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MODAL CHOICE IN INTERMODAL TRANSPORT

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MODAL CHOICE IN INTERMODAL TRANSPORT

Het Steunpunt Goederen- en personenvervoer doet beleidsrelevant onderzoek in het domein van transport en logistiek. Het is een samenwerkingsverband van het Departement Transport en Ruimtelijke Economie van de Universiteit Antwerpen en het Departement Business Technology and Operations (BUTO) van de Vrije Universiteit Brussel. Het Steunpunt Goederen- en personenvervoer wordt financieel ondersteund door de coördinerende minister Philippe Muyters, Vlaams minister voor Werk, Economie, Innovatie en Sport en Ben Weyts, Vlaams minister van Mobiliteit en Openbare Werken, de functioneel aansturende en functioneel bevoegde minister.

Table of Contents

Table of Contents 1

List of figures 3

List of tables 5

Nederlandstalige samenvatting 6

1 Introduction 9

2 Modal choice in hinterland transport 11

2.1 Modal choice variables 11

2.2 Differences in modal choice preferences 12

2.3 Studies on modal choice 13

2.3.1 Vannieuwenhuyse et al. (2003) 13

2.3.2 Beuthe et al. (2005) 15

2.3.3 Grosso (2011) 16

2.3.4 Vermeiren (2013) 17

2.4 Overview 18

3 Break-even in intermodal transport 19

3.1 The concept of break-even distance 19

3.2 Relevant break-even studies 21

3.3 Break-even in inland waterway transport 22

3.4 Break-even in rail transport 25

3.5 Lowering the break-even distance 26

3.6 Overview 31

4 Modelling modal choice with LAMBIT 33

4.1 Introduction 33

4.2 Combined GIS-MCDA Methodology 33

4.3 The case of Flanders 35

4.3.1 Selection of alternative routes 35
4.3.2 Modal choice criteria 36
4.3.3 Decision matrix 36
4.4 Discussion 37
4.5 Overview 45
5 Conclusion and outlook 46
6 Bibliography 48
7 Appendix 54
7.1 Main transport mode choice criteria 54
7.1.1 Transport cost/price 54
7.1.2 Service quality 54
7.1.3 Transport time 55
7.1.4 Reliability 55
7.1.5 Environment 55
7.1.6 Frequency and flexibility 56
7.1.7 Goods damage and security 56
7.1.8 Transport mode 56
7.2 Data collection methods 56

List of figures

Figure 1 – Modal choice decisions can be made based on knowledge of the transport alternatives and their (perceived) performance. 13

Figure 2 – Cost functions for intermodal (red) – and unimodal road transport (blue), for a maritime-based transport chain. 20

Figure 3 – Market areas of intermodal terminals, based on price comparisons. (Source: Meers et al. (2013a)) 23

Figure 4 – Average break-even points barge transport in Belgium. 24

Figure 5 – Break-even distance variation, depending on the direction of the post haul transport. A visualization in the left upper corner shows how the shape of the market area is influenced (O=origin, MH=main haul, T=terminal, PH=post haul). 26

Figure 6 – Lower transhipment costs at the intermodal terminal (left) or at the sea port (right) decrease the total cost of intermodal transport. (Source: based on Macharis and Verbeke (2004)) .. 27

Figure 7 – Decreasing the variable costs of intermodal transport will benefit intermodal transport over longer distances. (Source: based on Macharis and Verbeke (2004)) 28

Figure 8 – A new terminal can decrease the costs of intermodal transport for shipments going to/from locations in its vicinity. (Source: based on Nemoto et al. (2006)) 28

Figure 9 – An increase in the variable cost of road transport will increase the price of both unimodal and intermodal transport, but the effect on the intermodal chain is more limited. (Source: based on Macharis & Verbeke (2004)) 29

Figure 10 – Increasing the fixed costs of road transport will not change the absolute cost difference between the unimodal and the intermodal transport chain. 29

Figure 11 – Framework for the calculation and the assessment of case-specific break-even distances. 31

Figure 12 – MCDA-GIS combined methodology (Meers et al., 2013b) 34

Figure 13 – PROMETHEE II ranking showing net preference flows for the three alternatives and the three scenarios. Increased importance for CO_2-equivalent emissions increases the preference for intermodal rail and to a lesser extent for intermodal barge transport (based on D-Sight). 38

Figure 14 – Evolution in the preference for intermodal rail services in Flanders for scenario 1 (top), scenario 2 (middle) and scenario 3 (bottom) 40

Figure 15 – Evolution in the preference for intermodal barge services in Flanders for scenario 1 (top), scenario 2 (middle) and scenario 3 (bottom) 41

Figure 16 – Evolution in the preference for road-only transport in Flanders for scenario 1 (top), scenario 2 (middle) and scenario 3 (bottom) 42

Figure 17 – Preferred transport mode (combination) in the Flemish municipalities, for scenario 1 (top), scenario 2 (middle) and scenario 3 (bottom). 44

List of tables

Table 1 Overview of modal choice criteria 11

Table 2 Modal choice criteria and their corresponding weights (Vannieuwenhuyse et al., 2003). 14

Table 3 – Average performance scores of different transport modes regarding 11 modal choice criteria (Vannieuwenhuyse et al., 2003) 15

Table 4 – Perceived performance of road transport and intermodal transport regarding 8 modal choice criteria (Grosso, 2011) 17

Table 5 - Reported break-even distances for intermodal container transport in (western) Europe (Source: based on Vermeiren, 2013).. 21

Table 6 – Weights, preference functions, indifference and preference values attached to the considered modal choice criteria. 37

Nederlandstalige samenvatting

Deze beleidsondersteunende paper biedt inzicht in modale keuze beslissingen in het goederentransport. Modale keuze beslissingen in het goederentransport zijn complexer dan die in het personentransport, omdat er meer actoren bij betrokken zijn en omdat logistieke ketens steeds complexer worden (Anderson et al., 2010). Het modale keuzegedrag van verladers en expediteurs of logistieke dienstverleners bepaalt de uiteindelijke modale verdeling. Deze paper focust voornamelijk op de keuze tussen wegvervoer en intermodale transportketens in het hinterland transport.

Inzicht in modale keuzegedrag is belangrijk voor een aantal toepassingen. Zo is het immers de bedoeling om beter te begrijpen waarom verladers al dan niet voor intermodale transportalternatieven kiezen. De kennis hieromtrent wordt dan onder meer gebruikt om transport te gaan modelleren en om de interactie tussen infrastructuurbeschikbaarheid en de transportstromen te bestuderen. Uiteraard is het ook relevant om te bestuderen welke impact beleidsmaatregelen op het modale keuzegedrag kunnen hebben. Verder is het ook voor transportoperatoren belangrijk om een goed inzicht te krijgen in de specifieke transportvereisten van hun klanten om oplossingen aan te bieden die aan hun verwachtingen tegemoet komen. Vanuit een maatschappelijk perspectief is het bovendien zinvol om het inzicht in modale keuzegedrag te koppelen aan een beleid gericht op een modale verschuiving naar een toename in het gebruik van meer duurzame transportmodi.

In het tweede hoofdstuk van deze paper worden de belangrijkste modale keuze variabelen toegelicht. Naast de transportprijs zijn er immers nog een aantal kwantitatieve en kwalitatieve variabelen die de keuze tussen verschillende transportmodi en –routes bepalen. De bestaande studies die modale keuze in Vlaanderen of België bespreken geven echter verschillende resultaten over het relatieve belang van deze criteria in de modale keuze. Globaal gezien zijn de variabelen die in deze studies als meest bepalend naar voor komen: de transportprijs, de transporttijd, de betrouwbaarheid, de flexibiliteit en de frequentie en veiligheid. Niettegenstaande kan het inzicht in het belang van deze variabelen, met een focus op containertransport op korte afstand in een Vlaamse context, nog verbeterd worden door een bijkomend keuze-experiment.

Het derde hoofdstuk van deze paper gaat dieper in op de belangrijke keuzecomponent transportprijs, aan de hand van de kritische drempelafstand (de *break-even distance*). De analyse benadrukt dat een eenzijdige focus op een *modal shift* beleid voor transport op lange afstand het potentieel van intermodaal transport niet ten volle kan benutten. De analyse toont aan dat dit in het bijzonder geldt voor binnenvaarttransport van en naar de Haven van Antwerpen, waar grote volumes vaak over een

korte afstand getransporteerd worden, waardoor intermodaal vervoer reeds op korte afstand prijscompetitief kan zijn Wel wordt er opgemerkt dat door de verschillen in kostenstructuur, binnenvaart en spoorvervoer een heel andere kritische drempelafstand kennen. De twee internationale gevalstudies tonen aan de kritische drempelafstand voor intermodaal spoorvervoer veel hoger ligt. Verder wordt er aangetoond dat de eigenlijke kritische drempelafstand steeds afhankelijk is van onder meer de karakteristieken van de bestaande transportinfrastructuur en lokale marktomstandigheden. Ook de definitie van het concept en de meetmethode zijn cruciaal wanneer kritische drempelafstanden gebruikt worden voor beleidsdoelstellingen. Verder worden er een aantal voorbeelden gegeven van hoe de kritische drempelafstand verlaagd kan worden, door de verschillende componenten van de kostenfuncties van de verschillende transportketens te linken aan een aantal (beleids)maatregelen.

Het vierde hoofdstuk van deze paper focust op het modelleren van meerdere modale keuze variabelen. Een modale keuze model voor containertransport wordt voorgesteld en uitgetest voor Vlaanderen. Het model is een combinatie van het Locatie Analyse Model voor Belgische Intermodal Terminals (LAMBIT (Macharis, 2000)), een op GIS-gebaseerd locatie-analyse model en een Multi-Criteria Analyse (MCA). De integratie van MCA in LAMBIT, laat toe om de competitiviteit van de intermodale sector vanuit een breder perspectief te analyseren. Verder beschouwt het model niet louter de 'traditionele' modale keuze variabelen, maar worden ook een aantal externe effecten van de transportkeuze in rekening gebracht. De resultaten tonen aan dat op basis van een set gemiddelde gewichten, de voorkeur voor intermodaal binnenvaartvervoer vanuit een geografisch perspectief het grootst is in Limburg en in het zuiden van West-Vlaanderen. In deze regio's is het potentieel voor het gebruik van intermodale transportalternatieven dus het grootst. Ten gevolge van de geografisch beperkte dienstverlening van intermodaal spoorvervoer is de voorkeur voor intermodaal spoorvervoer in heel Vlaanderen echter beperkt. Om de algemene voorkeur voor intermodale transportalternatieven te vergroten, dient het belang van externe effecten aanzienlijk toe te nemen, uitgaande van onveranderde vervoersprestaties en een gelijke relatieve gewichtsverdeling binnen de 'traditionele' keuzecriteria. Het is immers duidelijk dat wanneer er bijkomende aandacht wordt besteed aan duurzame transportindicatoren dat dit tot een (beperkte) modale verschuiving kan leiden. Maar ook een betere 'score' op de traditionele criteria kan de competitiviteit van de intermodale transportsector doen toenemen. In het eerste geval is de bijkomende vraag dan hoe het relatieve belang van deze indicatoren kan toenemen in de modale keuze. Enerzijds is er de mogelijkheid om maatregelen met een dwingend karakter te implementeren, door bijvoorbeeld een internalisering van de externe kosten of het introduceren van een doorgedreven vorm van rekeningrijden. Anderzijds bestaat er ook de mogelijkheid dat 'zachte' initiatieven bijdragen tot een *mental shift* en zo het bewustzijn rond duurzaam vervoer doen toenemen, door bijvoorbeeld stimuleringsprogramma's als *Lean & Green*. Uiteraard kan ook het wegtransport haar score op deze criteria met betrekking tot de externe effecten van transport verbeteren door het gebruik van milieuvriendelijkere voertuigen en een beter gebruik van de bestaande netwerkcapaciteit.

Verder kan dit model ook gebruikt worden door bedrijven om hun modale keuze te maken of te evalueren in de vorm van een (offline of online) beslissingsondersteunend instrument. Zo kunnen verladers hun voorkeuren en transportkeuzes opnieuw evalueren door de gewichten toegekend aan de verschillende criteria en andere modelparameters aan te passen of door extra criteria toe te voegen. Zelfs indien er lage gewichten aan variabelen met betrekking tot de externe transporteffecten wordt toegekend, kan de output van het model nog steeds dienen om het bewustzijn rond duurzaam transport te vergroten.

In het vijfde hoofdstuk van deze paper worden tenslotte de verschillende conclusies uitgebreid beschreven en wordt de link naar bijkomend onderzoek gelegd.

1 Introduction

This paper provides insight in modal choice decisions in freight transport. These modal choice decision are in general more complex than the ones in passenger transport, as more actors are involved and supply chains are becoming increasingly complex (Anderson et al., 2010). In the end, the modal choice behaviour of the relevant decision makers determines the modal split of freight transport. In this paper, the focus is on modal choice decisions in hinterland transport between unimodal road transport and its alternatives by intermodal barge or intermodal rail transport.

Insight in modal choice behaviour is useful for several purposes. The main motivation is to better understand the reasons why decision makers choose (or do not choose) for intermodal transport services. Choice behaviour is used in transport modelling, to predict interactions between transport flows and infrastructure availability. Also the effect of policy measures can be estimated by using simulations, based on modal choice preference estimations. Transport operators are interested in their customers' requirements to provide appropriate transport solutions and to anticipate on possible future problems and opportunities. From a societal perspective, insight in modal choice is necessary to move decision makers towards more environmentally friendly transport choices.

