0,1924	Consistent
Shipping line 2 (global)	3	9	0,2122	0,1912	Consistent
Shipping line 2 (local c&b)	3	7	0,2090	0,1832	Consistent
Shipping line 2 (local market)	4	9	0,3653	0,2710	Consistent
Shipping line 2 (local technical)	3	9	0,2122	0,1912	Consistent
Shipping line 3 (global)	3	5	0,2111	0,0837	Consistent
Shipping line 3 (local c&b)	3	9	0,2122	0,1644	Consistent
Shipping line 3 (local market)	4	4	0,2352	0,2173	Consistent
Shipping line 3 (local technical)	3	5	0,2111	0,0837	Consistent
Terminal operator 1	8	7	0,4108	0,3072	Consistent
Terminal operator 2	8	7	0,4108	0,3072	Consistent
Terminal operator 3	8	9	0,4587	0,3589	Consistent
Rail transport operator 1	5	8	0,4029	0,3859	Consistent
Rail transport operator 2	5	9	0,4055	0,2792	Consistent
Truck transport operator	9	9	0,4747	0,3298	Consistent

Table I.2: Criteria comparison consistency check

J

Criteria weight intervals (numerical)

Actor	*Criterion*	Lower bound	Upper bound
	Inland terminal CAPEX	0,0245827949938	0,0263387089244
	Intermodal market profitability	0,1712016080071	0,1843709624838
	Total inland transport costs	0,1597881674631	0,1712016080473
	Governmental policy	0,0164657736975	0,0164657737054
Shipping line 1	*Market proximity*	0,1546868667380	0,1546868668505
	Market volume potential	0,1546868667147	0,1546868668271
	Regional transport/logistics competition	0,0429024176762	0,0429024176841
	Expansion possibilities	0,0403279577353	0,0403279577421
	Local depot capacity	0,1669599608564	0,1669599608600
	Transport infrastructure in area	0,3573034897902	0,3573034897946
	Inland terminal CAPEX	0,1727408744963	0,1727408744996
	Intermodal market profitability	0,4001757921689	0,4001757921739
	Total inland transport costs	0,0520833333265	0,0520833333333
	Governmental policy	0,0321875852410	0,0376901641523
Shipping line 2	*Market proximity*	0,0509392900827	0,0596475377313
	Market volume potential	0,3353117328228	0,3926344321026
	Regional transport/logistics competition	0,1350278660272	0,2065613918592
	Expansion possibilities	0,0195312499970	0,0195312499999
	Local depot capacity	0,0976562499986	0,0976562500003
	Transport infrastructure in area	0,1953124999986	0,1953125000004
	Inland terminal CAPEX	0,0614716894370	0,0614716894382
	Intermodal market profitability	0,1930244823741	0,1930244823756
	Total inland transport costs	0,0195766285988	0,0195766286009
	Governmental policy	0,0284138364764	0,0284138368544
Shipping line 3	*Market proximity*	0,1237209102146	0,1237209102364
	Market volume potential	0,0751759424785	0,0751759451594
	Regional transport/logistics competition	0,0467621086079	0,0467621108961
	Expansion possibilities	0,3611134991639	0,3611134991837
	Local depot capacity	0,1646978004261	0,1646978004474
	Transport infrastructure in area	0,0751158999395	0,0751158999443
	Expansion possiblities	0,0390661973069	0,0443462235998
Rail transport operator 1	*Inland terminal CAPEX*	0,1670047594955	0,1895764348039
	Market proximity	0,0913513937705	0,1277535818528
	Market volume potential	0,3799220028034	0,4312706955934
	Transport infrastructure in area	0,2269320066607	0,3063098063942
	Expansion possiblities	0,1138040748491	0,1138040874603
Rail transport operator 2	*Inland terminal CAPEX*	0,1138040825999	0,1138040874603

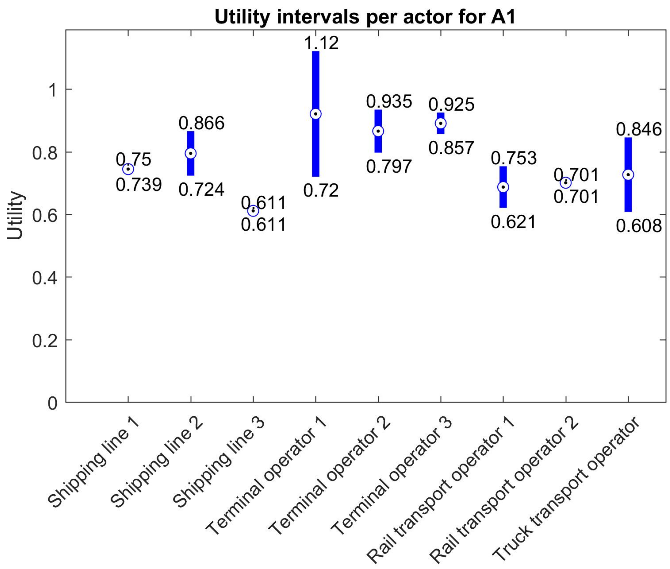
	Market proximity	0,0526315789158	0,0526315827420
	Market volume potential	0,3598800922144	0,3598801232771
	Transport infrastructure in area	0,3598801230115	0,3598801675947
Truck transport operator	*Expansion possiblities*	0,0253541829227	0,0473675108963
	Intermodal market profitability	0,1287640651046	0,2178532643295
	Land use near location	0,0226740843849	0,0281869481487
	Market proximity	0,1543529312345	0,2498250121623
	Market volume potential	0,2431814320425	0,3023073522774
	Regional transport/logistics competition	0,0518567120329	0,0702533196097
	Terminal market profitability	0,0742557493463	0,0923099218049
	Total inland transport costs	0,0979056587640	0,1312608247442
	Transport infrastructure in area	0,0294133097392	0,0561110150128
Terminal operator 1	*Anchor customer proximity*	0,0874391833525	0,1740695753380
	Enabling modality shift	0,0817026598987	0,1046589148472
	Inland terminal CAPEX	0,0286263983785	0,0366696481362
	Market volume potential	0,1180755041238	0,2078964359154
	Regional economic development	0,2331877222647	0,2987072146509
	Regional transport/logistics competition	0,0546404199492	0,1009568622316
	Total inland transport costs	0,0854689244252	0,1524980499364
	Transport infrastructure in area	0,1120591956893	0,1579816474807
Terminal operator 2	*Anchor customer proximity*	0,1355517007683	0,1621455718821
	Enabling modality shift	0,0345160214077	0,0376557796700
	Inland terminal CAPEX	0,0985122445701	0,1074734347972
	Market volume potential	0,2811639909273	0,3067401415757
	Regional economic development	0,1355517007689	0,1621455718856
	Regional transport/logistics competition	0,1355517007690	0,1621455718819
	Total inland transport costs	0,0400909683476	0,0619366981786
	Transport infrastructure in area	0,0645745306102	0,0788178919659
Terminal operator 3	*Anchor customer proximity*	0,2710224921485	0,2836335189680
	Enabling modality shift	0,0312298645874	0,0540970849911
	Inland terminal CAPEX	0,0785228674390	0,0899740491139
	Market volume potential	0,1276537958719	0,1335936921761
	Regional economic development	0,0249172680013	0,0260767006828
	Regional transport/logistics competition	0,1276537958719	0,1335936921761
	Total inland transport costs	0,2710224921485	0,2836335189594
	Transport infrastructure in area	0,0252488124839	0,0392790238432

Table J.1: Criteria weight intervals for each actor, rounded to 13 decimal points.

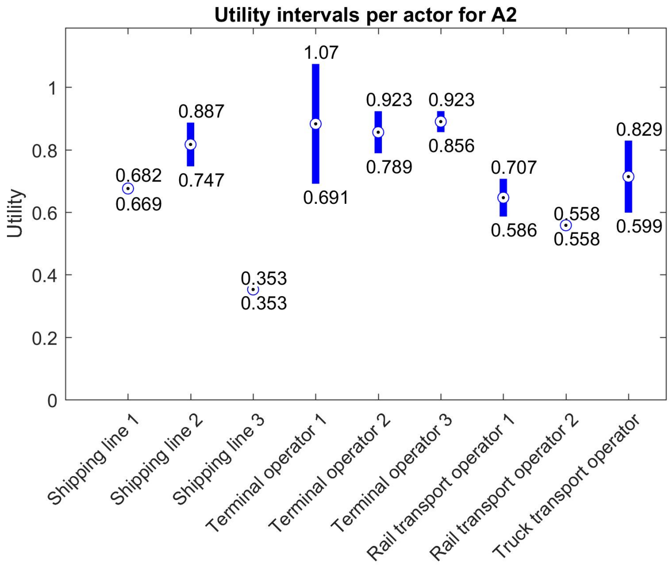
K

Utility interval analysis - Gross utility intervals of all alternatives

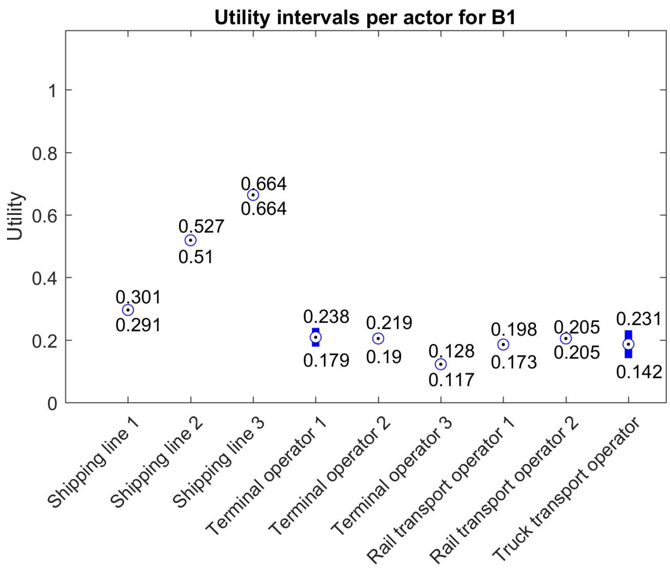
The gross utility intervals of all actors for alternative A1 are displayed in the following figure.



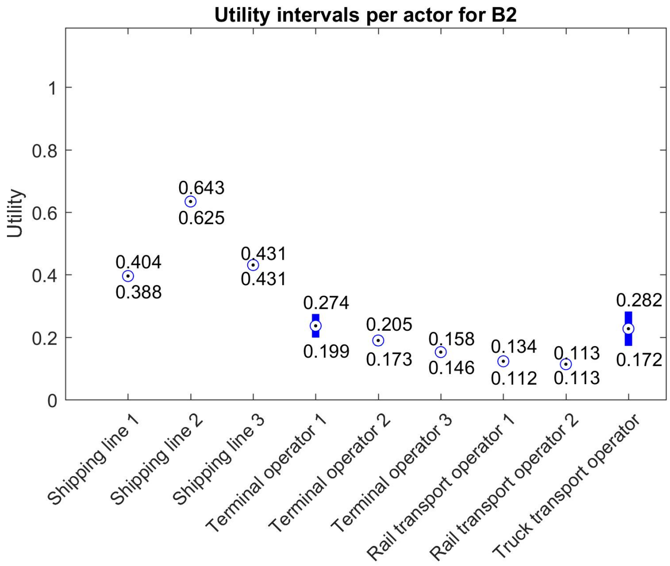
The gross utility intervals of all actors for alternative A2 are displayed in the following figure.



