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INTERMODAL TRANSPORT VALUE OF TIME & NEW TERMINAL LOCATIONS

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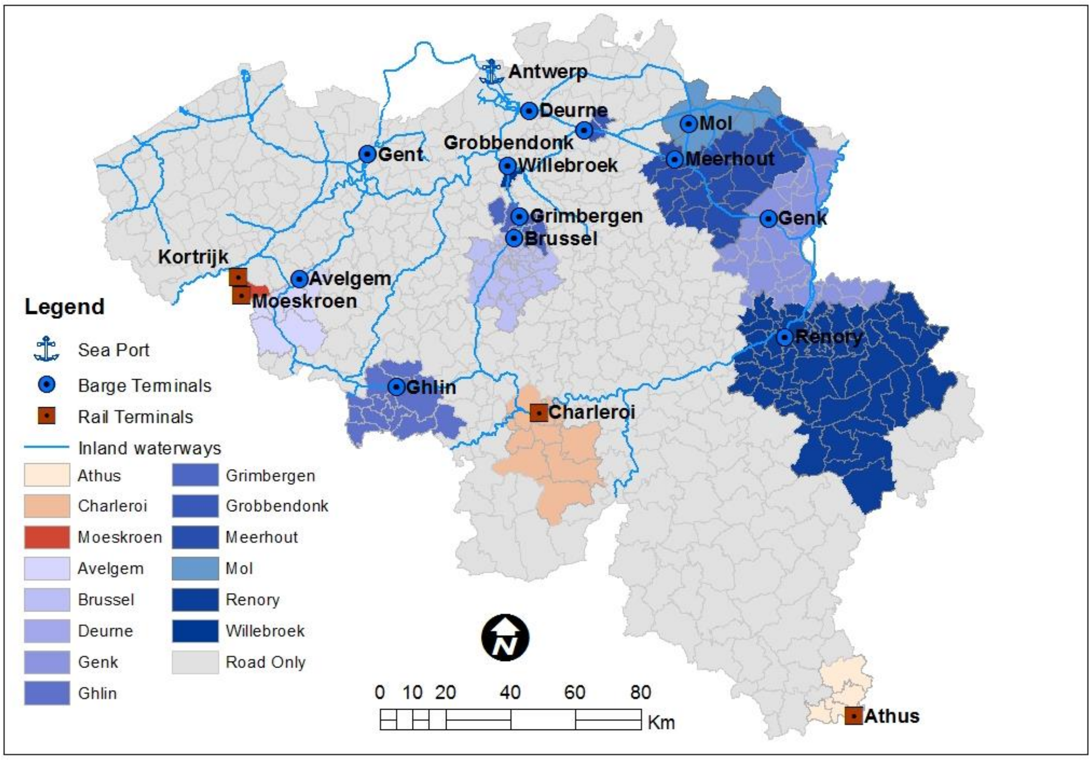
NEDERLANDSE SAMENVATTING

De sterke groei van goederentransport in Vlaanderen tijdens de laatste decennia heeft tot een aantal belangrijke uitdagingen voor het regionale beleid geleid. Zo is een modale verschuiving van unimodaal wegvervoer naar intermodaal binnenvaart- en/of spoorvervoer een belangrijke beleidsdoelstelling geworden. Intermodaal transport is de combinatie van minstens twee transportmodi in één transportketen, waarbij eenheidsladingen zoals containers worden gebruikt (Macharis et al., 2011). Een intermodale keten kan verschillende transportmodi bevatten, maar hier wordt gefocust op de combinaties binnenvaart/weg en spoor/weg voor containertransport van en naar de zeehavens. Als een belangrijke voorwaarde van intermodaal transport in Vlaanderen, werden de afgelopen decennia dan ook verscheidene intermodale terminals gebouwd. Bovendien werden er verschillende beleidsinitiatieven genomen om de modale verschuiving te stimuleren. Desondanks wordt het volledige potentieel van intermodaal transport in Vlaanderen vandaag nog niet benut.