The second chapter of this paper, we list the main modal choice attributes that were accounted for in earlier studies and discuss the outcome of the studies which are relevant in the Flemish context. Besides the price of the different transport alternatives, a list of other criteria can determine the final mode and route choice decisions. Obviously mode choice is not fixed in time and space and different actors shipping different goods might have different modal choice preferences.

The third chapter focuses on transport price as a main determinant of the competitiveness of the intermodal transport sector. The concept of break-even distance is introduced as the transport distance that needs to be travelled for intermodal transport to be a cheaper alternative than road-only alternative. We find that the break-even distances for intermodal rail and intermodal barge transport are rather different and we propose a comprehensive framework for the calculation of these break-even distances. The break-even distance can be used in the promotion of intermodal transport and broader, in modal shift initiatives.

The fourth chapter of this paper focuses on the integration of several modal choice criteria in the Location Analysis Model for Belgian Intermodal Terminals (LAMBIT) (Macharis, 2000). A previous *Steunpunt paper*, already showed the impact of two main modal choice criteria: transport price and transport time on the market area extent of inland intermodal terminals. The methodology suggested in this paper allows including even more quantitative and qualitative choice criteria at the same time. This integration enables to check the influence of changing mode choice preferences on the competitiveness of intermodal transport in Flanders. The geographical scope is extended as also foreign terminals are included in this analysis. A Multi-Criteria Decision Analysis Approach (MCDA) is used to model the impact of differing modal choice criteria preferences.

The fifth chapter presents a general conclusion and an outlook for further research.

2 Modal choice in hinterland transport

In this section we focus on relevant studies that were conducted to investigate the modal choice behaviour in hinterland transport. Modal choice criteria are the quantitative and qualitative criteria that determine the transport mode choice. These qualitative criteria can be objective, but also subjective, which makes them more difficult to validate. Insight in modal choice characteristics and behaviour can give insight in the (future) use of intermodal transport in Flanders. First we briefly describe the different attributes or criteria that are included in modal choice studies and focus on potential difference in outcome between studies. In 2.3 the outcome of the most relevant studies are discussed.

2.1 Modal choice variables

In this section, we briefly describe the different modal choice criteria, mentioned in earlier studies. Flodén et al. (2010) point to the importance of clearly defining the considered criteria, when attempting to compare their relative importance in modal choice. Examples of such dubious criteria can be reliability or transport quality. In their literature review, Flodén et al. (2010) witness a remarkable lack of criteria definitions and commonly studied criteria. While some studies focus on a limited list of studied criteria, others consider over 30. These practices make it much harder to compare similar studies and this partly explains differences in their outcome.

Table 1 provides an overview of the most studied mode choice criteria. It should however be noted that this list is not exhaustive and the indicators to measure these criteria can vary strongly. A more extensive description of these criteria is included in the appendix (section 7.1).

Table 1 Overview of modal choice criteria

Criterion	Possible indicator
Transport cost/price	Total cost/price of transport service
Transport time	Planned or actual transit time
Reliability	(Standard) deviation of transport time or share of shipments arriving early/late
Environment	External effects of a transport service not included in transport cost
Frequency	Number of departures offered
Flexibility	E.g. ease to change departure/arrival time
Damage risk and security	Chance on goods being damaged or stolen

2.2 Differences in modal choice preferences

Differences in the evaluations of modal choice criteria can be attributed to individual preferences and the characteristics of the survey and/or the modelling method used. But also external factors are influencing the modal choice. Rotaris et al. (2012) claim that also the **commodity type**, the **distance** travelled and **geographical differences** can influence the decision. In addition, Beuthe and Bouffioux (2008) also mention the influence of the **shipment size** and the **network** configurations. Another factor which might influence the decision is who the final **decision maker** is.

As different actors are involved in the organization and the set-up of a transport service, different actors might have different modal choice preferences. Flodén et al. (2010) indicate that a freight forwarder might not fully adopt the preferences, derived from a shipper. In her case study, Grosso (2011) found that out of 20 freight forwarders interviewed, in 11 cases the forwarder himself choses the transport mode, in 5 cases, the decision was taken by the shipper, while in the other 4 cases, the choice was made by shipper and forwarder together. Vermeiren (2013) also mentions the importance of the dominant **haulage type**: merchant or carrier haulage. He states that as the Rhine-Scheldt area is predominantly operated under merchant haulage, shippers ultimately choose among ports and transport routes.

Fries and Patterson (2008) discuss if shippers choose among different transport services offered by certain transport providers or if they make an actual choice between transport modes. They find that shippers, without own transport equipment, rather choose between the offers of different **logistics service providers** (LSPs) without explicitly considering the transport modes. They claim that LSPs make the actual choice based on the shippers' modal choice requirements. In addition, Truschkin and Elbert (2013) note that forwarders without an own fleet can have **arrangements** with transport companies, who offer a limited portfolio, what makes them less 'neutral' in decision making.

Despite the package (container, semi-trailer, swap-body) which remains the same, the **type of goods** transported might demand for different modal choice preferences. These differences mainly related to the value of goods and their time-sensitivity. Bolis and Maggi (2003) state however that goods classifications are not relevant to analyse transport decisions (with some exemptions such as dangerous good though), as only the value of the goods is. In addition, also the type of supply chains is relevant, with higher importance attached to time and reliability for firms operating just-in-time.

Finally, modal choice decisions are not always made by an explicit consideration of all the available transport alternatives. **Knowledge** of the local transport market, earlier **experiences** etc. can limit the available possibilities or bring prejudices for transport modes or operators (Figure 1). Tsamboulas and Kapros (2000) divide transport service buyers in three groups. A first group almost exclusively decides on the cost criterion, while being flexible for the service quality level. A second group combines cost and quality criteria, while the third group does not possess a general decision pattern, as they have specific quality requirements. It is mainly in the first group that users of intermodal transport can be found.

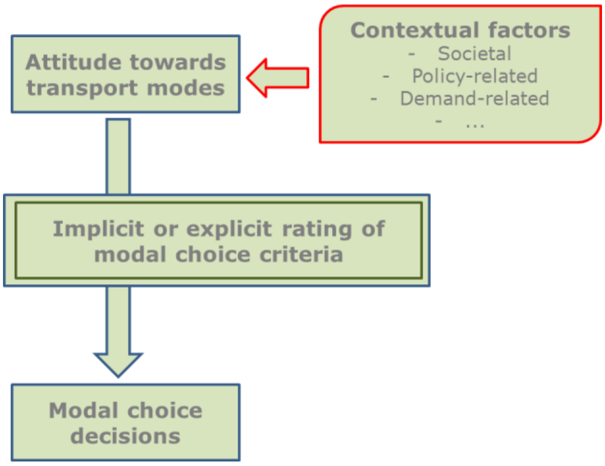

Figure 1 – Modal choice decisions can be made based on knowledge of the transport alternatives and their (perceived) performance.

2.3 Studies on modal choice

In this section, the studies which are most relevant for the Flemish or Belgian context are discussed. In many cases nevertheless, the research focus is on transport over longer distances, corresponding to typical European corridors.[1]

2.3.1 Vannieuwenhuyse et al. (2003)

Vannieuwenhuyse et al. (2003) performed an online survey among Flemish logistics decision makers, regarding their perception of different transport modes, following an earlier study conducted in 1999. A finding of the 1999 study was that users of a certain transport mode give higher performance scores to a transport mode than non-users do, so users of intermodal transport have a more positive view on its performance than shippers who are solely relying on road transport.

[1] Appendix 7.2 elaborates on the most relevant data collection methods used in these studies.

Vannieuwenhuyse et al. (2003) employ a Multi-criteria Decision Making (MDCM) approach in their interactive web application. By using this online MCDM tool, they could receive immediate feedback from users of the application, while at the same time aid them in the actual decision making process. Respondents were asked to rate a list of modal choice criteria for general freight transport. This allowed calculating weights which correspond to the importance attached to each criterion (Table 2). The importance scale used ranges from 0 (totally unimportant) to 10 (very important). The highest importance is given to the cost, reliability and flexibility.

Table 2 Modal choice criteria and their corresponding weights (Vannieuwenhuyse et al., 2003).

Factor	Definition	Weight
1 Transportation cost	Direct cost of transportation, e.g. fuel, driver's wages, …	8.34
2 Reliability	Ability to respect the promised delivery date	7.82
3 Flexibility	Ability to adapt to changing customer requirements and circumstances	7.05
4 Transportation time	Duration of the overall transportation process (from door-to-door)	7.61
5 Safety	Probability of avoiding damage and loss of quality of the goods	7.95
6 Capacity	Remaining capacity available	5.02
7 Density of network	Availability of (alternative) links	4.87
8 Regulation and legislation	Set of rules, obligations, customs facilities, etc.	5.64
9 Impact	Impact and control potential on goods flow	5.68
10 Image	Company image with respect to environment, safety, etc.	5.34
11 Strategic elements	Considerations of strategic nature	5.13

The respondents of the questionnaire were also asked to score the different criteria on their (perceived) performance for the considered transport modes, using a similar scale (Table 3). Vannieuwenhuyse et al. (2003) differentiate between road haulage, rail transport, inland waterway transport and intermodal transport. The results of their analysis show that for the transport of small volumes and for transport on short distances, road haulage remains the dominant choice, while for longer distances intermodal becomes more attractive. For the specific case of container transport, intermodal transport and inland navigation perform very well. It is striking that rail transport performs worst on 7 out of 11 criteria.

Table 3 – Average performance scores of different transport modes regarding 11 modal choice criteria (Vannieuwenhuyse et al., 2003)

	Average performance scores			
	Road transport	**Rail transport**	**Inland waterway transport**	**Intermodal transport**
Transportation Cost	**7,51**	6,62	7,50	7,38
Reliability	**7,53**	5,45	6,31	6,68
Flexibility	**7,46**	4,59	6,00	6,21
Transportation Time	5,23	6,31	**6,81**	6,54
Safety	6,58	6,93	**7,62**	7,25
Capacity	6,17	6,28	6,58	**6,73**
Density of network	**7,31**	5,03	6,65	6,64
Regulation and legislation	**6,74**	5,45	6,73	6,54
Impact	**6,56**	5,90	6,31	6,18
Image	**6,17**	5,62	5,73	5,75
Strategic elements	5,85	5,90	**6,31**	6,07

2.3.2 Beuthe et al. (2005)

A large-scale study was performed by a consortium of university partners in the framework of SPSDII (Beuthe et al., 2005). The goal of this research project was to investigate the factors that affect the modal split. The study started with a survey, studying actual choices in different industrial settings (RP approach)[2] and looking at the choices when decision parameters are altered (SP approach)². The set-up of this experiment is discussed in more detail in Beuthe et al. (2003). Six criteria were included in the analysis: cost, time, loss, frequency, reliability and flexibility.

Based on the SP survey, Beuthe and Bouffioux (2008) indicate weights to the 6 criteria that were analysed. Global weights are clearly highest for the criterion out-of-pocket costs (63.67%). Next come the door-to-door transport time (15.92%), reliability as the share of deliveries arriving at the scheduled time (8.47%) and flexibility as the share of non-programmed shipments that are executed without undue delay (5.63%). Transport frequency and the commercial value lost from damages,

[2] See appendix 7.2

theft and accidents are considered less important. When looking at some relevant sub compartments, slight differences occur. For instance for short distance transport (<300 km), cost seems even more important (75.30%) while reliability is listed second (8.32%) and transport time becomes almost irrelevant (3.77%). When focusing on container transport only, cost remains important (71.42%) before transport time (9.72%) and reliability (6.88%).

2.3.3 Grosso (2011)

The PhD dissertation of Grosso (2011) discusses the competitiveness of intermodal transport by comparing the different internal and external costs components of transport chains. The outcome of her research is also discussed in a *Steunpunt paper* (Grosso et al., 2013). Grosso distinguishes between distance-dependent and time-dependent cost components. The different costs were combined in a general cost function and tested for different corridors connecting the Port of Antwerp to Basel, Frankfurt and Strasbourg. In addition, also the external costs were calculated, based on the classification proposed in the IMPACT study of the European Commission (Maibach et al., 2008), which was recently updated (Korzhenevych et al., 2014). Grosso finds that on these long distances intermodal rail transport can often outperform the unimodal road alternative, when comparing total transport costs.

Next, Grosso (2011) conducted 20 interviews with freight forwarders to gain insight in the qualitative factors that influence modal choice. She found that the most important criterion for a general transport service is the reliability to meet the established time window and service level. Next came the possibility of loss and damage to occur, customer service and cost. When comparing the performance of road transport to intermodal transport, it became clear that road transport is favoured for its perceived flexibility, higher frequency and performance regarding transport time. Table 4 shows the scores on the different criteria, ranging from 1 (worst performing) to 5 (best performing). Intermodal transport is perceived to perform better on the criteria of having loss or damage, the total cost and the environmental impact. The important criterion of reliability received similar scores for unimodal and intermodal transport.

Table 4 – Perceived performance of road transport and intermodal transport regarding 8 modal choice criteria (Grosso, 2011)

	Reliability	Flexibility	Loss/damage	Frequency	Cost	Transport time	Customer service	Environment
Road	**3.85**	**4.35**	3.75	**4.40**	3.45	**4.10**	**4.00**	2.30
Intermodal	3.80	3.25	**4.10**	3.40	**3.95**	3.20	3.65	**3.95**

2.3.4 Vermeiren (2013)

In his PhD, Vermeiren (2013) questions whether ports can increase their hinterland share by well-developed hinterland services. He conducts a choice based experiment with stated choices[2]. A particularity in his research is that he considers the port of origin as a choice criterion for the hinterland transport chain choice. Instead of including port performance characteristics, respondents evaluate their general perceived port performance of the ports of Antwerp and Rotterdam. This follows the rationale of port competition and port choice in the wider context of the overall network performance, when searching for high quality and cost-effective door-to-door transport chains.