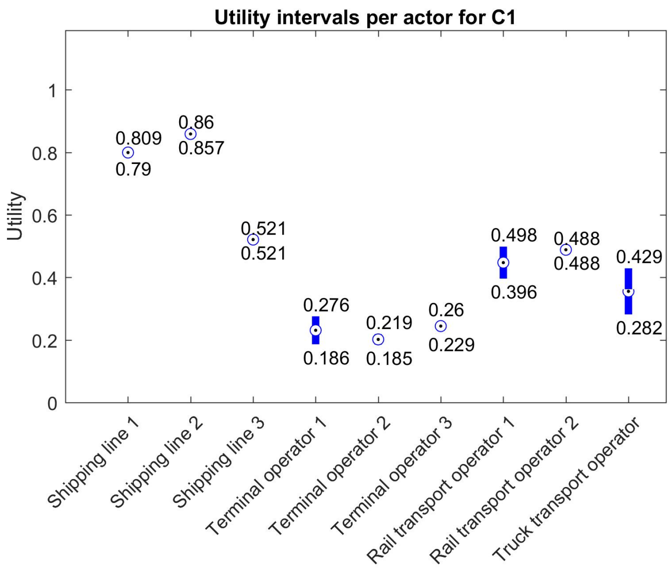
The gross utility intervals of all actors for alternative B1 are displayed in the following figure.



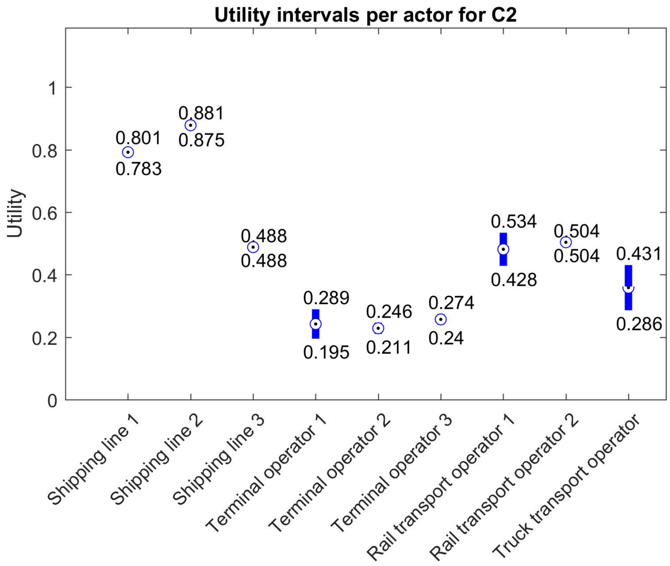
The gross utility intervals of all actors for alternative B2 are displayed in the following figure.



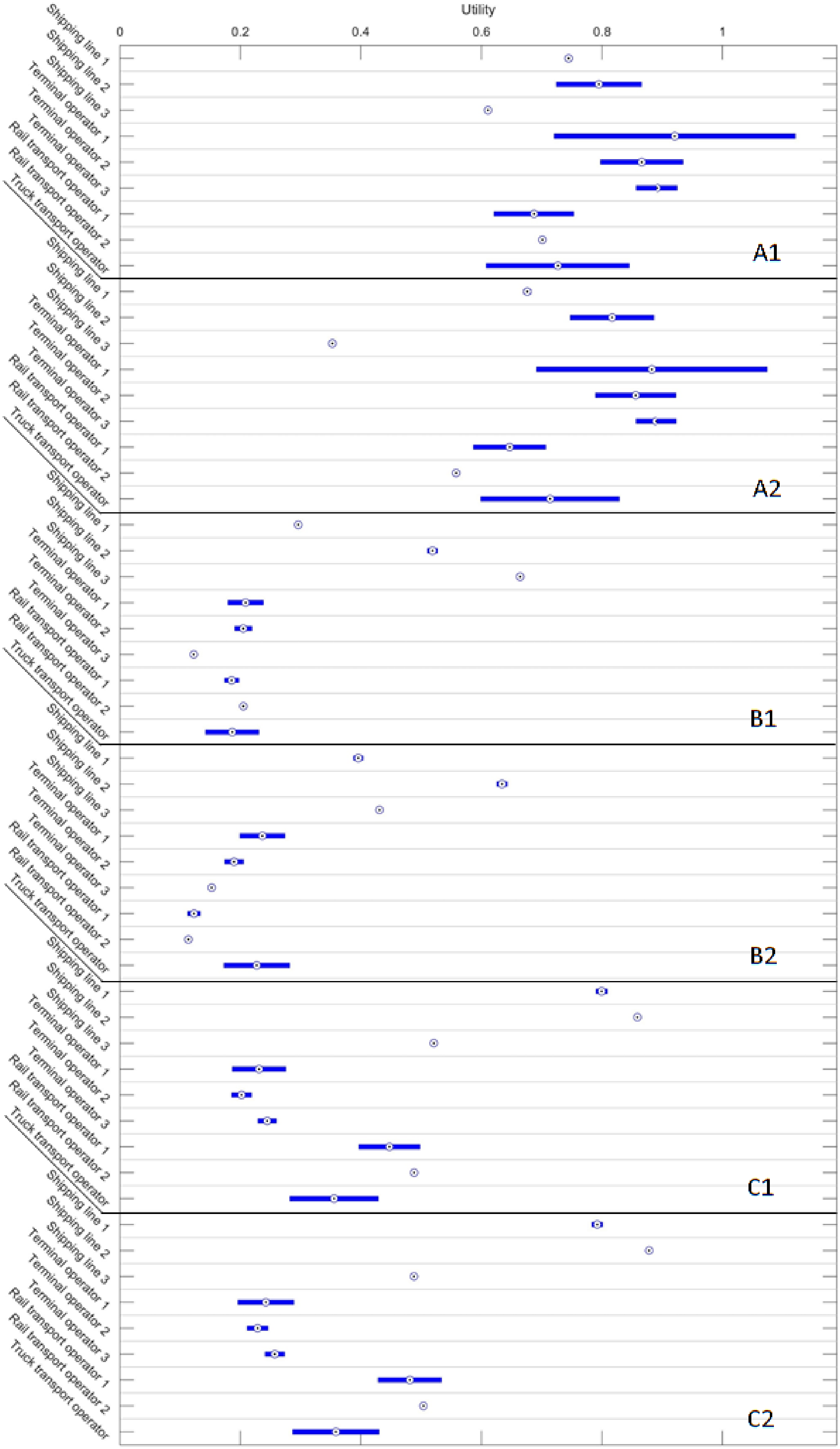
The gross utility intervals of all actors for alternative C1 are displayed in the following figure.



The gross utility intervals of all actors for alternative C2 are displayed in the following figure.



The following figure shows all actors' gross utility intervals for each alternative location.


Utility
0
0.2
0.4
0.6
0.8
1
Shipping line 1
Shipping line 2
Shipping line 3
Terminal operator 1
Terminal operator 2
Terminal operator 3
Rail transport operator 1
Rail transport operator 2
Truck transport operator
A1
A2
B1
B2
C1
C2

Scientific paper

Inland terminal location selection: Strengthening the position of the shipping line in the container port hinterland

Kyle Verhoeven[a,*], Jafar Rezaei[a], Bart Wiegmans[b], Fuqi Liang[a], Matej Vybiral[c]

[a] *Delft University of Technology, Faculty of Technology, Policy and Management. Jaffalaan 5, 2628 BX Delft, the Netherlands*
[b] *Delft University of Technology, Faculty of Civil Engineering and Geosciences. Mekelweg 5, 2628 CD Delft, the Netherlands*
[c] *A.P. Møller – Mærsk A/S, Boompjes 40, 3011 XB Rotterdam, the Netherlands*

Abstract

Purpose - As shipping lines aim at vertically integrate into the container port hinterland by offering inland transport and logistics services to their customers, the need for effective intermodal transport chain set-ups grows. Choosing a location for setting up inland terminals dedicated to the needs of the shipping lines and their customers contributes to these aims. The purpose of this paper is to develop an inland terminal location selection methodology, viewed from the perspective of the shipping line designing the inland transport chain, which additionally includes terminal operator and terminal user stakeholders and their corresponding objectives related to the inland terminal.
Design/methodology/approach - A literature review is performed to identify methods and factors used commonly for inland terminal location selection problems. Multi-Criteria Multi-Actor Criteria Analysis (MAMCA) is considered to take into account the varying stakeholders and their objectives, presenting the Best-Worst Method (BWM) to determine multi-optimal criteria weight intervals based on actor-specific sets and evaluations. By means of min - max aggregation of subsequent utility intervals, alternatives' final utilities are involving all actors' preferences in an equal manner.
Findings - The application of the methodology on a case study including six alternatives and three shipping line decision-makers, three terminal operator decision-makers and three terminal user decision-makers results in a most desirable inland terminal location based mainly on the high container volume potential related characteristics of the area.
Contribution - First of all, a non-conventional perspective of the shipping line with regards to the inland terminal location selection problem leads to an interesting point of view of the location problem. By considering MAMCA and the multi-optimality properties of the non-linear BWM model, actor-specific criteria sets instead of a fixed set of criteria for all stakeholders can be involved. This improves the flexibility of the decision-making process and the desirability of the results.

Keywords: Inland terminal location selection, MAMCA, BWM, multi-optimality, utility aggregation

1. Introduction

A major component of global container supply chains consists of hinterland transport. The importance of such inland transport legs are increasingly noticed by scholars [1, 2], as well as by shipping lines [3, 4]. As shipping lines were originally merely involved with maritime transport between seaports across the globe, they now increasingly try to integrate their ocean transport set-ups with connecting inland transport services in order to offer full door-to-door business propositions to their customers, which is called *vertical integration* [3]. By vertically integrating into the hinterland, shipping

*Corresponding author
Email addresses: verhoeven-k@hotmail.com (Kyle Verhoeven), j.rezaei@tudelft.nl (Jafar Rezaei), b.wiegmans@tudelft.nl (Bart Wiegmans), f.liang-2@tudelft.nl (Fuqi Liang), matej.vybiral@maersk.com (Matej Vybiral)

lines can improve coordination of container flows and inland repositioning tactics [3, 5, 6, 4], subsequently leading to increased (cost-)efficiency of provided hinterland operations. In turn, such efficient inland transport chain services enables attracting customers and increase their market share in and control on the hinterland.