In his questionnaire, Vermeiren (2013) included six criteria, namely cost, CO_2-emissions, frequency level, perceived port performance, the direction of the trade flow (import versus export) and transport mode. The analysis focused mainly on medium and long distance transport chains. The ANOVA repeated measure technique was applied to investigate the stated preference of shippers regarding these characteristics, a methodology similar to the one used in Brooks and Trifts (2008). The idea was to divide the yearly shipping volume among the choice alternatives, using an 11-point Likert scale.

Vermeiren (2013) finds that shippers do not perceive a difference in port performance between the Port of Rotterdam and the Port of Antwerp which would alter their mode choice for hinterland transport. Also CO_2 emissions are not found to be a decisive factor, as shippers' decisions are mainly driven by the cost criterion even when CO_2 savings can be realized. The frequency of service is a more influential factor, but transport chains with cost savings still received more volume than transport chains with improved transport frequencies. There was no indication that the choice behaviour would have been different for import or export flows. Regarding the transport mode, no unambiguous conclusions could be drawn and it was not considered to be a good estimator of mode choice.

2.4 Overview

This chapter on modal choice in hinterland transport showed that an elaborate list of criteria might influence modal choice decisions. Studying modal choice criteria is complicated as different types of factors can influence preferences. A first type of factors is product-related: type of goods characteristics and shipment size. Next, the transport networks and transport distances strongly influence the accessibility of transport modes and the cost structure of transport chains. Third, factors such as haulage type and contracts determine who the final decision maker is in the modal choice process. Finally, subjective influences such as knowledge of the transport market and experiences with certain modes can impact the decision makers' preferences.

Concerning the most relevant studies described, all four mention transport cost/price as one of the main determining modal choice criteria. Reliability is put forward in three of the studies, while flexibility and transport time are considered to be very important in two studies. Finally, also frequency and the risk of damage are mentioned as important. If one wants to promote intermodal transport services, two actions can be implemented. First, it is important to provide modal choice decision makers with accurate information on the performance of the different modes regarding these criteria, to avoid biased decisions disadvantaging intermodal solutions. This is already partly done by offices such as 'Promotie Binnenvaart', the 'Flanders Logistics consulenten' and the 'Transportdeskundigen' of VOKA, who can help companies in analysing if intermodal transport can be beneficial for their specific transport flows. Other broad-scaled initiatives might however complement their work. Second, the focus should be on improving the performance of intermodal transport on these 'important' modal choice criteria, when compared to road transport. When intermodal transport is outperformed by road transport on certain criteria, action might be required when improvements can help to switch the balance to the advantage of intermodal transport solutions.

3 Break-even in intermodal transport

The current focus of the European modal shift policy is on road freight transport over distances over 300 km. The aim set in the European Commissions' white paper (European Commission, 2011) is to shift 30% of the road freight transport in this segment to more sustainable transport modes by 2030 and over 50% by 2050. But currently, more than 75% of the goods in Europe are transported over distances under 150 km. This short distance transport is the focus of this research, as the maritime-based transport flows within Flanders are on short distances. As an illustration, the 'road distance' to drive from the north of Flanders (Hoogstraten) to the south (Halle) is approximately 110 km, while the distance to drive from the west (De Panne) to the east (Kinrooi) is about 250 km. Tavasszy and van Meijeren (2011) analysed the goals of the White Paper and concluded that also on shorter distances promising cases exist which address a big market segment.

In this section we focus on one of the main modal choice criteria, mentioned in the previous section: cost/price. We research the critical distance that needs to be travelled before intermodal transport can become price competitive. Therefore, the concept of break-even distance is highly relevant in modal choice, especially when price is one the major decision criteria. We construct a framework for calculating this distance and determine the preconditions that must be monitored, when applying the concept of break-even. We briefly discuss relevant studies on break-even distances and address the factors that explain major differences in break-even distances between regions. After, we discuss the break-even distance for intermodal barge transport in Flanders and for two cases of intermodal rail transport, using the LAMBIT model. In the following section, different alternatives to decrease the break-even distance are discussed.

3.1 The concept of break-even distance

Break-even analysis is used to calculate the price competitiveness of intermodal transport when compared to unimodal road transport (Pekin, 2010). At the break-even distance, the price for both transport services is equal. Due to the cost structure of intermodal transport, it will be cheaper over longer distances while unimodal road transport will be cheaper over shorter distances.

Break-even distances can be calculated in two ways: by a comparison of empirical price data and by modelling the cost structure of both types of transport chains, assuming that transport price will follow this cost structure. These cost structures are displayed in Figure 2 for maritime-based transport chains. The figure shows that the intermodal chain has higher handling cost in the sea port, but lower variable costs for the main haul by barge or rail transport due to economies of scale. The vertical leap in the intermodal cost function indicates the transhipment which takes place at an inland intermodal terminal. The rightmost part indicates the post haulage which connects the inland terminal to the final destination. The actual break-even distance will depend on the ratio of these different cost components (transhipments and transport costs). In addition, the break-even distance can also be derived from total logistics cost functions, to account for other modal choice criteria, such as transport time.

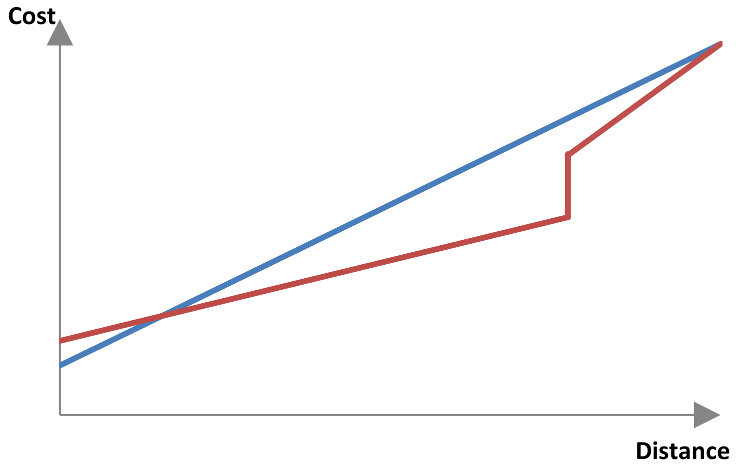

Figure 2 – Cost functions for intermodal (red) – and unimodal road transport (blue), for a maritime-based transport chain.[3]

The price of the transport chains will depend on the transport time and the distance. Both factors on their turn depend on other features such as the existing network infrastructure and capacity. Spatial differences in these factors, together with local market conditions lead to local differences in break-even distances. Therefore, these break-even distances can hardly be generalized. Following this network reasoning would advocate the start-up of new terminals, as more intermodal terminals will lower the average break-even distance of a region. But when accounting for economies of scale, required starting up a new intermodal service and/or an intermodal transhipment terminal, the number of terminals cannot increase endlessly, which is an argument for the optimization of the existing terminals.

A second possible factor which might lead to indistinctness in the calculation of break-even values is the measurement method. In practice, the transport distances of an intermodal and a unimodal

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[3] This representation doesn't include the return trip.

chain will never be equal. Different types of distances can therefore be used as comparison base: road distance, intermodal main haul distance, intermodal distance, the Euclidian distance between origin and destination … This choice of 'comparison distance' becomes even more important when comparing different break-even distance studies. So far, no standard has been set.

3.2 Relevant break-even studies

In this section we will discuss spatially relevant studies, reporting break-even distances. A first distinction should be made between intermodal transport modes. In general, intermodal barge transport has lower break-even distances, compared to intermodal rail transport. Already in 1994, the Dutch Ministry of Transport, Public Works and Water Management (Ministerie van Verkeer en Waterstaat, 1994) calculated a break-even distances of 100 kilometres for inland waterway transport when considering maritime containers and 250 for continental transport chains. For Flanders, Macharis and Verbeke (2001) found a break-even distance of intermodal barge transport of approximately 95 km, while Pekin (2010) reported a distance range between 57 and 99 km.

For intermodal rail transport, more studies which (partly) relate to the western European context are available. The previously mentioned study of the Dutch Ministry of Transport, Public Works and Water Management (Ministerie van Verkeer en Waterstaat, 1994) reports a break-even distance of 200 kilometres for maritime-based railway transport and 400 km for continental transport chains. Rutten (1995) and Janic et al. (1998) report distances within the same range: 120-500 km. Pekin (2010) finds a break-even distance of 173 km for maritime-based intermodal rail transport within Belgium. Tsamboulas (2008) argues that intermodal rail services below 400 km are usually not competitive in Europe. Although, two major exceptions exist: transalpine links and inter-port traffic, for example between Antwerp and Rotterdam. Additional break-even distances are reported in table 5.

Table 5 - Reported break-even distances for intermodal container transport in (western) Europe (Source: based on Vermeiren, 2013)

Study	Break-even distance/range (km)	Transport Mode	Continental/ maritime-based
Ministerie van Verkeer en Waterstaat, 1994	100-250	Barge	C/M
Macharis and Verbeke, 2001	95	Barge	M

Pekin, 2010	57-99	Barge	M
Ministerie van Verkeer en Waterstaat, 1994	200-400	Rail	C/M
Rutten, 1995	117-417	Rail	C/M
Janic et al., 1998	150-500	Rail	
van Klink and van den Berg, 1998	500	Rail	
Kombiverkehr (in Bärthel and Woxenius, 2004)	350	Rail	
Janic, 2007, 2008	600-1.050	Rail	
Kreutzberger, 2008	600	Rail	
Pekin, 2010	173	Rail	M

Table 5 shows clear differences in the estimates of break-even distances, especially for the intermodal rail sector. Other European studies even mention break-even distance up to 1.858 km (Sandberg Hanssen et al., 2012) as consequence of regional market conditions and differences over time. In addition, also fluctuations in the market price of road transport can bias the estimates of break-even distances. In the next sections we use a case-study approach and discuss additional parameters influencing break-even distances: the geographical direction of the post haulage, the importance of network characteristics and the difference between a price function and a generalised price function.

3.3 Break-even in inland waterway transport

This case describes maritime-based container transport, originating from the Port of Antwerp leaving for all Belgian municipalities. The Port of Antwerp aims to increase the modal share of barge transport up to 42% by 2020 (Port of Antwerp, 2013).

The LAMBIT model, developed by Macharis (2000), is used to calculate the break-even distances. This is a GIS-based model, used for intermodal transport related policy analyses. For given origin-destination combinations, the model calculates the cheapest transport routes, using a shortest path algorithm. To calculate these cheapest routes, price information, derived from surveys, is used. This same input data also allows calculating the break-even distance for network distances and for the Euclidean distance.[4]

[4] A more elaborate description of the model can be found in Meers et al. (2013a).

Figure 3 shows an output image of the LAMBIT model, depicting the market areas of Belgian intermodal terminals. It is clear that the transport network influences the extent of a terminals' market area. The barge terminals in the east (Meerhout, Genk, Renory) have extended market areas, in comparison to the barge terminals in the west (Avelgem, Gent). One explanation for this phenomenon is that the ratio between the distance to these terminals by barge and the distance by road in the east is closer to one than the same ratio for the western terminals, as barge route to these terminals involves a bigger 'detour'. Relatively short barge distances (compared to the road-only distance) also explain why terminals in the vicinity of the sea port can have a (small) market area.

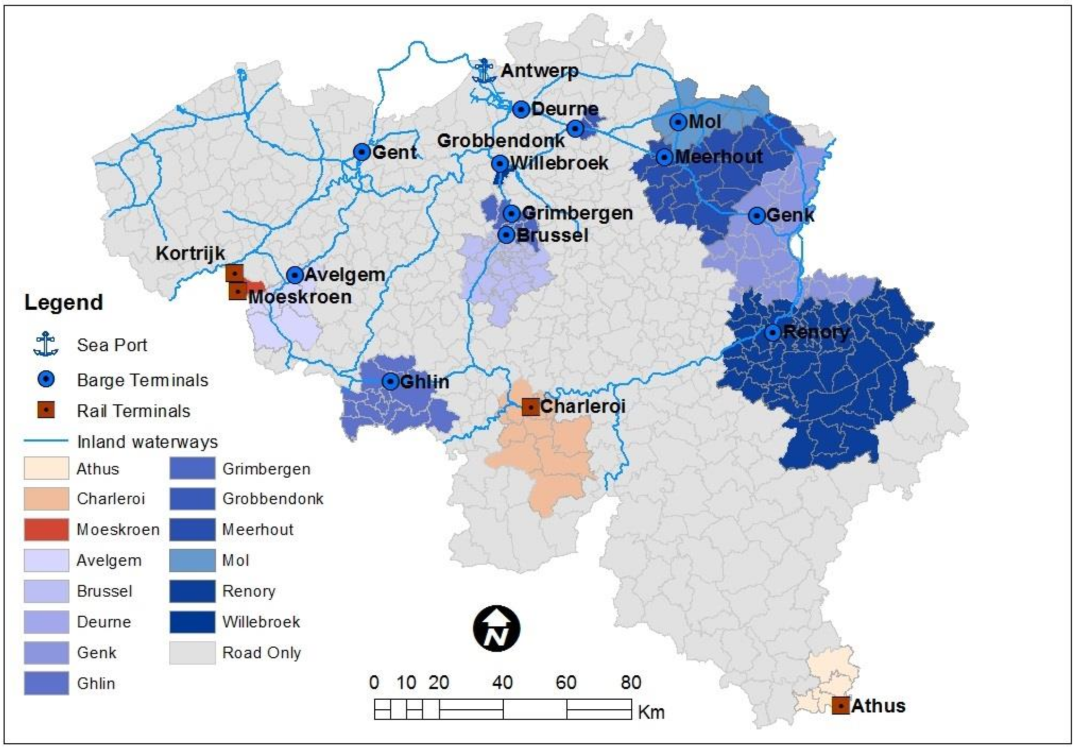

Figure 3 – Market areas of intermodal terminals, based on price comparisons[5]. (Source: Meers et al. (2013a))

Obviously, break-even distances depend on the post haulage distance of the intermodal route. Therefore, we calculated the break-even distance in function of this post haulage distance. We chose to express the break-even distance with the door-to-door unimodal road-only distance as reference

[5] Anno December 2014, the terminals of Charleroi and Moeskroen (Mouscron) are no longer served by direct trains from/to the Port of Antwerp (Port of Antwerp, 2014a).

distance. To account for the previously mentioned 'detour' effect, the ratio between the intermodal main haul transport distance and the unimodal road only distance was calculated, this ratio is calculated as a floating average of the existing post haulage distances from 0 to 50 km (Figure 4). When accounting for the transport price only, the break-even distance varies between more or less 30 km and 160 km, depending on the length of the post haulage and assuming the linear LAMBIT price functions based on 2013 market conditions. Short post haulage can thus drastically reduce the break-even distance of intermodal barge transport. These short break-even distances can be related to several factors. Due to the use of shuttle services, prices can be kept low as reasonable volumes are transported between port and terminals.

In Figure 4 represents the break-even distances when considering a total logistics price function. This means that besides the transport price, also time is accounted for, using a Value Of Time (VOT) component (see Meers et al. (2013a)). As intermodal barge transport is slower, the break-even distance will increase for a constant post haulage distance. The trend breaks in both graphs are due to (detours as consequence of) the network infrastructure.

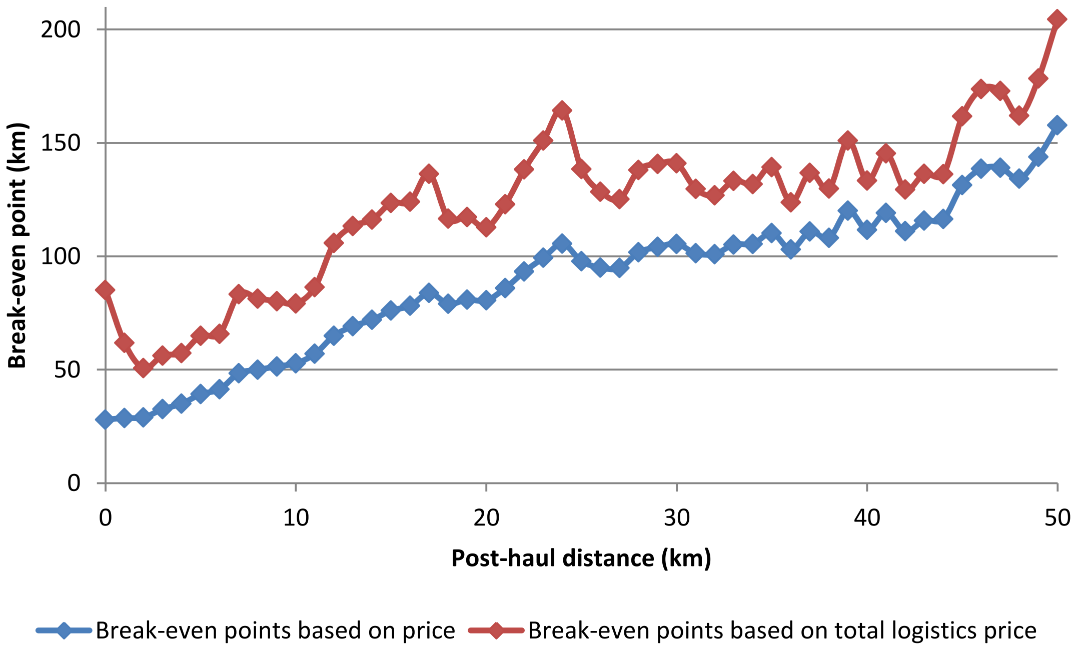

Figure 4 – Average break-even points barge transport in Belgium.

This analysis shows that break-even distances for intermodal barge transport can become really short, when post haulage distances can be kept to a minimum and when the network topology allows short distances between the port and the hinterland terminal. Therefore, a case-specific approach is recommended when discussing the competitiveness of intermodal barge transport.

3.4 Break-even in rail transport

Few domestic intermodal rail services persist in Flanders and in Belgium. Inter ferry Boats (IFB), part of NMBS logistics, strongly reduced its offer for domestic services. For this reason, this break-even analysis will focus on international intermodal rail transport. The following section is based on simulations in the context of Twin Hub, an INTERREG NWE program funded by the European Union. The aim of the project is to bundle container flows between the Port of Antwerp and the Port of Rotterdam for intermodal rail services to their mutual hinterland, to increase their competitiveness. Two case studies based on the research of Pekin and Macharis (2013) will be discussed and elaborated.

The methodology used in this analysis is based on the LAMBIT model, but the geographic scope is extended to the rest of Europe. The first case discussed is connecting the Twin Hub to Slaskie in Poland. From the Rail Service Centre (RSC) in Rotterdam to Slaskie, the road distance is 943 km, compared to 1.028 km by rail. Based on the price function for intermodal rail transport, the door-to door unimodal road break-even transport distance is 464 km when the post-haulage distance is limited to 20 km (for the 2013 market conditions). In this calculation, it is assumed that the distances of unimodal road transport and rail transport are equal, while the distance of the post haulage is the dependent variable. Longer post haulages increase the break-even distance, e.g. for 100 km drayage, the break-even distance increases up to 636 km.

An important aspect when calculating break-even distances, is the geographical direction of the drayage. The shape of the market area of a terminal is not a circle, but rather an egg-shaped oval Figure 5 presents the deformation of the market area based on calculations with the Slaskie price function, assuming Euclidian distances between origin and destination. The sketch in figure 5 shows the effect that the transport direction has on the distance of the post haul transport to break-even. The short distance is in the case of Slaskie only 15% of the distance of the long distance. The post haul in the direction north or south (top/down) is twice the distance of the short distance.

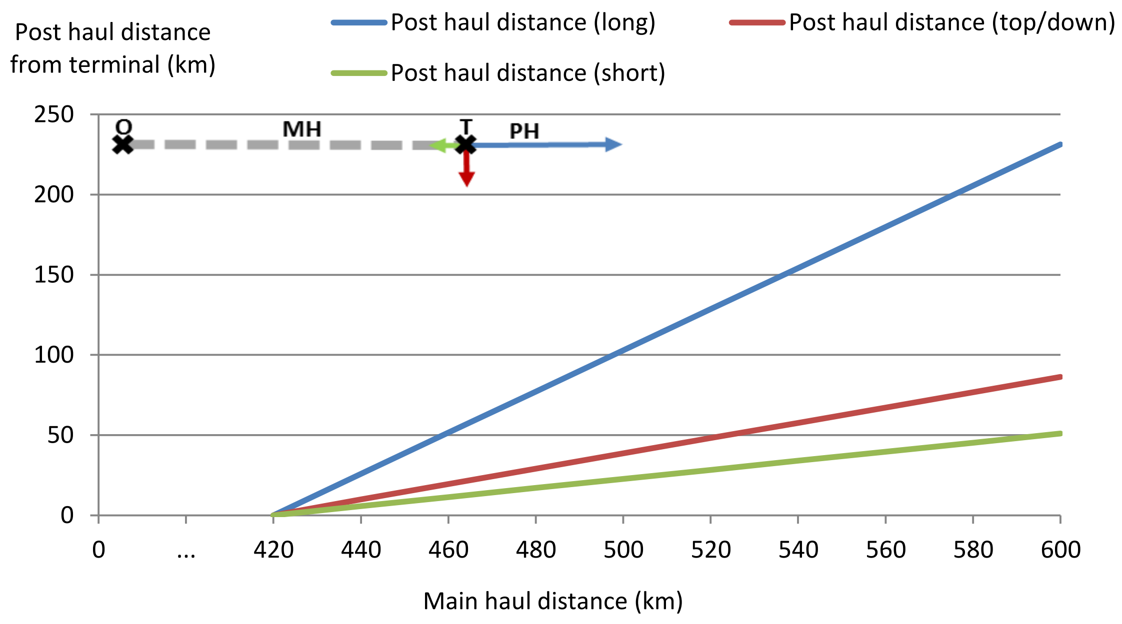

Figure 5 – Break-even distance variation, depending on the direction of the post haul transport. A visualization in the left upper corner shows how the shape of the market area is influenced (O=origin, MH=main haul, T=terminal, PH=post haul).

A second case discusses intermodal rail transport from the Port of Antwerp to Basel. In this case a lower break-even distance is found. For a post haulage distance of 20 km, a break-even distance of 384 km is found. A post haulage distance up to 100 km increases the break-even point up to 527 km. The lower break-even distance is explained by the higher prices for road transport in Switzerland. But still, the break-even distances calculated for both cases are above the 300 km modal shift target of the European Commission.

3.5 Lowering the break-even distance

In this section we elaborate the question: 'how can the break-even distance of intermodal transport be decreased?' This means the same as lowering the total cost (and thus the price) of intermodal transport compared to unimodal road transport, or increasing the cost/price of unimodal transport relative to the cost/price of intermodal transport. Therefore, we discuss the cost functions of both types of transport and focus on the different parameters that can be altered in favour of intermodal transport chains. We start by discussing the possibilities to impact the intermodal cost function.

A first option is to reduce the transhipment costs at the inland terminals (Figure 6 (left), see also Konings (2009)). According to Macharis and Verbeke (2004), approximately 30% of the total cost of the intermodal transport, relates to this transhipment. These transhipment costs can be decreased by for instance ICT innovations that make the operations more reliable. Faster cranes also lower the non-productive berthing time of the barges during the transhipment. In addition, the service level can be increased. This aspect also relates to economies of scale, as the transhipment cost per unit can be reduced by increasing the volume up to a certain level. Big transhipment volumes might however necessitate longer post haulage distances, increasing the cost for this part of the transport chain. As a second option, also the cost for the port handling can be decreased for the intermodal transport chain (Figure 6 (right)). An example to reduce this cost in intermodal rail transport is the collection of containers by barge at the different port terminals, as done by IFB's port distribution system.

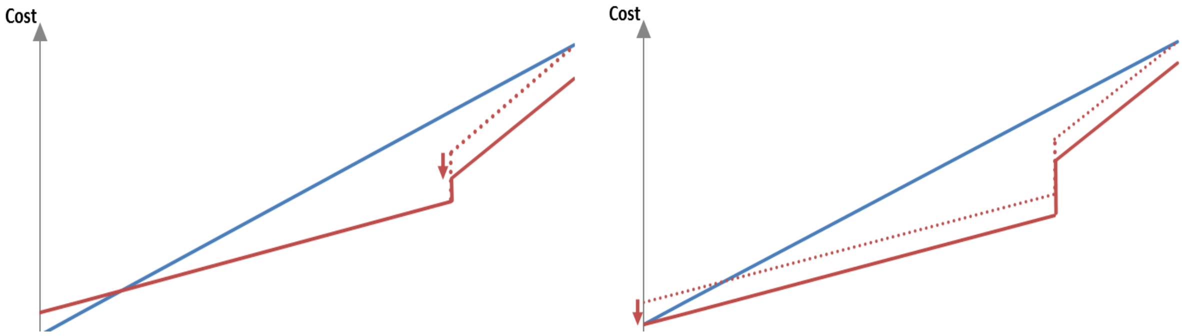

Figure 6 – Lower transhipment costs at the intermodal terminal (left) or at the sea port (right) decrease the total cost of intermodal transport. (Source: based on Macharis and Verbeke (2004))

A third option relates to the cost of the main haulage in the intermodal transport chain (Figure 7). The variable cost of this part of the transport chain is determined by inter alia, the loading degree of the trains/barges. This loading degree depends on the size and the balance of the transport flows between origin and destination. The shippers' time-related requirements and the type of barges or the number of wagons used influence the final loading and the frequency. Bigger volumes allow bigger vehicles and higher transport frequencies and enhance economies of scale. Konings (2009) reports a break-even loading degree of 75% for barge transport, although this percentage depends on the circulation times. Also the type of network service used (e.g. hub-and-spoke, shuttles), will be influencing. The physical infrastructure network, the water levels, the type of locks and the height of bridges however limit the type of barges that can be used.