With regards to cost-efficiency of the inland transport chain, *intermodal transport* has significant economic advantages due to the possibility to bundle containers on larger vehicles, reducing the costs per transported container [7]. A major component of intermodal transport is the inland terminal, at which containers get transshipped between truck and intermodal vehicle or vice versa. Because of the necessity of the transshipment operations for intermodal transport, the inland terminal considerably influences the cost-efficiency of the broader inland transport chain [8]. Therefore, active engagement with inland terminals by shipping lines enables them to effectively use these facilities in their inland transport configurations [4]. Since numerous competing actors also make use of these facilities (e.g. freight forwarders, logistics service providers and competing shipping lines), setting up an own inland terminal dedicated to the needs of the shipping line and its (potential) customers enables effective incorporation in a designed inland transport chain. Highly important is the location of the terminal, since it determines the attractiveness to use it based on the distances to the (potential) customers which influence transport times and costs. Therefore, this research is concerned with the location problem of the inland terminal to be set up by a shipping line. Since this location selection problem is derived from the specific purpose of the inland terminal to contribute to the shipping line's inland transport chain proposition, the location is viewed within the structure of the container port hinterland.

1.1. The inland terminal within the multi-layer structure of the container port hinterland

Based on the four-layer model [9], as applied to the container port hinterland, four interrelated hinterland layers are distinguished, consisting of a *logistical layer* in which transport services and chains are organized; a *transport layer* in which transport and transshipment operations take place; an *infrastructural layer* which contains the provision of transport and transshipment infrastructure; and a *locational layer* which contains the geographic locations of the infrastructure within the economic space of the hinterland (Figure 1.1).

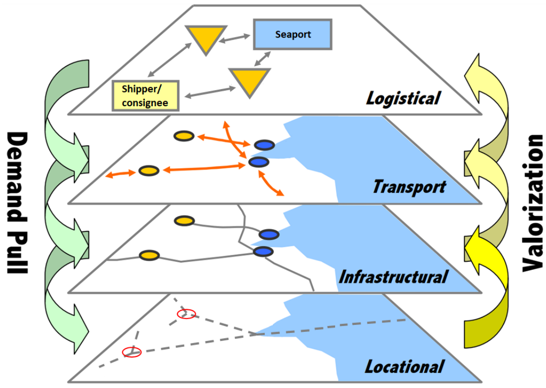


Figure 1: Four-layer structure of the container port hinterland [edited from 9]

Key actors and their activities with regards to the inland transport chain are identified. First of all, these include the shipping lines themselves as organizers of the inland transport and transshipment services (logistical layer). Secondly, transport operators perform the designed transport services, while terminal operators perform the designed transshipment operations (transport layer). Thirdly, transshipment infrastructure is provided and owned by the same inland terminal operators. Lastly, particularly in the sense of this study, the transshipment infrastructure location is selected by the shipping line (as organizer) and the inland terminal operator (as operator/owner). As each of these stakeholders has its own objectives with regards to the inland terminal, the evaluation and consequent selection of the location based on these objectives differ. The study takes into account these different objectives as follows:

- The shipping line evaluates an inland terminal location and makes the decision to select it based on the objective to *incorporate the terminal in the designed inland transport chain.*
- The terminal operator evaluates an inland terminal location and makes the decision to select it based on the objective *to ensure profitability of transshipment operations at the site.*
- The transport operator does not actually select the inland terminal location, since it is only *using* the facility in its own transport

operations. Nevertheless, as they and their operations are influenced by the decision, the broader inland transport chain is as well. Therefore, the terminal user's evaluation of the location, based on the objective to *use the inland terminal to optimize their transport operation scheme*, is also taken into account.

As the research is involved with multiple different actors and corresponding objectives, a *Multi-Criteria Decision Making* approach is proposed in order to deal with the location selection problem. A review of literature on such methods, specifically focused on the inland terminal location selection problem, is discussed in Section 2. Consequently, the methodology considered for this research is presented in Section 3. Section 4 involves the application of the proposed location selection methodology on a case study region. Based on the results of the case study, a conclusion including practical implications and recommendation for further research are discussed in Section 5.

2. Literature review

In contemporary literature on the inland terminal location selection problem, two general approaches are mostly applied; the *quantitative mathematical modeling* approach and the (semi-)qualitative multi-criteria analysis approach [10].

2.1. Quantitative methods for inland terminal location selection problems

Location optimization by means of mathematical modeling is mostly performed through a (transport) network approach. Classical approaches to location problems are the *p-Median problem* [11]; the *Fixed-Charge Facility problem* [12]; and the *p-Center problem* [13]. Such classical mathematical programming methods have been extended to more advanced location optimization techniques, e.g. *facility location under uncertainty*, *multiple-criteria location problems* and *hub location problems* [14]. Location optimization studies for inland terminals are mostly focused on minimizing costs, particularly for the transport operations [15, 16, 17, 18, 19, 20]. Some also explicitly include the terminal-related transshipment and handling costs [21, 22, 23]. Although mathematical optimization methods can be efficiently used to transform quantitative aspects of the location selection problem into useful results and are generally extendable to other settings, a drawback is the fact that qualitative information cannot easily be taken into account [24].

2.2. (Semi-)qualitative methods for inland terminal location selection problems

The use of qualitative data in decision-making studies is praised for it allowing the preservation of integrity and elimination of complexity [24]. However, it also brings limitations since qualitative analyses are prone to ambiguities and findings of qualitative studies are not easily extendable to other/wider subjects with the same level of certainty as quantitative studies. As a consequence, a large amount of studies make use of both quantitative and qualitative data. The combination of using both quantitative and qualitative data is usually facilitated by *Multi-Criteria Decision-Making (MCDM)* methods. These techniques make the qualitative data quantifiable and the different kinds of information able to be evaluated by relevant experts and compared to each other [25]. MCDM[1] involves a predetermined number of alternatives, each satisfying the objectives of a decision-maker to some extent. The method helps the decision-maker select the best objective-reaching solution from this set, according to the priority of each objective and the interactions between the objectives [26]. Generally, the approach is mathematically displayed in a matrix form [27]:

$$A = \begin{array}{c} \\ a_1 \\ a_2 \\ \vdots \\ a_m \end{array} \begin{array}{c} \begin{array}{cccc} c_1 & c_2 & \cdots & c_n \end{array} \\ \begin{pmatrix} p_{11} & p_{12} & \cdots & p_{1n} \\ p_{21} & p_{22} & \cdots & p_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ p_{m1} & p_{m2} & \cdots & p_{mn} \end{pmatrix} \end{array}$$

, in which $\{a_1, a_2, \cdots, a_m\}$ is the set of alternatives; $\{c_1, c_2, \cdots, c_n\}$ is the set of criteria on which the

[1]This literature review and research is focused on *Multi-Attribute Decision-Making (MADM)* or *discrete MCDM*, in most literature referred to with the global term *MCDM*, as a subset of Multi-Criteria Decision-Making. *Multi-Objective Decision-Making (MODM*, which is also categorized as a subset of Multi-Criteria Decision-Making, is not considered in the scope of this study.

[2]As the original data for various criteria differ in contentual and numerical characteristics, they have to be normalized making use of a common scale in order to be applicable and comparable

decision has to be based; and p_{ij} is the *normalized*[2] score of alternative i regarding corresponding criterion j. The normalized scores of p_{ij} add up to overall score V_i for alternative a_i by making use of the *Additive Value Function* [28]:

$$V_i = \sum_{j=1}^{n} w_j p_{ij}$$

, in which $w_j \geq 0, \sum w_j = 1$, represents a weight factor for criterion j. The best overall scoring a_i then represents the most desirable option from this set of alternatives, based on the degrees of importance given by the decision-maker which add value to the several criteria of the alternative.

MCDM approaches are used in multiple inland terminal location selection studies in order to take into account the preferences of (multiple) experts with regards to varying criteria involved with the selection process. Whereas some studies include only the perspectives of single decision-making experts [29, 30, 31], others apply broader perspectives based on the inputs of several experts with varying backgrounds combined [32, 33, 34]. Common characteristic of these multi-actor approaches for inland terminal location selection in particular as well as for multi-criteria decision studies in general is the fact that fixed decision criteria sets are used for all actors involved. This means that every actor evaluates the same criteria, regardless of the relevancy of particular factors with regards to the stakeholder's objective. Because of the differing stakeholders' objectives involved in many multi-criteria problems, criteria relevant to certain actors might also differ [35]. A useful methodology in which every stakeholder group can be assigned its own criteria set is *Multi-Actor Multi-Criteria Analysis (MAMCA)* [35, 36].

2.3. Multi-actor Multi-Criteria Analysis

The MAMCA methodology, as been graphically displayed in Figure 2, consists of seven steps.

- **Step 1:** Defining the problem and the alternatives submitted for evaluation. In some studies. alternatives are predetermined, whereas in others they have to be generated through specific techniques [37] or early involvement of stakeholders and their objectives [38].

- **Step 2:** Stakeholder analysis, in which the actors which are likely to use or get influenced by the researched system are examined.

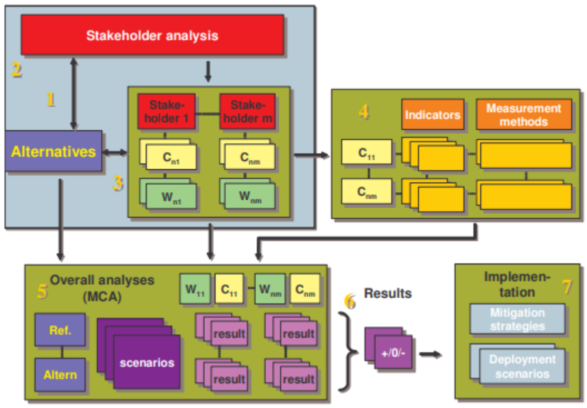


Figure 2: MAMCA methodology framework [from 36]

- **Step 3:** Determination of criteria by means of literature research [35] and further stakeholder interaction, e.g. through surveys [39]. Subsequent to determining the criteria they are weigthed, which is a fundamental parts of MCDM approaches in general and the MAMCA approach in particular. Multiple techniques for weighting criteria exist, of which a widely used one is the *Analytical Hierarchy Process (AHP)* [40, 41], in which weighting gets based on the arrangement of the relevant factors in a hierarchical order; the ultimate goal at the top level, specific alternatives at the bottom level and in between criteria and subcriteria. Other commonly used techniques include *Analytic Network Process (ANP)*, in which the hierarchy structure used in AHP is replaced by a network structure [42]; *TOPSIS* [43] and *VIKOR* [44], which are based on the compromise principle in which the chosen solution is supposed to have the shortest distance from the best solution as well as the longest distance from the worst solution; and *PROMETHEE* [45] and *ELECTRE* [46], which are based on the assessment of alternatives outranking each other. A recent development in MCDM techniques is the *Best-Worst Method (BWM)* [27, 47], in which the best (most desirable) and worst (least desirable) criteria are identified. Consequently, the best criterion is compared to the remaining criteria and the remaining criteria are compared to the worst criterion and weights are defined by minimizing the maximum absolute difference between the weight ratios and their corresponding comparisons.