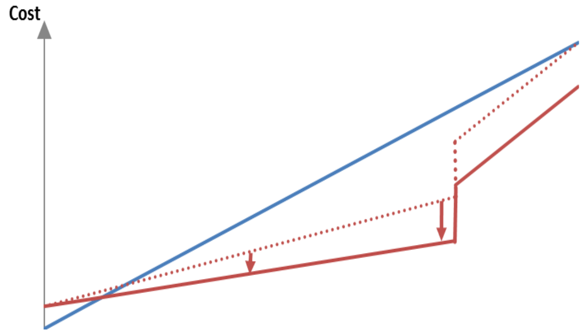

Figure 7 – Decreasing the variable costs of intermodal transport will benefit intermodal transport over longer distances. (Source: based on Macharis and Verbeke (2004))

A fourth possibility that impacts the cost function of intermodal transport is the set-up of new transhipment terminals in the hinterland (Figure 8). As discussed in a previous paper: (Meers et al., 2013a), the set-up of an additional terminal will usually lower the total intermodal transport costs for shipments originating in the vicinity of the new terminal. The intermodal transport distance might be reduced, but more important: the distance of the main haul transport, having a lower variable cost, will increase, while the distance of the post haulage transport, with a higher variable cost, will be reduced. It should however be kept in mind, that when constructing new terminals it should be investigated in advance if it's desirable to add an additional terminal to the existing terminal network, with regards to inter-terminal competition (Meers et al., 2013a).

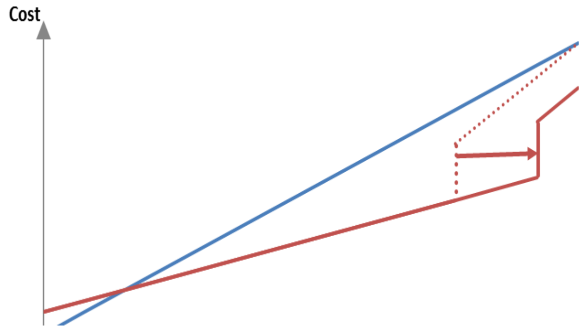

Figure 8 – A new terminal can decrease the costs of intermodal transport for shipments going to/from locations in its vicinity. (Source: based on Nemoto et al. (2006))

Also the cost of the post haulage can be altered in favour of intermodal transport (Figure 9). When the variable cost of road transport in general increases, the intermodal transport chain will become more cost competitive when compared to the unimodal road transport chain. The total cost increase for the intermodal transport chain will indeed be lower than the cost increase of the road-only alternative. A road pricing measure, where trucks are charged per kilometre driven will have such an effect on the cost functions. Also an increase in fuel prices might have such an impact when comparing to rail transport operating on electricity. Obviously, this will only be the case when the length of the post haulage is shorter than the length of the road transport alternative (as will be in all competitive cases).

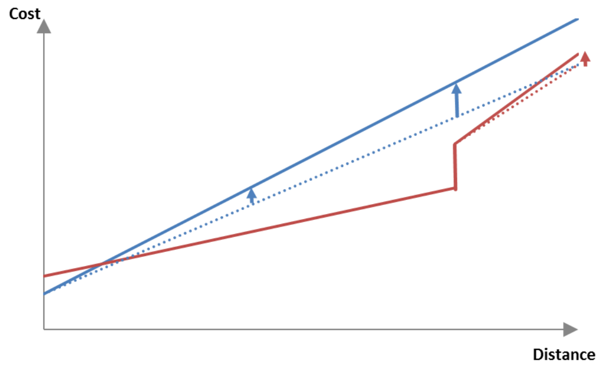

Figure 9 – An increase in the variable cost of road transport will increase the price of both unimodal and intermodal transport, but the effect on the intermodal chain is more limited. (Source: based on Macharis & Verbeke (2004))

The road transport cost function could also be altered by increasing the fixed cost (Figure 10). This change will however have no effect on the absolute cost difference between the unimodal and the intermodal transport chains, as strictly speaking, the cost of both functions will increase by the same amount.

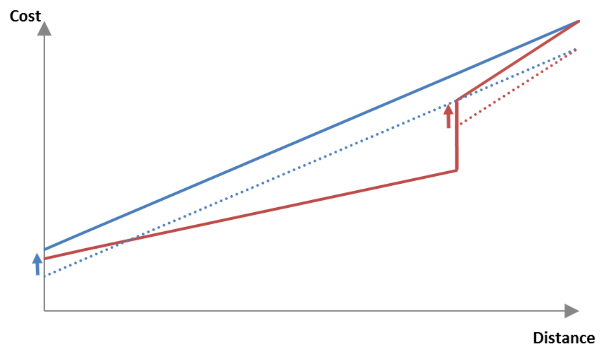

Figure 10 – Increasing the fixed costs of road transport will not change the absolute cost difference between the unimodal and the intermodal transport chain.

Besides these 'basic' impacts on the cost functions, also other elements will impact the total cost of the intermodal and the unimodal transport chain. The balance of transport flows and the share of empty trips strongly influence the cost functions. In addition, the inland terminal can be used as a depot for empty containers, to avoid an unnecessary return trip with an empty container if this container can later be used for a return trip in the other direction. Innovative solutions, such as the empty depot service' that is part of the Port of Antwerp connectivity platform (Port of Antwerp, 2014b) can decrease this number of empty trips and better align the inbound and outbound container flows in a region.

Some policy measures to impact both cost functions have been briefly discussed (e.g. pricing). But some measures, such as a full internalisation of the external transport costs can combine the effect of some of the suggested measures. This will lead to a reduction of the break-even distance, as the increase of the cost for unimodal road transport will be greater than the cost increase for intermodal transport.

Two groups of variables influencing the break-even distances can be identified from the previous sections. A first group entails variables is related to physical infrastructure networks: the distances of the main haul, the post haul and the unimodal road haul. These distances clearly depend on the origins and destinations of the transport flows, and for the intermodal chain, also on the location of the transhipment terminal. A second group of variables is mainly related to cost and price structures. These include the transhipment rates in the port and in the terminal and the fixed and variable prices for using the different transport modes. These factors highly depend on a multitude of factors, such as the energy prices, the capacity (utilisation), tax regimes and possible subsidies.

Obviously, this analysis focuses solely on direct costs and price-related factors. But when a total logistics chain perspective is taken, also value added services will impact the aggregated cost functions.

All factors mentioned above, can be combined in an integrated framework which can be used to evaluate break-even distances and the price competitiveness of intermodal transport (Figure 11). As stated before, a case-study approach is best suited, especially when break-even distances are to be translated into modal shift policies.

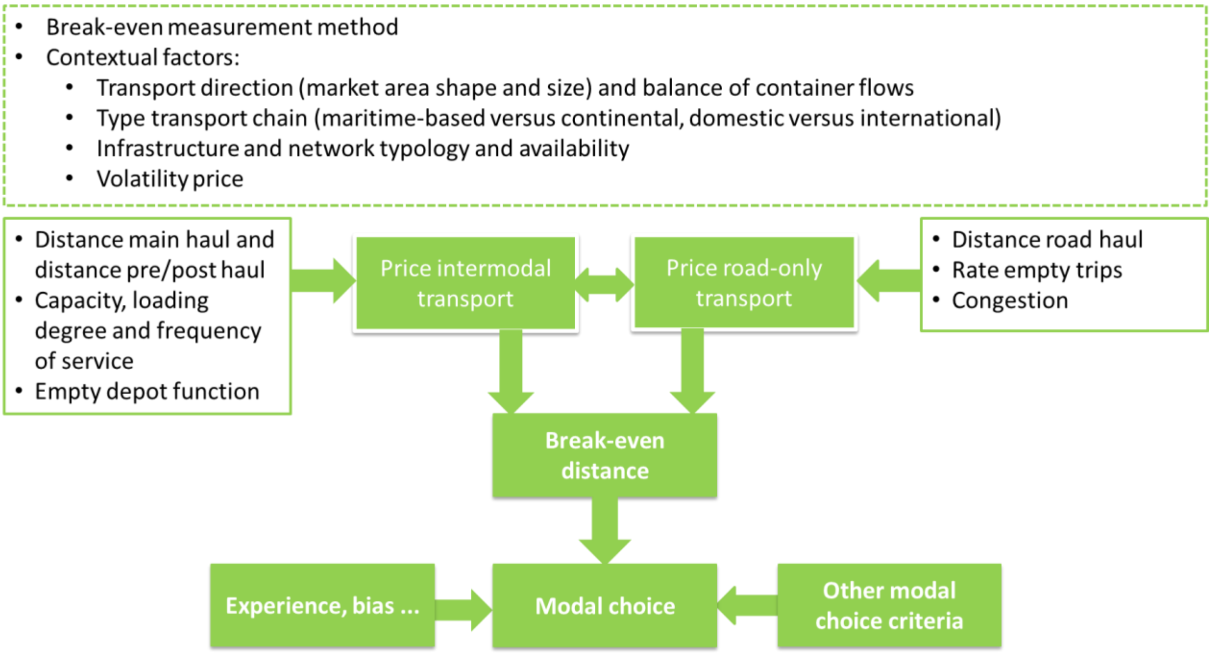

Figure 11 – Framework for the calculation and the assessment of case-specific break-even distances.

Besides ways to decrease break-even distances, also ways to increase the break-even distance can be discussed. Obviously, when transhipment costs or variable cost of the intermodal main haul are negatively influenced (in se, when they increase) intermodal transport will become less competitive. Finally, it should be noted that, as the framework suggests, the actual modal choice will usually not solely depend on the break-even distance.

3.6 Overview

This study on break-even distances shows that modal shift policies focusing solely on long distance hinterland transport, do not exploit the full potential of maritime-based intermodal transport. This holds in particular for the case of hinterland transport to and from the Port of Antwerp where distances are short and volumes are big. The majority of maritime containers are transported over distances below the modal shift threshold of 300 km, promoted by the European Commission.

As argued in the previous section, cost is still a critical modal choice variable, which makes break-even distances an important evaluation criterion. The break-even distances reported in literature range from less than 100 km up to over 1,000 km. This range can be explained by local market conditions, infrastructure network characteristics and the difference in measurement methods. We found that defining the concept of break-even is crucial, when calculated break-even distances are to be used in policy making. The suggested framework should allow to place (the calculation of) break-even distances in perspective. The break-even distances in Flanders are however much shorter for inland waterway transport. When drayage distances can be kept short, inland waterway transport can even become profitable on very short distances. The reported break-even distances for (international) rail transport are however much longer.

The framework also shows that different policy levels can clearly impact the break-even distances of intermodal transport, by impacting on the relevant influential factors. Measures such as road pricing can strongly reduce break-even distances, as the case of Switzerland proves. Other measures that are discussed are: an internalisation of external costs, supporting for the set-up of intermodal terminals and innovative transhipping techniques. Besides, it is shown that not only the distance of the (post haul) transport is highly influencing the break-even distance, also the transport direction is clearly not negligible.

4 Modelling modal choice with LAMBIT

In this section, we simulate the making of modal choice decisions for maritime-based container transport in Flanders. LAMBIT, in combination with a Multi-Criteria Decision Aid (MCDA) analysis, is used to determine the preference for the different transport alternatives. This allows incorporating different modal choice criteria in the decision process without the need to monetize each of them, as was done in previous analyses. This combined methodology is tested for all transport options between the Port of Antwerp and the rest of Flanders, using preferences derived from Beuthe and Bouffioux (2008). The goal of this analysis is twofold. On the one hand side, it allows to simulate the spatial impact of changing modal choice preferences on the modal split. Second, this comprehensive model can also be used by shippers to make modal choice decisions, meeting the specific modal choice requirements of a single shipper.

4.1 Introduction

Insight in modal choice decisions is crucial for policy makers to act upon negative consequences of transport. In transport modelling, modal choice determines the modal split of the models. In the methodology presented here, model choice decision can be estimated for different transport flows at the same time, but the methodology can also be used for individual decision making. This allows explicitly considering and comparing the choice criteria, making users aware of the performance of the alternatives on all criteria. In this model, users can specify and weigh the modal choice criteria they consider to be important. This approach allows including the more 'traditional' modal choice criteria described above, but also other characteristics such as the societal impact of a transport decision. A last advantage of this approach is that transport chains can be evaluated on quantitative and qualitative criteria simultaneously (Vincke, 1992).

4.2 Combined GIS-MCDA Methodology

The overview of the combined methodology is presented in Figure 12. The model consists of three sub-models, relating to three modelling stages. First LAMBIT, a GIS-based model, is used for data collection and simulation. In a second stage, the Analytical Hierarchy Process (AHP) is used for setting up the decision framework and for weighting the modal choice criteria. Finally, in a third stage, PROMETHEE[6] is used in the overall evaluation to come to a final modal choice decision. In this section, the eight different steps are elaborated.

The input for the MCDA is derived from LAMBIT.[7] LAMBIT uses the transportation networks to calculate the shortest routes between a given origin and destination (OD). Intermodal terminals serve as nodes in the networks to change from one mode to another. In this analysis, also terminals in France and the Netherlands where included as possible transhipment locations. For every OD combination, the three shortest, cheapest or fastest routes are selected: one unimodal road route, one intermodal barge route and one intermodal rail route (step 1). The modal choice criteria that are linked to the network characteristics (transport price, time etc.) are than derived from the output routes (step 2). Non-network related criteria can be directly used as input in the MCDA.