- **Step 4:** Determine criteria indicators and measurement methods, in which the previously defined criteria are *operationalized* by means of determining the criteria metrics that can be used to measure whether or to what extent an alternative contributes to each individual criterion.

- **Step 5:** Overall analysis and ranking of alternatives, in which each alternative gets evaluated based on the different criteria weights and metrics (i.e. scores) for each stakeholder.

- **Step 6:** Results and sensitivity analysis, in which the elements with a clearly positive or clearly negative impact on the alternatives can be pointed out.

- **Step 7:** Implementation of the results.

A key component of the MAMCA methodology in particular and MCDM studies in general consists of the actual criteria used.

2.4. Factors typically considered in inland terminal location selection studies

Various factors used in multi-criteria inland terminal location selection problems are observed in the literature, of which several are further reviewed based on the fact that they are frequently mentioned by multiple authors and/or their applicability to the case study considered in this research. For this research, the factor review is structured according to the earlier introduced four-layer model considered to define the inland terminal location problem within the context of the container port hinterland. Factors used for inland terminal location selection affiliated with **logistical layer** aspects are mostly related to local market characteristics and related indicators. These are characteristics and indicators which influence the decisions involved in the organization of transport chains (at those locations). Often observed factors include *market volume potential* [29, 34, 48, 33, 49, 50, 51, 52, 32]; *governmental policies* [29, 31, 48, 25, 32, 51, 33]; *local labor market* characteristics [31, 49, 50, 25, 48]; *regional economic development* indicators [29, 34, 33, 51]; and *regional transport/logistics* characteristics [31, 25].

Factors used for inland facility location selection affiliated with **transport layer** aspects are directly related to the operational activities at and around the inland facility. These can be *conditions* under which these operations (have to) take place, but also effects as a consequence of such operations. *Transport costs* [32, 29] and *costs for operating the inland terminal* [29, 48] are observed, next to *traffic congestion* indicators [51, 50] (which can also be represented by e.g. delivery times [31]). Next to that, *environmental effects* of the transport/transshipment operations are indicated [30, 48, 34, 33, 31]

Factors used for inland facility location selection affiliated with **infrastructural layer** aspects are first of all related to local infrastructure and its characteristics. In this sense, *local transport infrastructure* metrics [29, 31, 34, 33, 49, 51, 52, 32]) are used to indicate the properties of the link infrastructure relevant to (potential) inland facilities in the area. Criteria with regards to the *development/construction* of the infrastructure are also commonly proposed. These factors are associated with the infrastructural layer since it also involves the *provision* of the infrastructures. Such factors are e.g. regarding investments costs for setting up an inland facility, such as *land costs* [48, 30, 32, 53]; *construction costs* [31, 48, 32]; or other types of *CAPEX* [29, 48]. Next to monetary factors, land availability in the form of *expansion possibilities* [31, 30, 48, 33, 53] is mentioned, next to the overall *spatial development* around an area [34, 48, 52].

Factors used for inland facility location selection affiliated with **locational layer** aspects are basically only involved with *proximity* measures. In that regard, the most observed as well as the most applicable factor with regards to this study is *market proximity* [31, 48, 30, 33, 53, 25], which encompasses the distances between the inland facility site and locations in the area at/to which a certain amount of container volumes are generated/attracted.

3. Multi-actor multi-criteria location selection methodology

Because of the multiple actors and multiple criteria involved in the decision-making process on inland terminal location selection, the research methodology considered for this study is largely based on the MAMCA framework, although adapted to the specific goal of the inland terminal selection problem as initiated by the shipping line in order to be contributive to its designed inland transport chain.

3.1. Research Step 1: Definition of the location selection problem

The first step of the research methodology involves the preparation of the multi-actor multi-criteria decision-making study by defining the inland terminal location selection problem of the particular case study considered. This is done by determining the geographical scope of the study, determining the alternatives within this scoped region to be submitted for evaluation and determining the experts from the shipping line, terminal operator and terminal user stakeholders to be included in the study for their evaluation input.

3.2. Research Step 2: Determination of criteria and criteria weights

The second step of the research methodology is subdivided into *Step 2a: Determination of criteria*; and *Step 2b: Determination of criteria weights*. The subdivision is made to emphasize the importance of considering actor-specific decision criteria sets as well as determining the weights of these criteria, for which the Best-Worst Method (BWM) is used. In that regard, the combination of using actor-specific criteria by using the MAMCA framework and the use of BWM for calculating the optimal criteria weights contributes to the contemporary literature on multi-actor multi-criteria decision-making.

3.2.1. Research Step 2a: Determination of criteria

The basis of the criteria selection procedure is formed by the criteria observed in the literature review. Through a *criteria selection survey*, a list containing the observed criteria is sent to and assessed by the experts as determined in Step 1. They are asked to indicate the criteria they find most important for evaluating and selecting a location for an inland terminal. Based on these indications, a list of relevant decision criteria for each stakeholder is developed.

3.2.2. Research Step 2b: Determination of criteria weights using Best-Worst Method

The Best-Worst Method (BWM) is used for calculating the decision criteria weights. The original BWM involves a non-linear model for calculating optimal criteria weight values as well as a consistency ratio in order to check the reliability of the comparisons made by the decision-maker [27]. Next to the original non-linear model, a linear approximation is proposed [47] as well as a multiplicative version which can be transformed into an equivalent linear program as well [54]. An extension of the method to group decision-making is also presented [55], besides hybrid extension such as *BWM-VIKOR* [56] and *BWM-MULTIMOORA* [57]. Applications of the method include a.o. transport and logistics [58, 59], supply chain structures [60] and management [61, 62], energy systems [63] and risk management [64]. Favorability of BWM over other MCDM methods is first of all based on the fact that the method involves a criteria comparison procedure which is relatively clear to involved decision-makers, which results in more consistent pairwise comparisons [27]. The use of integers rather than e.g. fractions in the BWM approach is also considered to be less problematic [65]. Next to that, BWM requires *fewer* comparisons for estimating consistent weights compared to e.g. the commonly used AHP method. Based on the relatively few amounts of data as well as the relatively low computation times needed to result in reliable weights, BWM is considered to be a rather data- and time-efficient technique [27]. Furthermore, particularly beneficial to the aims of this study is the possibility to take into account multi-optimality in not-fully consistent cases with more than three criteria or alternatives when using the (original) non-linear BWM model [47]. Multi-optimal solutions increase the flexibility in studies where multiple decision-makers are involved, resulting in higher chances for desirable compromise solutions compared to models resulting in unique solutions.

Estimating the criteria weights w_j consists of two main steps. First of all, *criteria preference statements* need to be performed by the corresponding experts in order to obtain relative preferences of the criteria relevant to the particular stakeholder. Through a preference statement survey, the stakeholders are asked to indicate which one of the decision criteria they find most important (**Best**) and which one of the decision criteria they find least important (**Worst**) for evaluating inland terminal locations. Next to that, they are asked to use a scoring system (ranging from scores of 1 - 9) in order to indicate;

- the preference of the **best** criterion over **all other** criteria. This results in a *best-to-others (BO) vector*: $A_B = (a_{B1}, a_{B2}, ..., a_{Bn})$, where a_{Bj} indicates the preference of the best criterion B over criterion j.

- the preference of the **all other** criteria over the **worst** criterion. This results in an *others-to-worst (OW) vector*: $A_W = (a_{1W}, a_{2W}, ..., a_{nW})$, where a_{jW} indicates the preference of criterion j over the worst criterion W.

The next step in the weight determination contains the calculation of the optimal weights w_j^*. The optimal weights for the criteria are determined by setting the conditions where for each pair of w_B/w_j and w_j/w_W, $w_B/w_j = a_{Bj}$ and $w_j/w_W = a_{ajW}$. To satisfy these conditions for all j, a solution in which the maximum absolute differences $\left|\frac{w_B}{w_j} - a_{Bj}\right|$ and $\left|\frac{w_j}{w_W} - a_{jW}\right|$ for all j are minimized, formulated by the following model:

$$\begin{aligned}
&\min \max_j \left\{ \left|\frac{w_B}{w_j} - a_{Bj}\right|, \left|\frac{w_j}{w_W} - a_{jW}\right| \right\} \\
&\text{subject to:} \\
&\sum_j w_j = 1, \\
&w_j \geq 0, \forall j
\end{aligned} \tag{1}$$

Model 1 gets converted into model:

$$\begin{aligned}
&\min \xi \\
&\text{subject to:} \\
&\left|\frac{w_B}{w_j} - a_{Bj}\right| \leq \xi, \forall j \\
&\left|\frac{w_j}{w_W} - a_{jW}\right| \leq \xi, \forall j \\
&\sum_j w_j = 1 \\
&w_j \geq 0, \forall j
\end{aligned} \tag{2}$$

, which is solved accordingly to obtain optimal weights $w_1^*, w_2^*, ..., w_n^*$ and ξ^*.

To assess the reliability of the comparisons, the *Consistency Ratio* [27] is considered. A comparison is fully consistent when $a_{Bj} \times a_{jW} = a_{BW}, \forall j$. As full consistency is an unrealistic expectation, a *Consistency Index* (Table 1) is used to calculate the level of consistency, i.e. the *Consistency Ratio*. In general, the closer the Consistency Ratio value is to 0, the more consistent a comparison is. Eventually, to assess if comparisons are consistent or not based on the Consistency Ratio value, consistency threshold values are considered [66]. These threshold values are based on the number of criteria considered in the comparison and on the corresponding value of a_{BW}, as displayed in Table 2. A comparison is considered to be consistent if the Consistency Ratio does not exceed the corresponding consistency threshold value. If the Consistency Ratio is larger than the corresponding consistency threshold value, the comparison is not consistent.

As multiple decision criteria per actor-specific set are considered, the BWM model can result in multiple *optimal* values for the weight factors [47]. Since each optimization corresponds to an approximation of an optimal setting of criteria weight factors, each optimization is considered to represent the real-life relative preferences of the decision-makers in an optimal way as well. Therefore, it is preferred to take into account all these optimal weight values instead of single solutions. The use of *weight intervals* enables taking into account these multiple optimal solutions by representing each solution within the range of the minimum optimal solution and the maximum optimal solution for the criterion weight determination. The lower and upper bounds of the weight intervals, i.e. $w_j^{\min}$ and $w_j^{\max}$, are calculated after having solved Model 2, by solving models:

$$\begin{aligned}
&\min w_j \\
&\text{subject to:} \\
&\left|\frac{w_B}{w_j} - a_{Bj}\right| \leq \xi^*, \forall j \\
&\left|\frac{w_j}{w_W} - a_{jW}\right| \leq \xi^*, \forall j \\
&\sum_j w_j = 1 \\
&w_j \geq 0, \forall j
\end{aligned} \tag{3}$$

$$\begin{aligned}
&\max w_j \\
&\text{subject to:} \\
&\left|\frac{w_B}{w_j} - a_{Bj}\right| \leq \xi^*, \forall j \\
&\left|\frac{w_j}{w_W} - a_{jW}\right| \leq \xi^*, \forall j \\
&\sum_j w_j = 1 \\
&w_j \geq 0, \forall j
\end{aligned} \tag{4}$$

a_{BW}	1	2	3	4	5	6	7	8	9
Consistency Index	0,00	0,44	1,00	1,63	2,30	3,00	3,73	4,47	5,23

Table 1: Consistency Index values [from [27]]

	Number of criteria						
a_{BW}	**3**	**4**	**5**	**6**	**7**	**8**	**9**
3	0,2087	0,2087	0,2087	0,2087	0,2087	0,2087	0,2087
4	0,1581	0,2352	0,2738	0,2928	0,3102	0,3154	0,3273
5	0,2111	0,2848	0,3019	0,3309	0,3479	0,3611	0,3741
6	0,2164	0,2922	0,3565	0,3924	0,4061	0,4168	0,4225
7	0,2090	0,3313	0,3734	0,3931	0,4035	0,4108	0,4298
8	0,2267	0,3409	0,4029	0,4230	0,4379	0,4543	0,4599
9	0,2122	0,3653	0,4055	0,4225	0,4445	0,4587	0,4747

Table 2: Consistency Ratio thresholds for different combinations of numbers of criteria and a_{BW} [from [66]]

Eventually, the minimum and maximum weight values for criterion j are used to form weight interval $W_j = [w_j^{\min}, w_j^{\max}]$, of which the center as derived through $w_j^* = (\min w_j + \max w_j)/2$ can be used as a representative weight for criterion j [67]. The intervals are generated for each stakeholder k with corresponding stakeholder-specific criteria. Thus ultimately, a collection of weight intervals W for each criterion j from each stakeholder k is generated: W_j^k.

The criteria of the different actors from the same stakeholder type are aggregated in order to get an indication of the common notion between these related actors. Aggregating by making use of a *min-max* function, which basically looks for the minimum of the maximum differences between the value to be determined for w_j^{agg} and each actor's utility value $w_j^k \in [w_j^{k,\min}, w_j^{k,\max}]$, all weight values within the ranges of these intervals are taken into account equally, thus the common notion is most optimally supported by each actor's inputs. Based on the criteria weights w_j^k from each actor k, an aggregate value w_j^{agg} is determined. This is done by solving the following min - max model:

$$\begin{aligned} &\min \max \left| w_j^{agg} - w_j^k \right| \\ &\text{subject to:} \\ &w_j^{\min} \leq w_j^k \leq w_j^{\max}, \forall i, k \end{aligned} \tag{5}$$

This model is converted to the following model:

$$\begin{aligned} &\min \omega \\ &\text{subject to:} \\ &\left| w_j^{agg} - w_j^k \right| \leq \omega, \forall j, k \\ &w_j^{\min} \leq w_j^k \leq w_j^{\max}, \forall i, k \end{aligned} \tag{6}$$

Solving Model 6 results in the aggregate weights of the stakeholder types based on the individual actors' inputs.

3.3. Research Step 3: Criteria operationalization and data gathering

Next to calculating the criteria weights, the outcomes of Research Step 2a are also used for determining the criteria indicators and measurement methods by means of *operationalization*. Determining the measure units makes it possible to know the types of data that have to be gathered in order to sufficiently represent the criteria, to define the criteria in comparable metrics and to determine if factors are *benefit criteria* or *cost criteria*.

3.4. Research Step 4: Determination of utilities using Multi-Criteria Analysis

Research Step 4 consist of the Multi-Criteria Analysis (MCA) performed on the inland terminal location selection study using the inputs from Step 1 to 3. The goal of the MCA is to determine the utilities of each alternative based on the weighted criteria and data. Each actor's criterion weight interval W_j^k gets multiplied with corresponding data score p_{ij} to result in utility intervals for each actor k. A pre-processing step of this operation is the determination of criterion scores p_{ij} by means of *normalization* of the corresponding data. max - min normalization is considered, in which the scale measurement of the data lies precisely between 0 and 1 for each criterion, supporting the preservation of the relationships between the original data [68, 69, 70]. max - min normalization is applied on each data point r_{ij}, as follows:

$$p_{ij} = \begin{cases} \frac{r_{ij} - r_j^{\min}}{r_j^{\max} - r_j^{\min}} & \text{if benefit criteria} \\ \\ \frac{r_j^{\max} - r_{ij}}{r_j^{\max} - r_j^{\min}} & \text{if cost criteria} \end{cases} \quad (7)$$

Eventually, the normalized scores p_{ij} can be used further in combination with the earlier computed weight intervals W_j^k to calculate the utility intervals. The utility intervals are computed based on interval arithmetic as follows:

$$p_{ij} W_j^k = \left[\, p_{ij} w_j^{k,\min},\ p_{ij} w_j^{k,\max} \,\right] \quad (8)$$

These separate actor-specific utility intervals for each criterion for each alternative are the *utility sub-intervals*. Consequently, the lower bounds and upper bounds of the sub-intervals $p_{ij} W_j^k$ are summed according to the following interval operation:

$$\sum_{j=1}^{J} p_{ij} W_j^k = \left[\sum_{j=1}^{J} p_{ij} w_j^{k,\min},\ \sum_{j=1}^{J} p_{ij} w_j^{k,\max}\right] \quad (9)$$

This operation generates actor-specific *gross utility intervals*, in which the lower and upper bounds result from actor k's criteria evaluations: $[V_i^{k,\min}, V_i^{k,\max}]$. With the gross utility intervals of each actor k (with a total amount of actors $k = 1, 2, \cdots, k$) for each alternative i known, each alternative's set of gross utility intervals is used to determine the overall final utility score for the alternative. For the same line of reasoning as applied to the weight aggregation procedure (Model 5), aggregation of utility scores is applied, resulting in the alternative's aggregate utility value V_i^{agg}. By aggregating the utility intervals, each actor's individually assigned utility score are taken into account in an equal manner, thus individual preferences are equally represented. To determine the final aggregated utility value, the following model is solved:

$$\begin{aligned} &\min \max \left| V_i^{agg} - V_i^k \right| \\ &\text{subject to:} \\ &V_i^{\min} \le V_i^k \le V_i^{\max}, \forall i, k \end{aligned} \quad (10)$$

This model is converted to the following model:

$$\begin{aligned} &\min \zeta \\ &\text{subject to:} \\ &\left| V_i^{agg} - V_i^k \right| \le \zeta, \forall i, k \\ &V_i^{\min} \le V_i^k \le V_i^{\max}, \forall i, k \end{aligned} \quad (11)$$

The resulting scores can consequently be ranked and a most desirable alternative can be selected based on this ranking.

3.5. Research Step 5: Sensitivity analysis

Based on the results from the MCA, the elements which have clearly positive or negative impacts on the study results are pointed out. By means of a sensitivity analysis, the model inputs which highly influence the final results can be tested. The first goal of the sensitivity analysis is to assess the influences of the stakeholders' preferences on the outcomes of the model. Accordingly, it is tested to which extent the inputs of specific stakeholders involved in the study determine the final aggregate utility scores. In this regard, the sensitivity analysis serves as an alternative to *expert validation* in order to assess the accuracy of the results. The second goal of the sensitivity analysis is to assess the influences of particular criteria involved in the study. Accordingly, criteria which distinctively contribute to the utility of (a) certain alternative(s) are tested in order to assess their impacts on the final ranking of all alternatives. Each parameter adjustment is represented by a certain *sensitivity analysis scenario*, which involves the particularly specified model parameter settings. In this regard, the model results of of Step 5 are represented by *Scenario 0*, to which the sensitivity scenario results are compared.

3.6. Research Step 6: Location selection

Based on the results of the initial model (Step 5) and the insights gained from the sensitivity analysis (Step 6), final recommendations on the inland terminal location selection problem are given. These are discussed at the end of this paper.

4. Application of multi-actor multi-criteria location selection model

The previously described research methodology is applied to the inland terminal location selection case study of shipping line Maersk. In this section the results of the case study application are discussed.

4.1. Results of Research Step 1: Location selection problem definition

The case study region on which the methodology is applied consists of six alternative locations to be submitted for evaluation, as depicted in Figure 3.

Figure 3: This figure is not available due to confidentiality reasons.

Next, relevant stakeholders are selected. Besides having shipping line and terminal operator stakeholders, two types of terminal user stakeholders are taken into account: Rail transport operators, which are considered as experts on main haulage operations using inland terminals; and truck transport operators, which are considered as experts on pre-/end-haulage operations musing inland terminals. A selection of relevant employees of Maersk and of relevant vendors[3] of the company are considered to represent the stakeholder expert groups. In total, 12 shipping line experts, 8 terminal operator experts and 5 terminal user actors are taken into account.

4.2. Results of Research Step 2a: Decision criteria

The actor-specific decision criteria are based on the particular expert evaluations of the criteria as observed in the literature gathered through the criteria selection survey. Next to the observed criteria from the literature, this survey also includes two additional criteria as proposed to be relevant by the case shipping line Maersk (although not observed in the literature review); *Intermodal market profitability* and *Terminal market profitability.* Literature criteria taken into account for each stakeholder are based on the amounts of times they are mentioned by each expert. Next to that, additional criteria as proposed by the experts are considered for the study as well, if possible and applicable to the study goal. The resulting criteria taken into account for each actor based on their survey responses are given in Table 3. Criteria which are additionally added based on the experts inputs are displayed in bold and with *.

4.3. Results of Research Step 2b: Criteria weights

In step 2b, the identified criteria are further evaluated in order to determine weight factors for each stakeholder by means of BWM. In this regard, a preference statement survey is sent to the expert group, in which they indicate the *most important* (Best) criterion; the *least important* (Worst) criterion; the relative preferences of the remaining criteria compared to the Best criterion; and the relative preferences of the Worst criterion compared to the remaining criteria. Based on the survey, eventually filled out by nine respondents, criteria weight intervals for each stakeholder are calculated by means of solving the non-linear BWM model with the respective preference statement inputs. An example showing such weight intervals is given in Figure 7, in which overlapping optimal weight values for the criteria can be clearly indicated. Next to calculating the weight intervals, the comparison consistencies are checked by means of the consistency threshold values. This consistency check, which is concluded with the notion that all made comparisons are sufficiently consistent, is presented in Table 4[4].

The results of the determined weight intervals for all stakeholders except for the truck transport operator (since there is only one set of weight intervals for this stakeholder) are discussed based on the *aggregate* weight values derived from these intervals. First of all, the aggregate weights of the shipping line actors are discussed, as presented in Figure 4.

[3]The vendors are the supplier companies of the shipping line, i.e. the terminal and transport operators performing the inland services as offered by Maersk.