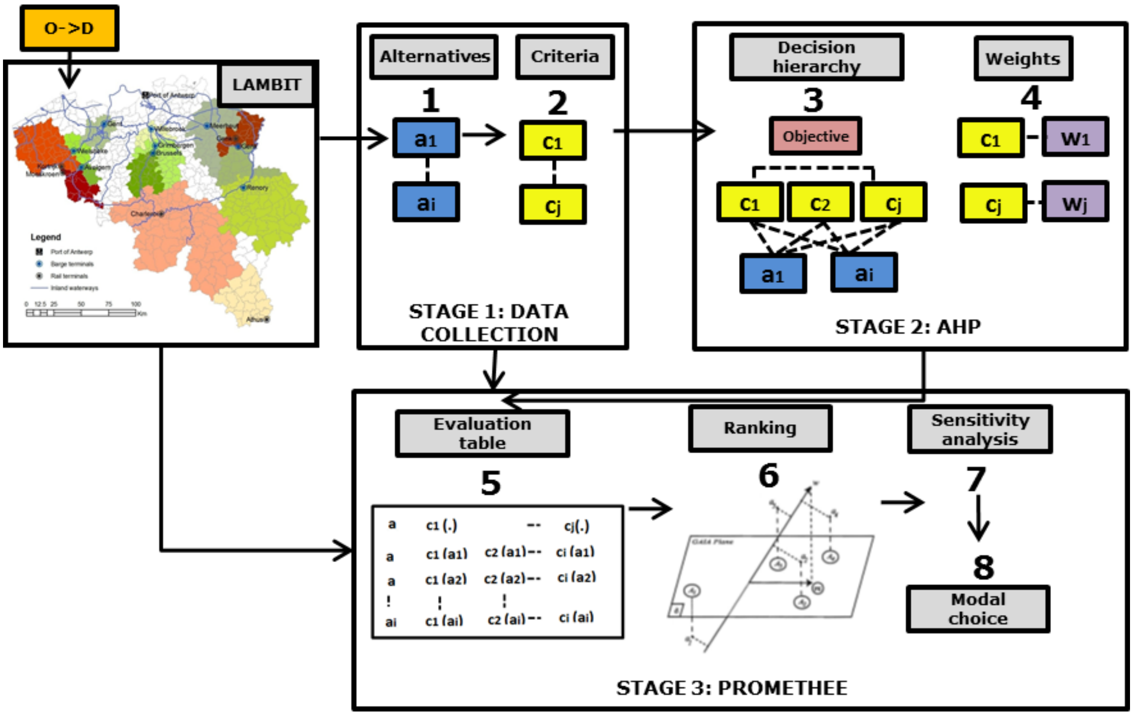

Figure 12 – MCDA-GIS combined methodology (Meers et al., 2013b)

In stage 2 and stage 3, the MCDA is performed. In the third step, all the criteria are structured in a decision hierarchy. The decision problem is structured with the overall objective on top, the criteria (and the indicators) and the alternatives at the bottom. For the evaluation of the criteria considered,

[6] An extensive description of the interaction of AHP and PROMETHEE can be found in Turcksin et al. (2011).

[7] A more extended description of the LAMBIT model can be found in Meers et al. (2013a).

indicators are used. These indicators are the output of the LAMBIT simulations from stage 1. Also the weights of the different criteria are determined (step 4). The weights are derived using pairwise comparisons.[8] The decision matrix is constructed, because different indicators are used for different criteria which cannot directly be compared. For instance a price difference of €20 cannot directly be compared to an accident risk of 0.5x10^-6 accidents per TEU km. This approach allows comparing a difference in transport price to a difference in for instance accident risk.

In the third stage, PROMETHEE is used for the aggregation (step 5). The importance of difference in values is accounted for by using preference functions and preference cut-off values (Brans et al., 1986). These preference functions are used to convert the deviation between the evaluations of the routes on a specific criterion into a preference degree. A list of preference functions can be used, to meet the nature of the considered criteria. The outcome of this aggregation is than a ranking of the considered alternative routes, based on an overall preference index, which consists of information on the score on each criterion (step 6). This index can be translated into a net preference flow, which allows easily comparing the available routes. Higher preference scores indicate a greater preference for an alternative. The actual decision making can be based on this output (step 8). A sensitivity analysis can show how (small) changes in preferences or weights can impact the final decision.

4.3 The case of Flanders

The methodology described above was applied on the case of maritime-based hinterland transport between the Port of Antwerp and the rest of Flanders. This means that the model compared the available alternatives for transport between the port and each municipality in Flanders and in Brussels.

4.3.1 Selection of alternative routes

As an illustration serve the possible routes between the Port of Antwerp and Zwevegem, in the southeast of West Flanders. The first alternative is the unimodal road route, which is the fastest and the cheapest road route. The second alternative is a transport to the inland terminal in Wielsbeke by barge, and the post-haul is performed by road transport. The third alternative goes via rail to Kortrijk and again, the drayage is performed by truck.

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[8] For more information on this methodology, see Meers et al. (2013b)

4.3.2 Modal choice criteria

Five different modal choice criteria were included in the analysis: three ‘traditional’ criteria and two related to the societal impact of mode choice. The most important ‘traditional’ criteria were selected based on the analysis of Beuthe and Bouffioux (2008) for container transport by Belgian shippers. This meant the consideration of transport time, transport time and transport frequency. Reliability could not be included due to a lack of elaborate data on on-time deliveries. The same problem arose for flexibility. Nevertheless the same ratio in the relative importance attached to the criteria was used. As external effect variables: transport-related CO_2-equivalent emissions and the accident risk were included. The values used in the following analyses are however average values as the value of the indicators depends on an extensive list of influencing variables. The transport price for instance will depend on the balance of container flows, while the emissions will depend inter alia on the type of barge that is used.

The variables relating to transport price and transport time were already discussed in the above sections and in Meers et al. (2013a). The price functions used are based on questionnaires and include the price for transhipments, main hauls and possibly drayage. The information on transport time is derived from speed data from ECMT (2006) and Janic (2007), coupled with specific route characteristics. Frequency of service was included as the number of departures or arrivals per week.

CO_2-equivalent transport emissions per TEU were included to account for CO_2-emissions and other greenhouse gases, recalculated to the same comparison base through their global warming potential. These values were derived from the report of McKinnon and Piecyk (2010). The values on accident risks were extracted from the report of De Vlieger et al. (2004) and expressed as chance on accidents per TEU-km. This information was linked to the route characteristics derived from LAMBIT to calculate the accident risk per considered transport route.

4.3.3 Decision matrix

As mentioned earlier, the weights for the traditional modal choice criteria were derived from Beuthe and Bouffioux (2008). Working with these average values, obviously doesn’t reflect the variability in preferences of decision-makers in reality, but they provide an average preference of the transport actors in Belgium. The pairwise comparisons can however still be used when individual shippers want to determine their preferred transport alternative. In a first scenario, only the ‘traditional’ modal choice criteria were considered, neglecting the external effects of transport. In a second scenario, a minor importance was given to these variables, while in a third scenario their total importance was set to 25% (Table 6).

For all criteria, the linear preference function was chosen (Table 6). This means that also a threshold value had to be included. If for instance the difference in transport price between two options is over €25, total preference will be given to the cheaper alternative. The indifference value is set as the maximum value for which it doesn't matter if you pick the cheaper or the slightly more expensive alternative. All criteria are minimized, except transport frequency. Due to the flexibility of road transport, each time a full preference is given to road transport over the other two alternatives on this criterion.

Table 6 – Weights, preference functions, indifference and preference values attached to the considered modal choice criteria.

	Transport Price (€/TEU)	Transport Time (h)	Transport frequency (x per week)	CO_2-eq. Emissions (kg/TEU)	Accident risk per TEU
Function	Linear	Linear	Linear	Linear	Linear
Indifference	5	0.5	1	0	0
Preference	25	3	3	50	1
Weights (%)	72.3	18.0	9.6	0	0
scenario 1	83.8	11.4	4.8	0	0
scenario 2	79.6	10.8	4.6	2.5	2.5
scenario 3	62.8	8.6	3.6	20	5

4.4 Discussion

The results are first briefly discussed for the case study of Zwevegem before the general results for Flanders are presented. To depict the output of the PROMETHEE analysis, different tools can be used.

Figure 13 shows how the net preference flows for each alternative in the case of transport to Zwevegem change according to the scenario simulated. Each alternative scores between -1 and +1 and higher scores indicate greater preferences for that transport mode. In this case, that means that the road alternative is slightly preferred above the intermodal barge alternative in the first two scenarios. Although, when an increased importance is attached to the external effects of transport, intermodal rail becomes more interesting and intermodal barge transport is preferred above the road-only alternative.

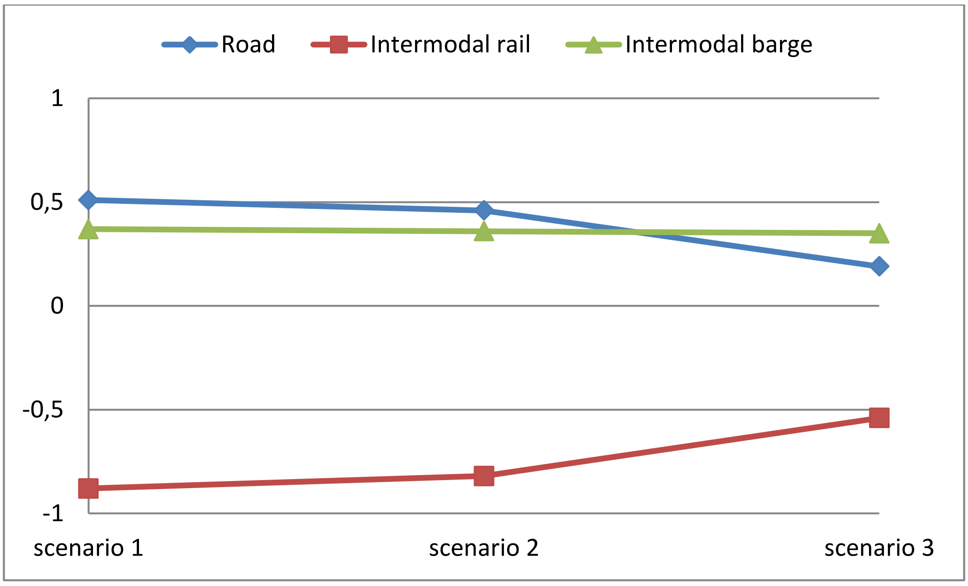

Figure 13 – PROMETHEE II ranking showing net preference flows for the three alternatives and the three scenarios. Increased importance for CO_2-equivalent emissions increases the preference for intermodal rail and to a lesser extent for intermodal barge transport (based on D-Sight).

For every municipality in Flanders, the net score of every transport option for transport to/from the Port of Antwerp was calculated and visualised. In general, there seems very little preference for intermodal rail services (Figure 14). This is mainly linked to the very limited availability of intermodal rail services within Flanders. Only in the region of Kortrijk, a small preference for intermodal rail services remains, although the preference values remain below 0 in all scenarios. Comparing the third to the first scenario will nevertheless in all cases feature increased preference values. In the third scenario, the preference for rail increases in particular in the south of West Flanders. Overall, the net preference scores for rail increases (or remains stable) in all municipalities when comparing the third to the first scenario.

The net preference scores for intermodal barge services are highest in Limburg and in the south of West Flanders (Figure 15). The values are lowest closer to the sea, in the north of Antwerp and in the east of East Flanders. Comparing the three scenarios, it is witnessed that some municipalities with a high score in the first scenario have a lower score in the third scenario. This is particularly the case in the south of West Flanders, due to an increased net score for the rail alternative. In the other regions, far from any rail terminal, the scores increase for the third scenario, but as the barge alternative already had a high score in scenario 1, the score remained stable.

Obviously road-only transport captures the main part of Flanders with a dominance of net preference score of over 0.5 (Figure 16). When these net scores are greater than 0.5, this alternative will be preferred to the intermodal alternatives. The scores are nevertheless lower in the east of Limburg and in the south of West Flanders. In scenario 2, reduced scores for truck transport preference are already visible, in particular in the area (south) of Brussels and in the south of West Flanders. These are obviously the regions with stronger preferences for the intermodal alternatives (Figure 14 and 15). In scenario 3, the previously mentioned clusters increase in size. It should be noted that in every municipality the net preference score for road transport decreases when comparing scenario 3 to scenario 1. The score remains stable in only two municipalities.