[4]Note that because the amount of shipping line criteria exceeds nine, the criteria are categorized into larger criteria categories in order to be sufficiently evaluated and processed in the BWM procedure [27].

Criterion	Stakeholder Shipping line	 Terminal operator	 Rail transport operator	 Truck transport operator
Anchor customer proximity*		x		
Enabling modality shift*		x		
Expansion possibilities	x		x	x
Governmental policy	x			
Inland terminal CAPEX	x	x	x	
Intermodal market profitability	x			x
Land use near location				x
Local depot capacity*	x			
Market proximity	x		x	x
Market volume potential	x	x	x	x
Regional economic development		x		
Regional transport/logistics competition	x	x		x
Terminal market profitability				x
Total inland transport costs	x	x		x
Transport infrastructure network in area	x	x	x	x

Table 3: Criteria to be taken into account in the study based on the criteria selection survey results

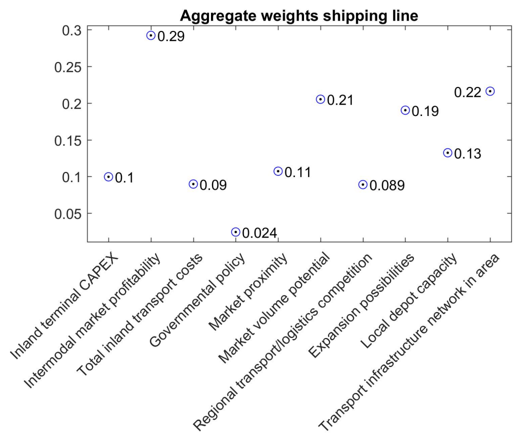


Figure 4: Aggregate weights of shipping line actors

The aggregate weight calculation results show *Intermodal market profitability*[5] to be the most impoertant factor. Second highest scoring criterion is *Transport infrastructure network in area*, which complies with the findings in [52] who observes a similar rank for the infrastructure factor as well. Closely following is *Market volume potential*. This is in line with the evaluated weight for this factor found in [34], however higher than found in [52]. Relatively poor scoring, yet not lowest, is *Total inland transport costs*, which is consistent with the findings in [34]. The same holds for the relatively low score of *Regional transport/logistics competition* and the corresponding literature [31]. The lowest scoring criterion based on the aggregate weight value is *Governmental policy*, mostly due to it being poorly evaluated by by all shipping line respondents. Relatable decision-maker evaluation as observed in [31] shows a much higher preference for this factor.

The aggregate weights of the terminal operator actors are presented in Figure 4. The highest scoring aggregate weight for *Anchor customer proximity*[5], closely followed by *Market volume potential* (which might suggest a direct relationship between the anchor customers and the local container volume potentials as perceived by the terminal operators). The relatively high aggregated score of *Market volume potential* is similar as been observed in [34] and [48]. *Enabling modality shift*[5] and *Inland terminal CAPEX* have the lowest aggregate scores. The low scoring criterion of *Inland terminal CAPEX* is interesting; firstly, it is evaluated much higher by terminal operators as observed in [48]; secondly, the relative importance of all the other factors compared to the investment costs thus im-

[5]Since this criterion is not observed in the literature, it cannot be compared to the findings of the literature review.

Comparison by actor	$n_{criteria}$	a_{BW}	Threshold	CR	Consistency check
Shipping line 1 (global)	3	6	0,2164	0,1049	Consistent
Shipping line 1 (local c&b)	3	7	0,2090	0,1340	Consistent
Shipping line 1 (local market)	4	8	0,3409	0,3120	Consistent
Shipping line 1 (local technical)	3	8	0,2267	0,1924	Consistent
Shipping line 2 (global)	3	9	0,2122	0,1912	Consistent
Shipping line 2 (local c&b)	3	7	0,2090	0,1832	Consistent
Shipping line 2 (local market)	4	9	0,3653	0,2710	Consistent
Shipping line 2 (local technical)	3	9	0,2122	0,1912	Consistent
Shipping line 3 (global)	3	5	0,2111	0,0837	Consistent
Shipping line 3 (local c&b)	3	9	0,2122	0,1644	Consistent
Shipping line 3 (local market)	4	4	0,2352	0,2173	Consistent
Shipping line 3 (local technical)	3	5	0,2111	0,0837	Consistent
Terminal operator 1	8	7	0,4108	0,3072	Consistent
Terminal operator 2	8	7	0,4108	0,3072	Consistent
Terminal operator 3	8	9	0,4587	0,3589	Consistent
Rail transport operator 1	5	8	0,4029	0,3859	Consistent
Rail transport operator 2	5	9	0,4055	0,2792	Consistent
Truck transport operator	9	9	0,4747	0,3298	Consistent

Table 4: Criteria comparison consistency check

plies a relatively high value of sufficient (local) market conditions for the inland terminal to be successful.

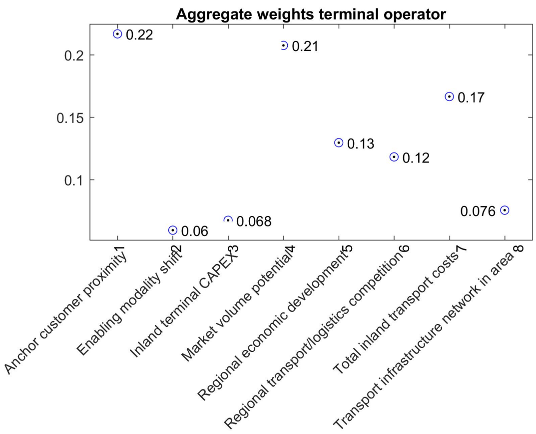


Figure 5: Aggregate weights of terminal operator actors

The aggregate weights of the rail transport operator actors are presented in Figure 6.

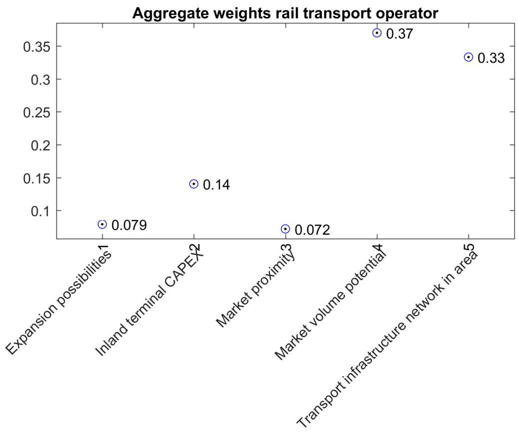


Figure 6: Aggregate weights of rail transport operator actors

The two most important criteria as perceived by rail transport operator actors are *Market volume potential* and *Transport infrastructure network in area*. This is higher than as been observed in [34], in which both these factors get evaluated averagely by the transport operator experts. However, the high evaluations for both these factors are in line with the findings in [49][6]. *Inland terminal*

[6]It must be noted that the decision-making experts in this study are undefined, thus it cannot be assessed if their perspectives are comparable to those of the rail transport operator.

CAPEX is rated relatively poorly, which is in line with the findings in [32] (although these findings are based on combined stakeholder inputs, not specifically from terminal user experts). The low score for *Market proximity* complies with the evaluation of this factor by terminal users as observed in [48]. As for the lowest score for *Expansion possibilities*, this criterion is not being assessed by comparable decision-making experts in the literature.

The weights *intervals* of the truck transport operator actors are presented in Figure 7. Since there is only one truck transport operator actor, weights do not have to be aggregated.

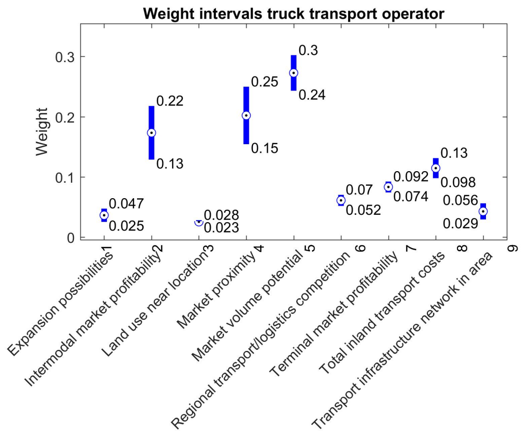


Figure 7: Weight intervals of truck transport operator actors

The highest scoring criterion is *Market volume potential*, which conforms with the evaluations of this factor by the rail transport operator actors. *Market proximity* is scores second best, which is interesting because this factor is evaluated much less by the shipping line and rail transport operator actors (as well as by the terminal user decision-makers in [48]). A possible explanation for this is the fact that the costs for truck transport are more sensitive to distance, which results in a higher importance of the proximity of customers for the operations of this stakeholder. *Intermodal market profitability*[5] is ranked third. The evaluation of *Total inland transport costs* being slightly below average is in line with the findings in [34] on this factor. However, in [48] this factor is evaluated higher by terminal user experts. The three lowest scoring criteria are *Land use near location*, *Expansion possibilities* and *Transport infrastructure network in area*, of which the weight values lie very close to each other. Especially the latter poorly scored criterion regarding the infrastructure is interesting, since it is observed as more important in [34], but even more since truck transport operators are assumed to be highly dependent on this infrastructure for their own operations/business.

4.4. Results of Research Step 3: Operationalized criteria and data

The operationalization of the involved criteria leads to data gathering methods and eventually to a collection of quantitative data corresponding to each criterion for each alternative. The original data values are are not included in this paper. However, the results of the data normalization procedure as performed in the next Research Step are presented in Table 5.

4.5. Results of Research Step 4: Overall ranking of alternatives based on Multi-Criteria Analysis

As been mentioned previously, the first operation of this research step involves the normalization of the data using max - min normalization. The results of this procedure are given in Table 5.

The normalized data in combination with the criteria weight intervals as determined in Step 2b are used to calculate the utility scores assigned to the alternatives. The separate utilities based on each stakeholder's criterion preferences and corresponding data are summed into a set of gross utility weight intervals for each alternative, after which these are aggregated using min - max model 11. These aggregate utility scores for each alternative are presented in Figure 8.

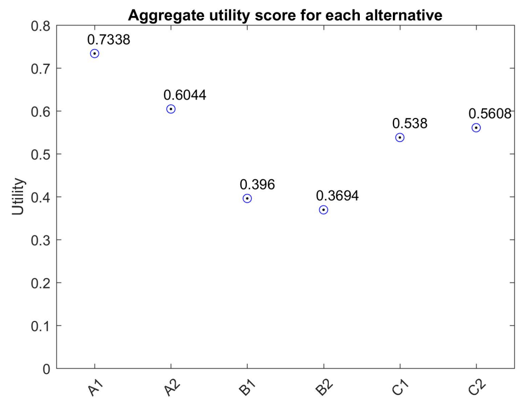


Figure 8: Aggregate utility scores of alternatives

Based on these aggregates, the highest ranked alternative is A1 with a score of 0,7338, which is almost 21% higher than second best alternative A2.

Criterion	Alternative					
	A1	A2	B1	B2	C1	C2
Anchor customer proximity	1,0000	0,9139	0,0767	0,0767	0,0000	0,0000
Enabling modality shift	1,0000	0,9422	0,0000	0,0000	0,0430	0,0735
Expansion possibilities	0,8006	0,0000	1,0000	0,1681	0,0989	0,0000
Governmental policy	1,0000	1,0000	1,0000	1,0000	0,0000	0,0000
Inland terminal CAPEX	0,0000	0,3333	0,7778	0,4444	0,8889	1,0000
Intermodal market profitability	0,0000	0,0829	0,6111	1,0000	0,9237	0,8890
Land use near location	1,0000	1,0000	1,0000	0,0000	0,0000	0,0000
Local depot capacity	0,0000	0,0000	0,5806	0,5806	1,0000	1,0000
Market proximity	0,8932	1,0000	0,0460	0,0501	0,0000	0,0013
Market volume potential	1,0000	0,9433	0,0000	0,0044	0,0447	0,1000
Regional economic development	1,0000	1,0000	0,6061	0,6061	0,0000	0,0000
Regional transport/logistics competition	1,0000	1,0000	0,1538	0,1538	0,0000	0,0000
Terminal market profitability	0,2850	0,2850	0,0000	0,0000	1,0000	1,0000
Total inland transport costs	0,9586	1,0000	0,0000	0,1941	0,4671	0,4498
Transport infrastructure network in area	0,5634	0,3556	0,0000	0,1097	1,0000	0,9834

Table 5: Normalized data scores for all criteria sets

The high score of A1 is mostly based on the fact that this alternative has a combination of highly scoring factors such as *Market volume potential*, *Expansion possibilities* and *Transport infrastructure network in area*, which are also relatively highly valued by most of the respondents. This also explains the relatively high score of A2, as some of these criteria represent area-wide rather than location-specific characteristics (e.g. *Market volume potential*, which is measured by taking into account the locations of volume generating customers in the wider area). The lower score for A2 compared to A1 is thus most likely related to other factors than the previously mentioned. A factor on which A2 scores distinctively worse is *Expansion possibilities*, which are not existent at the location. The scores of the two C alternatives lie considerably close to each other, indicating the fact that their data scores do not differ that much. This is also the case for the B locations, although B1 scores somewhat better (most likely due to the high amount of *Expansion possibilities* around its location). Overall worst scoring alternative is B2. This alternative scores worse on the previously mentioned highly valued criteria, which results in a low final aggregate utility.

4.6. Results of Research Step 5: Sensitivity analysis

The sensitivity analysis involves testing the critical model inputs leading to the final aggregate utility scores of the alternatives. First of all, the importance of the particular stakeholders in the decision-making process is assessed. The first sensitivity analysis scenario is therefore involved with elimination of actors from the MCDM study; firstly, the terminal user actors, which in reality are also not involved in the actual location decision-making, are eliminated (sub-scenario 1.1); secondly, the terminal user and terminal operator actors are eliminated to assess the influence of merely the shipping line actor preferences (sub-scenario 1.2); lastly, the terminal user and shipping line actors are eliminated to assess the influence of merely the terminal operator actor preferences (sub-scenario 1.3). The results of these analyses are given in Table 6.

The figures show nearly the same results when the locations are evaluated by only the shipping line and terminal operator actors, which indicates the limited influence of the terminal user actors on the final aggregate utility scores. When the locations are assessed by only the shipping line actors, a stronger preference for the C alternatives is noticeable (mostly due to those locations' high scoring *Intermodal market profitability* and *Transport infrastructure area* characteristics, which are evaluated highly by the shipping line actors). When the locations are assessed by only the terminal operator actors, a stronger preference for the A alternatives is noticeable (mostly due to those locations' high scoring container volume related characteristics, which are evaluated highly by the terminal operator actors).

A second sensitivity analysis involves assessing the impacts of sudden container volume influxes in the areas of B and C, which score considerably lower in the initial model because of the low volume potentials around these areas. Container volume influx rates of 5.000 FEU p.a. per sub-scenario are applied, starting with 10.000 FEU p.a. for the respective first sub-scenario. The results of the analyses applied to both the B and C alternatives are presented in Figures 9 and 10.

Whereas for B2 an additional amount of 25.000 FEU p.a. is necessary to be ranked first, for C2 this amount is only 10.000 FEU p.a.. Most interesting is the fact that for C1 and C2 to end up highest in ranks, the total container volume potential of the C area is considerably lower than the total potential of the A area in Scenario 0. This indicates that of all alternatives, the C locations have particularly high scoring non-container volume related characteristics, making them considerably good options compared to the A locations if market conditions would allow.

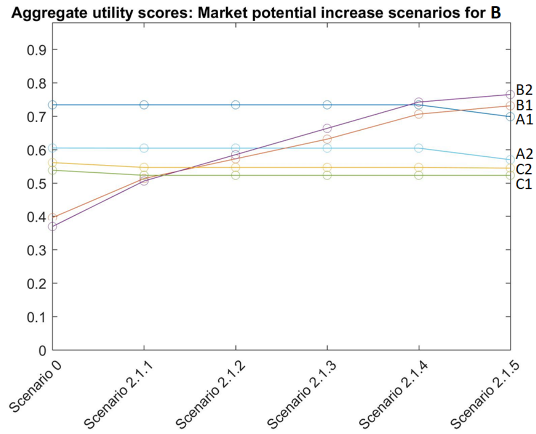


Figure 9: Aggregate utility scores of alternatives after container volume influx in the B area

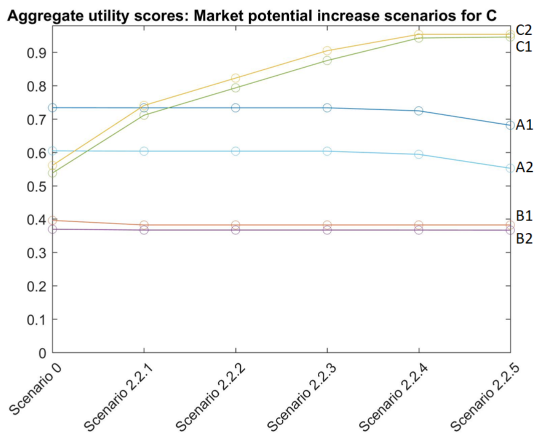


Figure 10: Aggregate utility scores of alternatives after container volume influx in the C area

5. Conclusion

This research is aimed at finding a desirable location for a shipping line to set up an inland terminal which can be incorporated in the inland transport services offered to its customers. In that regard, multiple different stakeholders with particular objectives are involved, including shipping line stakeholders, terminal operator stakeholders and

Alternative	A1	A2	B1	B2	C1	C2
Utility score	***0,7338***	***0,6044***	***0,3960***	***0,3694***	***0,5380***	***0,5608***
Utility score 1.1	0,7338	0,6044	0,3960	0,3918	0,5380	0,5608
Percentage difference	0%	0%	0%	+6%	0%	0%
Utility score 1.2	0,6750	0,5497	0,4822	0,5146	0,6892	0,6817
Percentage difference	−8%	−9%	+22%	+39%	+28%	+22%
Utility score 1.3	0,8565	0,8563	0,1591	0,1783	0,2237	0,2403
Percentage difference	+17%	+42%	−60%	−52%	−58%	−57%

Table 6: Scenario 1.1: Aggregate scores and increase ratios.

terminal user stakeholders. To take these different stakeholders and objectives into account, the MAMCA framework is considered as an approach for the Multi-Criteria Decision-Making study, in which BWM is considered for determining the optimal criteria weights for each stakeholder. While the use of MAMCA allows the inclusion of multiple stakeholders and their objectives, BWM allows to consider specific criteria sets for each stakeholder by means of the multi-optimality properties of the non-linear weight determination model. The multi-optimal weight intervals stemming from the different stakeholder-specific criteria sets are eventually used to calculate utility intervals, which are subsequently aggregated into final utility scores using a min - max model.

As expected, the outcomes of the study show differently evaluated criteria for each actor. While the shipping line actors assign most value to *intermodal market profitability* and *transport infrastructure* characteristics of a studied area, terminal operators and terminal users prefer *container volume related* factors the most. Overall, these container related characteristics are highly evaluated by all involved actors including the shipping line. The preferences of all involved actors combined lead to the two A locations ending up with the highest ranks, mostly due to the high amount of container volume potentials in the A area. A high amount of *expansion possibilities* results in A1 being first and A2 being second in rank. Sensitivity analyses turned out that the influence of the terminal user actors on the final outcomes of the model based on the actual decision-making actors is limited. Whereas individual preferences of the shipping line actors lead to the C locations being most preferred, the individual preferences of the terminal operator actors are much more in favor of selecting a location in the A area (due to its high container volumes), resulting in a compromise solution for the latter one. However, it must be noted that as the locations in the C area score best on their non-container related characteristics, it would take less potential volumes at those places to become equally attractive as the A locations, implying the relatively good positions regardless of poorer market conditions.

Based on the results, the main recommendations to be made to the decision-making actors of the shipping line and the terminal operator are first of all involved with the container volume potentials of an area. Since these factors are regarded as important by all stakeholders involved, alternatives having high potentials are in line of the preferences of the majority of the affected group. Next to that, room for expansion possibilities can be an important final decisive factor with regards to the final utility score. For further research, it is advised to test the applicability and practicality of utility aggregation on more multi-actor multi-criteria decision-making problems within different fields of studies.

References

[1] M. R. Van Der Horst, P. W. De Langen, Coordination in hinterland transport chains: a major challenge for the seaport community, Maritime Economics & Logistics 10 (1-2) (2008) 108–129.

[2] M. Acciaro, A. McKinnon, Efficient hinterland transport infrastructure and services for large container ports, in *Port Investment and Container Shipping Markets*, OECD Publishing, Paris.

[3] P. Franc, M. Van der Horst, Understanding hinterland service integration by shipping lines and terminal operators: a theoretical and empirical analysis, Journal of Transport Geography 18 (4) (2010) 557–566.

[4] R. Van den Berg, P. W. De Langen, Towards an 'inland terminal centred' value proposition, Maritime Policy & Management 42 (5) (2015) 499–515.

[5] A. Frémont, Shipping lines and logistics, Transport Reviews 29 (4) (2009) 537–554.

[6] D.-P. Song, J.-X. Dong, Empty container repositioning, in: Handbook of ocean container transport logistics, Springer, 2015, pp. 163–208.

[7] D. Simina, S. Patrick, C. Radu, et al., Economic benefits of developing intermodal transport in the european union, Annals of Faculty of Economics 1 (2) (2012) 81–87.

[8] J.-P. Rodrigue, T. Notteboom, The terminalization of supply chains: reassessing the role of terminals in port/hinterland logistical relationships, Maritime Policy & Management 36 (2) (2009) 165–183.

[9] T. Notteboom, J.-P. Rodrigue, Re-assessing port-hinterland relationships in the context of global commodity chains, in: Ports, cities, and global supply chains, Routledge, 2017, pp. 67–82.