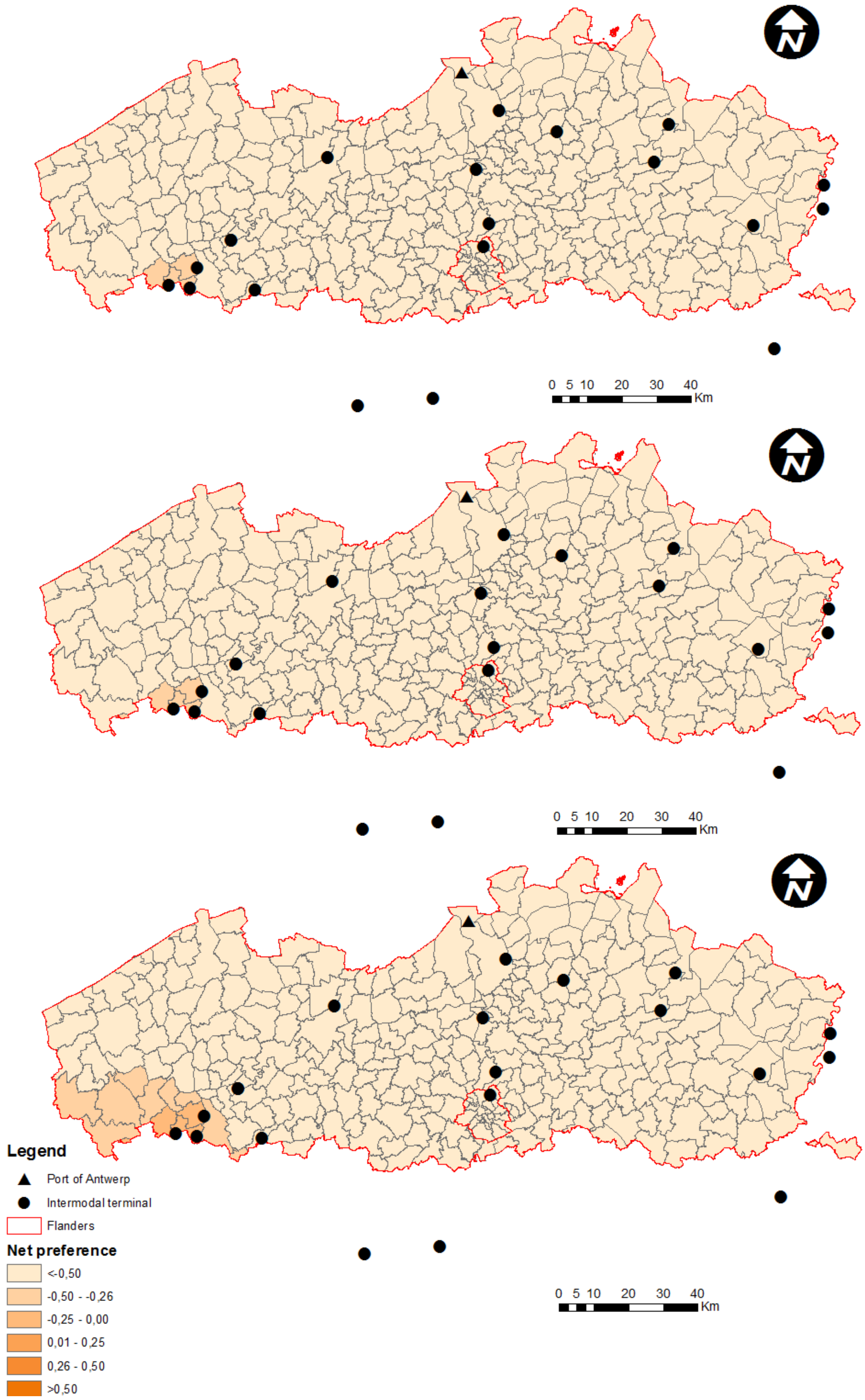

Figure 14 – Evolution in the preference for intermodal rail services in Flanders for scenario 1 (top), scenario 2 (middle) and scenario 3 (bottom)

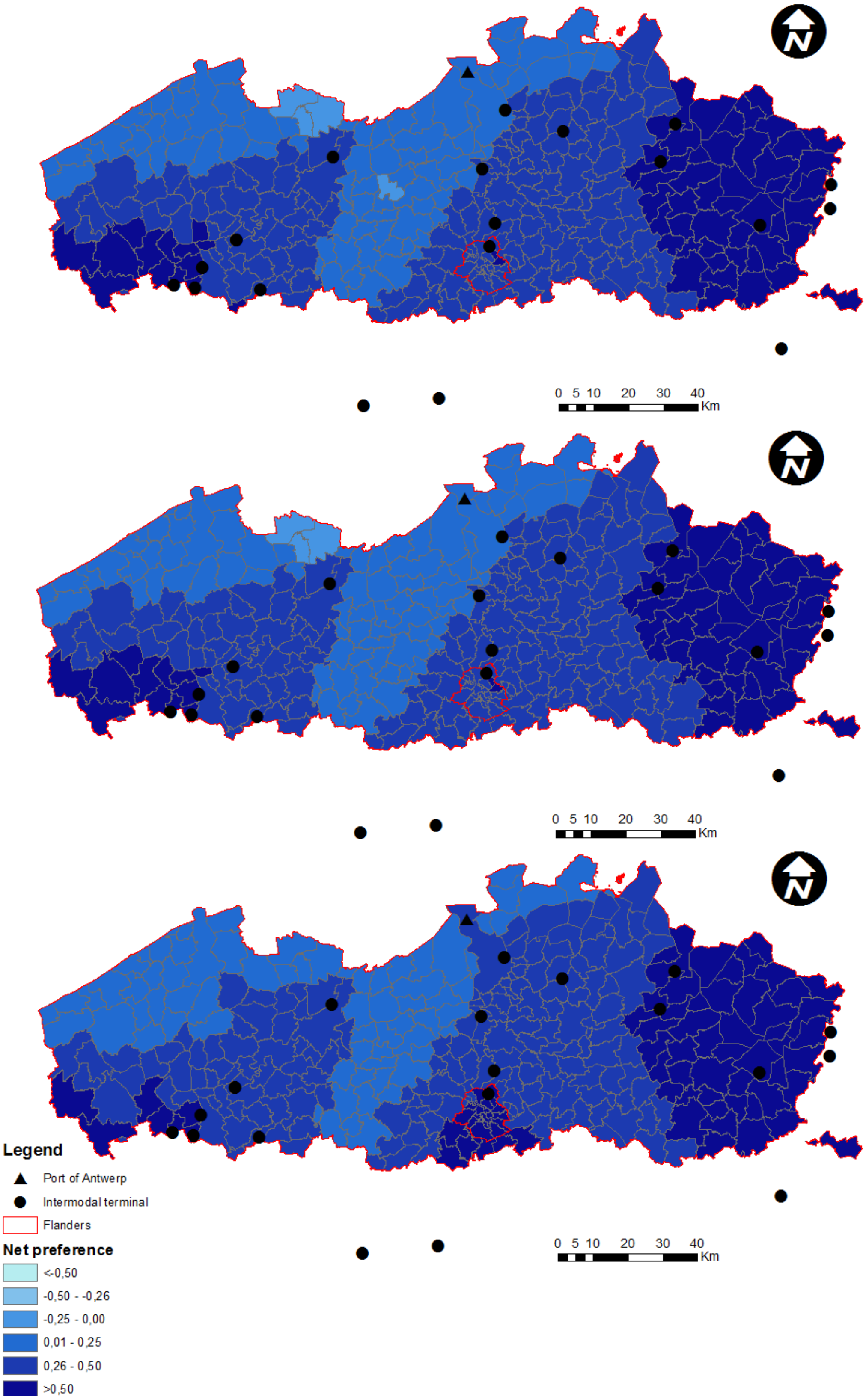

Figure 15 – Evolution in the preference for intermodal barge services in Flanders for scenario 1 (top), scenario 2 (middle) and scenario 3 (bottom)

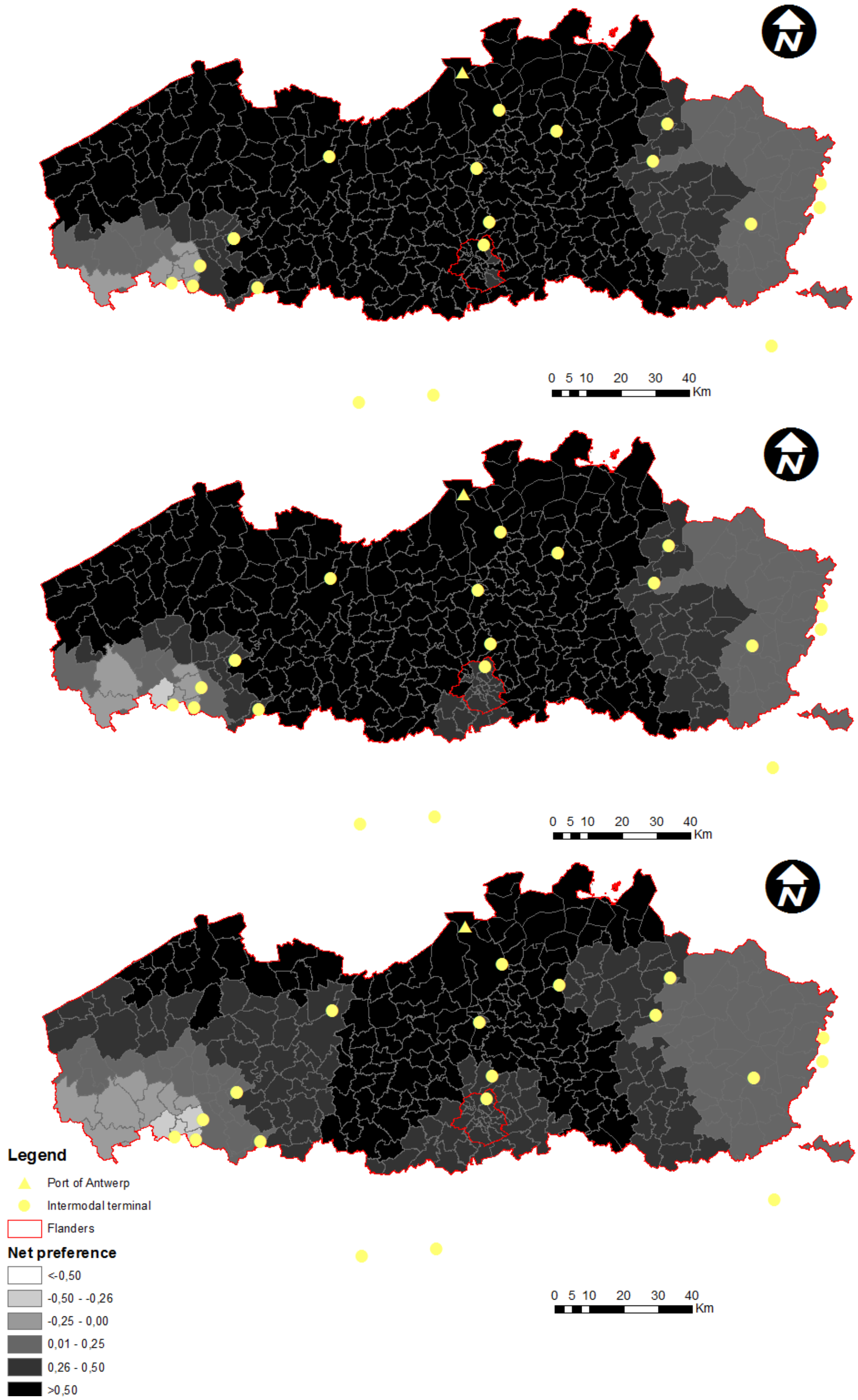

Figure 16 – Evolution in the preference for road-only transport in Flanders for scenario 1 (top), scenario 2 (middle) and scenario 3 (bottom)

For every municipality in Flanders, the most preferred option for transport to/from the Port of Antwerp was visualised (Figure 17). In the base scenario, three clusters can be identified where intermodal barge is preferred above unimodal road transport. A first cluster is in the south of West Flanders, where different terminals can offer competitive prices compared to road transport. A second cluster more or less entails the province of Limburg, where the terminals of Meerhout, Mol and the Port of Genk have their hinterland. A third cluster is rather small and is situated next to the Port of Brussels. It should be noted that this visualisation is somehow different from earlier LAMBIT simulations where only transport price was considered as a modal choice criterion (e.g. Figure 2). Especially the centre of the country is dominated by a preference for unimodal road transport.

Comparing the output for scenario 2 to the output of scenario 1 doesn't bring many changes. The three clusters are slightly (or not) extended. It seems that even when external effects of transport have a small importance in decision making, only few locations will have a relative preference for the intermodal alternatives. Comparing the third scenario to the first, results in some differences. The three existing intermodal clusters have extended in size. Especially the central cluster in and around Brussels grew strong, due the increased attention for external effects in decision making. The cluster in West Flanders extended to the north. As in most municipalities, the preference for intermodal barge increases in the third scenario and southwest of Ghent, two municipalities balance between a preference for road transport and intermodal barge transport.

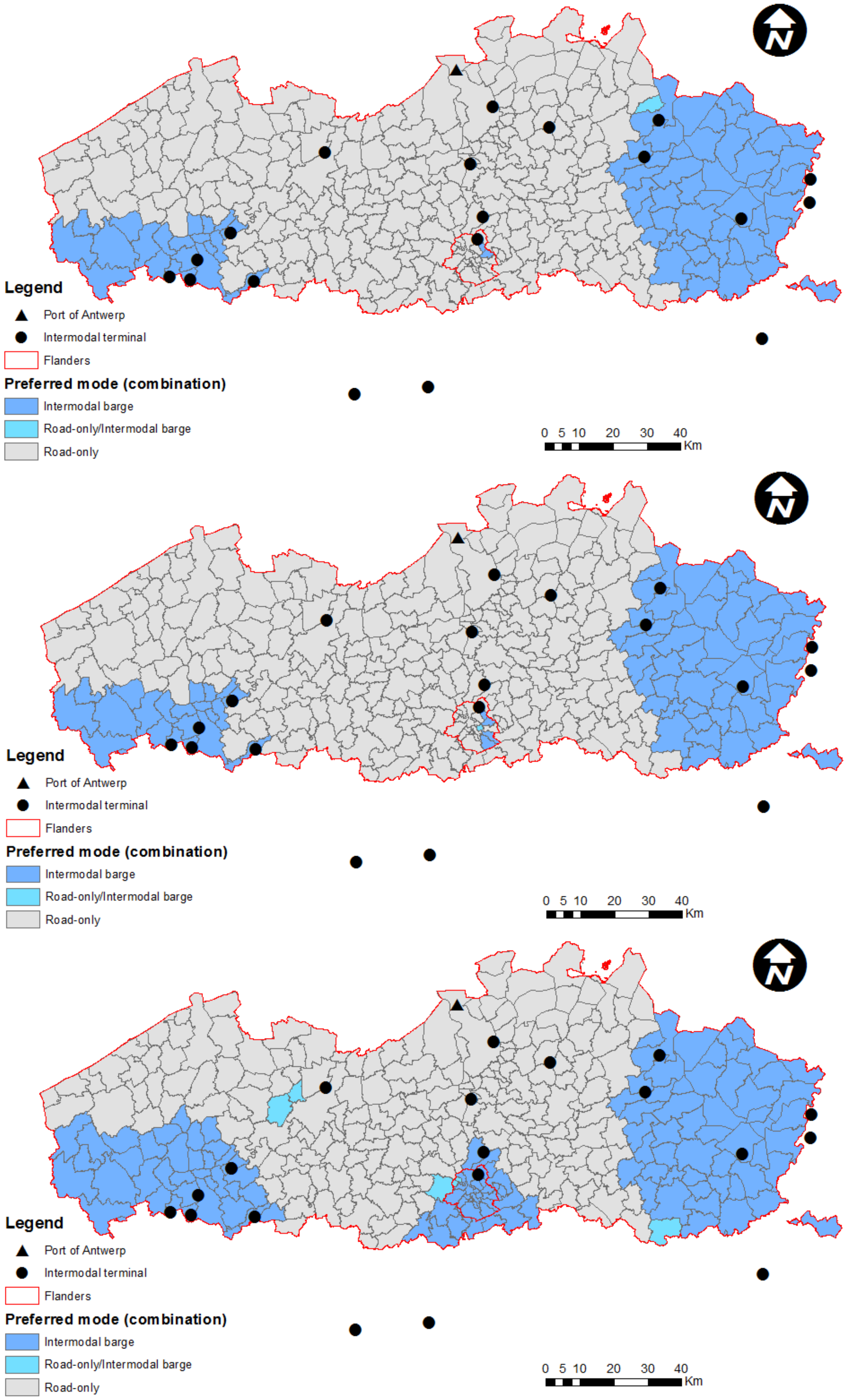

Figure 17 – Preferred transport mode (combination) in the Flemish municipalities, for scenario 1 (top), scenario 2 (middle) and scenario 3 (bottom).

4.5 Overview

In this section, a comprehensive modal choice model for container transport is proposed and tested for Flanders, based on existing modal choice criteria and their respective average weights. The model uses 'traditional' modal choice criteria in combination with external effects of freight transport. The results show that based on the given set of weighted criteria, the preference for intermodal barge services is greatest in Limburg and in the south of West Flanders. To change the overall preference for intermodal services, the importance of external effects in modal choice should be considerable, when the values of the criteria (their actual performances) remain unchanged.

This model can be used by shippers to analyse their modal choice behaviour, given their specific requirements. Custom-made analysis could be elaborated for individual companies and additional modal choice criteria could be added in the corresponding required data is made available. Even when environmental and societal criteria receive low weights, the model can clearly show the environmental and societal impact of the mode choice to create more awareness on the topic of sustainable transport services. Shippers can analyse their current decisions and change weights and preferences accordingly. This tool can also help users to make a thoughtful modal choice decision, considering a wide set of choice criteria.

Another application of this combined methodology can be in the prediction of transport flows, as in a transport model or as an (online or offline) decision aid instrument. Such a tool can include relevant information in the decision process to allow users to make decisions which meet their preferences. Besides, the previous analyses subdivide Flanders in regions with a greater or lesser potential for modal shift, based on the average modal choice preferences. This can help in identifying promising cases for modal shift from a mere spatial perspective.

Finally, this tool is also useful for analysing shippers' choice behaviour. It is obvious that when increased attention is paid for sustainable transport indicators, this might result in (modest) modal shifts. A better performance on the 'traditional' modal choice criteria can increase their competitiveness and the provision of services at the inland terminal can create an added value. Also increasing the weight of sustainability indicators can enhance a modal shift. This leads to the question on how to increase the relative importance of these indicators in decision making: by force (e.g. internalisation of external costs, road pricing…) or by the creation of awareness (e.g. through stimulation programmes such as Lean & Green). On the other hand can more environmentally friendly vehicles and improved network and capacity utilisation, decrease the environmental and societal impact of road transport.

5 Conclusion and outlook

This paper discussed modal choice in hinterland transport and consists of three main parts.

The second chapter discussed in detail which criteria determine the modal choice of shippers or forwarders to gain insight in their reasoning when opting for (or not opting for) intermodal services. The analyses revealed that the importance attached to the different criterion can vary strongly. Studies focusing on the Belgian context find however that cost, transport time, reliability, flexibility and frequency and safety are the criteria which are ranked highest. Nevertheless, the insight in modal choice behaviour can be improved by an additional survey, focusing on short distance container transport – as most studies have a different or broader focus – to give an up-to-date overview of modal choice criteria.

The third chapter focused on the price criterion, using the concept of break-even distance. Break-even distances reported in literature can be found within a wide range, which can be explained by local market conditions, infrastructure network characteristics and differences in measurement methods. Clearly defining the concept of break-even is crucial, when calculated break-even distances are to be used in policy making. This analysis shows that modal shift policies focusing solely on long distance hinterland transport, do not fully exploit the potential of maritime-based intermodal transport. This applies in particular to domestic inland waterway transport to and from the Port of Antwerp where distances are rather short and volumes big. Break-even distances for intermodal rail transport are however much longer necessitating an international perspective, as indicated by two case studies. The suggested break-even framework shows that different policy levels can clearly impact the break-even distances of intermodal transport, by impacting the relevant influential parameters (e.g. road pricing, internalization of external costs, supporting the set-up of intermodal terminals etc.).

The fourth chapter again provides a broader perspective in the analysis of modal choice decisions in Flanders, focusing on the modelling of modal choice decisions. A comprehensive modal choice model for container transport is proposed and tested for Flanders. The model combines 'traditional' modal choice criteria and external effects of freight transport. The results show that using a given set of criteria weights – based on the average evaluation of these criteria – the preference for intermodal barge services is greatest in Limburg and in the south of West Flanders. From a mere spatial perspective, these are the regions with the most promising cases for modal shift. This tool is also interesting to simulate changes in shippers' choice behaviour. It is obvious that when increased attention is paid for sustainable transport indicators, this might result in increased preferences for intermodal alternatives and in (modest) modal shifts. To change the overall preference for intermodal services, the importance of external effects in modal choice should however be considerable, when the relative weights of the other criteria remain unaltered. Different options are available to increase the relative importance of these indicators in decision making: by force (e.g. internalisation of external costs, road pricing…) or by increasing awareness (e.g. through stimulation programmes such as Lean & Green). On the other hand can more environmentally friendly vehicles and improved network and capacity utilisation also decrease the environmental impact of road transport while a better performance on the 'traditional' modal choice criteria can increase intermodal competitiveness and the provision of services at the inland terminal can create added value.

The model described in chapter 4 can also be used by shippers to evaluate their modal choice. When including external effects in mode choice, choices can become more sustainable. Even when these criteria receive low weights, the model can already show the environmental impact of mode choice and create awareness on the topic of sustainable transport services. Shippers can analyse their decisions and change weights and preferences accordingly. Also the reverse is possible to for instance check the performance of intermodal alternatives, compared to current practices. The methodology does also allow adding additional choice criteria in the decision process. Other applications of this combined methodology can be in the prediction of transport flows or as an (online or offline) decision aid instrument. Such a tool can include relevant information in the decision process to allow users to make decisions meeting their preferences.

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7 Appendix

7.1 Main transport mode choice criteria

7.1.1 Transport cost/price

The criterion of transport cost (or rate or price) is considered in almost all mode choice studies. It is important however to distinguish between transport price and cost. The transport price will be based on the total costs of a transport chain, but other factors such as competition among and between modes, bargaining power, profit margins, transport volumes and frequency of shipments etc. will differentiate total price from total cost. A freight forwarder for example might be in a better position to negotiate price levels than a small shipper.

Also the concept of cost is not always used unambiguously. Direct costs include elements such as the actual transport service and the handlings (see e.g. Grosso (2011)), while indirect costs might include additional costs for e.g. inventory. Such indirect costs can be related to attributes such as the transport frequency, necessitating higher inventory levels or the travel time reliability, necessitating additional safety stocks. Direct and indirect costs can be combined in a total logistics cost (Blauwens et al., 2002). Another division can be made between internal and external costs, where the latter encompasses transport-related costs which are not accounted for in the transport price and are therefore ‘carried’ by the society.

Despite the fact of its inclusion in most mode choice studies, there exists a high disagreement upon its importance relative to other criteria. Cost is ranked as most important criterion in for instance: Vannieuwenhuyse et al. (2003) and Danielis and Marcucci (2007) while other studies stress the importance of the general service level (Danielis et al., 2005). It can also be the case that once certain service level requirements are met, cost becomes the dominant determinant again.

7.1.2 Service quality

Transport service quality is a broad concept, which might include different modal choice criteria, opposed to transport service cost, such as transport time, reliability, frequency, damage risk etc. Anderson et al. (2010) find that as intermodal transport services are more complex and more difficult to manage, compared to unimodal transport services, it is more difficult to measure their service quality. In the following sections, the concepts relating to the quality of a transport service are discussed.

7.1.3 Transport time

Woxenius (2006) identifies five time components, of which transport time is one. The others are frequency, timing, punctuality and order time of which most are discussed in the following sections. He defines transport time as the planned duration of a transport service. It should be clear that due to different reasons such as the occurrence of accidental congestion, the planned and the actual transport time might differ.

Different studies attempt to monetize transport time (savings) by using a Value of Time component (see also (Meers et al., 2013a)). Kreutzberger (2008) and Zamparini and Reggiani (2007) notice a strong variation in these values between and among transport modes. Danielis et al. (2005) for example conclude that the importance of transport time diminishes when longer transport times are expected, while Beuthe and Bouffioux (2008) find that on shorter distances (<300 km) transport time receives a smaller weight in decision making than for medium to long distances.

7.1.4 Reliability

Rotaris et al. (2012) define reliability as the (standard) deviation of the travel time or as the (reduction) in the share of shipments arriving late or on time. It should however be noted that foreseeable delays due to for instance structural congestion can be incorporated in travel time, as the expected travel time. Reliability is than related to unforeseeable delays or early arrivals. Dullaert and Zamparini (2013) characterize reliability as the share of shipments arriving within the scheduled time (window) or as the relative variation of the transit times. Danielis et al. (2005) find that reliability is more important in road transport than in rail transport, and in particular for shorter distance transport and when dealing with just-in-time supply chains.

7.1.5 Environment

Criteria regarding the environmental performance of transport modes are rarely included in modal choice studies. The environmental performance of transport is however receiving increased attention. This can be witnessed by numerous Corporate Social Responsibility initiatives and by shippers and transport operators promoting themselves as green, based on environmental performance certifications. Studies that do include environmental performance as a criterion, mainly find its importance to be very limited. Fries (2009) nevertheless finds that Swiss shippers have a willingness to pay for transport services with reduced CO_2 emissions. A Swedish survey (Lammgård, 2007) however found a very low willingness to pay for improved environmental performance. Although freight forwarders indicate in a Spanish study (Feo-Valero et al., 2011) that environmental performance is a main advantage of rail transport, it is not indicated as a reason for freight forwarders to choose for rail transport.

7.1.6 Frequency and flexibility

Frequency is usually considered in modal choice studies as the number of departures offered within a defined time interval. Danielis and Marcucci (2007) note however that frequency and flexibility are somewhat ambiguous concepts, as road transport doesn't use a fixed schedule and operates on demand. Intermodal transport usually has fixed schedules. Rotaris et al. (2012) find that the value for the frequency of service is seldom monetized.

7.1.7 Goods damage and security

The chance on goods damage and more general the security of the goods during the transport operations is considered as an additional modal choice criterion. Its importance however, is valued very differently in different studies, which can be explained by the use of different definitions and heterogeneity in the samples (Rotaris et al., 2012). Flodén et al. (2010) conclude that goods damage is not considered to be a problem for shippers. Fries (2009) also relates goods damage to the actor responsible for it, which usually is not the shipper himself. Most damages occur during the loading and unloading, making the transport service provider not always responsible for it.

7.1.8 Transport mode

Preference for a certain transport mode, disregarding its actual performance, or bias might occur in modal choice studies. Maier et al., (2002) for instance find that Austrian shippers try to avoid rail services, even when all other considered criteria would be performing equally. In addition, Vannieuwenhuyse et al. (2003) find that users of a certain transport mode value its performance higher than non-users.

7.2 Data collection methods

Before comparing the relative importance of modal choice criteria, it has to be determined first which criteria are to be considered and how they are defined, because most methodologies comparing different criteria only allow a limited set of criteria to be compared (Cullinane and Toy, 2000). Methods to identify these criteria are: focus groups interviews, regular interviews, reviews of previous research, or the hypotheses of researchers. The relative importance of these criteria can then be tested with stated preference (SP) or revealed preference (RP) experiments.

Revealed preference experiments are based on observed market behaviour, in se the real-world supply of transport services. This means that shippers value the current transport alternatives offered. Therefore, RP provides information on real choice behaviour. But, RP cannot fully evaluate new market conditions and sometimes, the real-world observations don't allow enough variability for good modelling afterwards (Feo-Valero et al., 2011).

Stated preference techniques on the other hand provide hypothetical choices in fictitious situations, suggested by researchers. Although it is not referring to reality, using SP has some advantages. The idea behind SP is that decision makers make rational decisions, aiming to maximize their total utility, the decision maker will choose the alternative which maximizes his utility from a choice set (Grosso, 2011). A main disadvantage is that SP uses hypothetical examples and researchers cannot be certain that actors in a real-world situation will behave exactly the same as in the hypothetical situation (Feo-Valero et al., 2011).

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