[10] B. Wiegmans, B. Behdani, A review and analysis of the investment in, and cost structure of, intermodal rail terminals, Transport Reviews 38 (1) (2018) 33–51.

[11] M. S. Daskin, K. L. Maass, The p-median problem, in: Location science, Springer, 2015, pp. 21–45.

[12] E. Fernández, M. Landete, Fixed-charge facility location problems, in: Location science, Springer, 2015, pp. 47–77.

[13] H. Calik, M. Labbé, H. Yaman, p-center problems, in: Location Science, Springer, 2015, pp. 79–92.

[14] G. Laporte, S. Nickel, F. S. da Gama, Location science, Vol. 528, Springer, 2015.

[15] D. Ambrosino, A. Sciomachen, Location of mid-range dry ports in multimodal logistic networks, Procedia-Social and Behavioral Sciences 108 (2014) 118–128.

[16] R. Ishfaq, C. R. Sox, Hub location–allocation in intermodal logistic networks, European Journal of Operational Research 210 (2) (2011) 213–230.

[17] S.-J. Jeong, C.-G. Lee, J. H. Bookbinder, The European freight railway system as a hub-and-spoke network, Transportation Research Part A: Policy and Practice 41 (6) (2007) 523–536.

[18] S. Limbourg, B. Jourquin, Market area of intermodal rail-road container terminals embedded in a hub-and-spoke network, Papers in Regional Science 89 (1) (2010) 135–154.

[19] D. Meers, C. Macharis, Are additional intermodal terminals still desirable? an analysis for belgium, European Journal of Transport and Infrastructure Research 14 (2).

[20] K. Sörensen, C. Vanovermeire, S. Busschaert, Efficient metaheuristics to solve the intermodal terminal location problem, Computers & Operations Research 39 (9) (2012) 2079–2090.

[21] P. Arnold, D. Peeters, I. Thomas, Modelling a rail/road intermodal transportation system, Transportation Research Part E: Logistics and Transportation Review 40 (3) (2004) 255–270.

[22] S. Limbourg, B. Jourquin, Optimal rail-road container terminal locations on the European network, Transportation Research Part E: Logistics and Transportation Review 45 (4) (2009) 551–563.

[23] S. Limbourg, B. Jourquin, Rail-road terminal locations: aggregation errors and best potential locations on large networks, European Journal of Transport and Infrastructure Research 7 (4).

[24] O. P. Atieno, An analysis of the strengths and limitation of qualitative and quantitative research paradigms, Problems of Education in the 21st Century 13 (1) (2009) 13–38.

[25] S. Long, S. E. Grasman, A strategic decision model for evaluating inland freight hub locations, Research in Transportation Business & Management 5 (2012) 92–98.

[26] R. Z. Farahani, M. SteadieSeifi, N. Asgari, Multiple criteria facility location problems: A survey, Applied Mathematical Modelling 34 (7) (2010) 1689–1709.

[27] J. Rezaei, Best-worst multi-criteria decision-making method, Omega 53 (2015) 49–57.

[28] R. L. Keeney, H. Raiffa, Decision analysis with multiple conflicting objectives, Wiley& Sons, New York.

[29] B. Ka, Application of fuzzy AHP and ELECTRE to China dry port location selection, The Asian Journal of Shipping and Logistics 27 (2) (2011) 331–353.

[30] E. Özceylan, M. Erbaş, M. Tolon, M. Kabak, T. Durğut, Evaluation of freight villages: A GIS-based multi-criteria decision analysis, Computers in Industry 76 (2016) 38–52.

[31] A. Karaşan, C. Kahraman, A novel intuitionistic Fuzzy DEMATEL–ANP–TOPSIS integrated methodology for freight village location selection, Journal of Intelligent & Fuzzy Systems (Preprint) (2019) 1–18.

[32] M. B. Regmi, S. Hanaoka, Location analysis of logistics centres in laos, International Journal of Logistics Research and Applications 16 (3) (2013) 227–242.

[33] V. Roso, N. Brnjac, B. Abramovic, Inland intermodal terminals location criteria evaluation: the case of croatia, Transportation journal 54 (4) (2015) 496–515.

[34] Y. Kayikci, A conceptual model for intermodal freight logistics centre location decisions, Procedia-Social and Behavioral Sciences 2 (3) (2010) 6297–6311.

[35] C. Macharis, L. Turcksin, K. Lebeau, Multi actor multi criteria analysis (MAMCA) as a tool to support sustainable decisions: State of use, Decision Support Systems 54 (1) (2012) 610–620.

[36] C. Macharis, The importance of stakeholder analysis in freight transport.

[37] C. Macharis, A. Verbeke, K. De Brucker, The strategic evaluation of new technologies through multicriteria analysis: the ADVISORS case, Research in Transportation Economics 8 (2004) 443–462.

[38] L. Turcksin, A. Bernardini, C. Macharis, A combined ahp-promethee approach for selecting the most appropriate policy scenario to stimulate a clean vehicle fleet, Procedia-Social and Behavioral Sciences 20 (2011) 954–965.

[39] H. Sun, Y. Zhang, Y. Wang, L. Li, Y. Sheng, A social stakeholder support assessment of low-carbon transport policy based on multi-actor multi-criteria analysis: The case of Tianjin, Transport Policy 41 (2015) 103–116.

[40] T. L. Saaty, How to make a decision: the analytic hierarchy process, European journal of operational research 48 (1) (1990) 9–26.

[41] T. L. Saaty, The modern science of multicriteria decision making and its practical applications: The AHP/ANP approach, Operations Research 61 (5) (2013) 1101–1118.

[42] T. L. Saaty, Decision making with dependence and feedback: The analytic network process, Vol. 4922, RWS Publ., 1996.

[43] Y.-J. Lai, T.-Y. Liu, C.-L. Hwang, Topsis for MODM, European journal of operational research 76 (3) (1994) 486–500.

[44] S. Opricovic, G.-H. Tzeng, Compromise solution by MCDM methods: A comparative analysis of VIKOR and TOPSIS, European journal of operational research 156 (2) (2004) 445–455.

[45] J.-P. Brans, P. Vincke, B. Mareschal, How to select and how to rank projects: The PROMETHEE method, European journal of operational research 24 (2) (1986) 228–238.

[46] B. Roy, The outranking approach and the foundations of electre methods, in: Readings in multiple criteria decision aid, Springer, 1990, pp. 155–183.

[47] J. Rezaei, Best-worst multi-criteria decision-making method: Some properties and a linear model, Omega 64 (2016) 126–130.

[48] L. C. Nguyen, T. Notteboom, A multi-criteria approach to dry port location in developing economies with application to vietnam, The Asian Journal of Shipping and Logistics 32 (1) (2016) 23–32.

[49] T. Rožić, D. Ogrizović, M. Galić, Decision making background for the location of inland terminals, Pomorstvo 30 (2) (2016) 141–150.

[50] J. Wei, A. Sun, J. Zhuang, The selection of dry port location with the method of Fuzzy-ANP, in: Advances in Wireless Networks and Information Systems, Springer, 2010, pp. 265–273.

[51] F. Li, X. Shi, H. Hu, Location selection of dry port based on AP clustering-the case of southwest China, Journal of System and Management Sciences Vol 1 (5).

[52] K. Komchornrit, The selection of dry port location by a hybrid CFA-MACBETH-PROMETHEE method: A case study of southern Thailand, The Asian Journal of Shipping and Logistics 33 (3) (2017) 141–153.

[53] B. Yıldırım, E. Önder, Evaluating potential freight villages in istanbul using multi criteria decision making techniques, Journal of Logistics Management 3 (1) (2014) 1–10.

[54] M. Brunelli, J. Rezaei, A multiplicative best–worst method for multi-criteria decision making, Operations Research Letters 47 (1) (2019) 12–15.

[55] M. Mohammadi, J. Rezaei, Bayesian best-worst method: A probabilistic group decision making model, Omega (2019) 102075.

[56] C. P. Garg, A. Sharma, Sustainable outsourcing partner selection and evaluation using an integrated BWM-VIKOR framework, Environment, Development and Sustainability (2018) 1–29.

[57] A. Hafezalkotob, A. Hafezalkotob, H. Liao, F. Herrera, Interval MULTIMOORA method integrating interval borda rule and interval best-worst-method-based weighting model: Case study on hybrid vehicle engine selection, IEEE transactions on cybernetics.

[58] J. Rezaei, L. van Wulfften Palthe, L. Tavasszy, B. Wiegmans, F. van der Laan, Port performance measurement in the context of port choice: an MCDA approach, Management Decision.

[59] L. Groenendijk, J. Rezaei, G. Correia, Incorporating the travellers' experience value in assessing the quality of transit nodes: A Rotterdam case study, Case Studies on Transport Policy 6 (4) (2018) 564–576.

[60] A. T. Onstein, M. Ektesaby, J. Rezaei, L. A. Tavasszy, D. A. van Damme, Importance of factors driving firms' decisions on spatial distribution structures, International Journal of Logistics Research and Applications (2019) 1–20.

[61] H. Gupta, M. K. Barua, A novel hybrid multi-criteria method for supplier selection among SMEs on the basis of innovation ability, International Journal of Logistics Research and Applications 21 (3) (2018) 201–223.

[62] H. B. Ahmadi, S. Kusi-Sarpong, J. Rezaei, Assessing the social sustainability of supply chains using Best Worst Method, Resources, Conservation and Recycling 126 (2017) 99–106.

[63] J. Ren, Multi-criteria decision making for the prioritization of energy systems under uncertainties after life cycle sustainability assessment, Sustainable Production and Consumption 16 (2018) 45–57.

[64] S. A. Torabi, R. Giahi, N. Sahebjamnia, An enhanced risk assessment framework for business continuity management systems, Safety science 89 (2016) 201–218.

[65] G. Van de Kaa, D. Scholten, J. Rezaei, C. Milchram, The battle between battery and fuel cell powered electric vehicles: a BWM approach, Energies 10 (11) (2017) 1707.

[66] F. Liang, M. Brunelli, J. Rezaei, Consistency Issues in the Best Worst Method: Measurements and Thresholds, Omega (2019) 102175.

[67] J. Rezaei, J. Wang, L. Tavasszy, Linking supplier development to supplier segmentation using best worst method, Expert Systems with Applications 42 (23) (2015) 9152–9164.

[68] S. Patro, K. K. Sahu, Normalization: A preprocessing stage, http://arxiv.org/ftp/arxiv/papers/1503/1503.06462.pdf.

[69] A. Çelen, Comparative analysis of normalization procedures in TOPSIS method: with an application to Turkish deposit banking market, Informatica 25 (2) (2014) 185–208.

[70] N. Vafaei, R. A. Ribeiro, L. M. Camarinha-Matos, Selection of normalization technique for weighted average multi-criteria decision making, in: Doctoral Conference on Computing, Electrical and Industrial Systems, Springer, 2018, pp. 43–52.