Om relevante beleidsaanbevelingen te maken wat betreft de verduurzaming van containertransport, werd het LAMBIT (Locatie Analyse Model voor Belgische Intermodale Terminals)-model ontworpen. Om ons bestaand transportsysteem te verduurzamen is het noodzakelijk om te identificeren waar en voor wie het gebruik van intermodaal transport een waardig alternatief is, en is het nodig om met behulp van dit model een realistisch beeld van de intermodale sector te scheppen. LAMBIT visualiseert de marktgebieden van bestaande intermodale terminals en berekent de mogelijke modale verschuiving binnen deze gebieden (Figuur 1). Hiertoe worden de verschillende modale alternatieven met elkaar vergeleken en wordt de beste (goedkoopste) optie weerhouden. Het bestaande model werd verder uitgebreid om de impact van transporttijd in de modale keuze te simuleren en meer specifiek om het belang van congestie hierin weer te geven. Op die manier kon de impact van verschillende snelheidsregimes geanalyseerd worden. Ten tweede werd er een extra module in het model ingebouwd om de optimale locaties voor nieuwe terminals in Vlaanderen te onderzoeken.



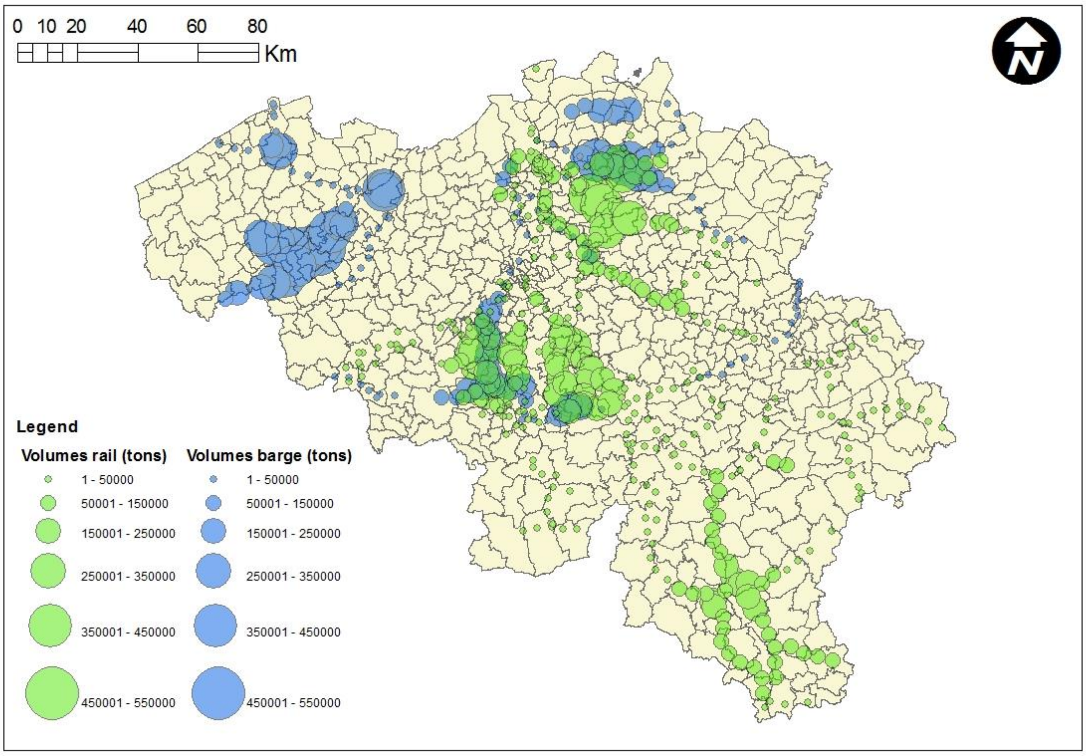
Figuur 1 Referentiescenario LAMBIT. In kleur worden de marktgebieden van de verschillende bestaande intermodale terminals weergegeven voor transport van/naar de Haven van Antwerpen. (Bron: eigen opmaak)

Impact transporttijd op aandeel intermodale transportmarkt

Het toevoegen van transporttijd (inclusief filetijd) als een modale keuze variabele in het model toont aan dat de impact van transporttijd en congestie erg afhankelijk is van de tijdsgevoeligheid van de getransporteerde goederen. Vier verschillende snelheidsscenario's werden hiervoor vergeleken om de impact van congestie op de totale transporttijd en de modale keuze te simuleren. De simulaties met betrekking tot deze snelheidsregimes zijn gebaseerd op gegevens van het Verkeerscentrum Vlaanderen (2010). Voor goederen met een hoge tijdswaardering is er weinig potentieel voor intermodaal transport. Alleen in de onmiddellijke omgeving van een aantal terminals kan er door een prijsvoordeel geconcurreerd worden met unimodaal wegtransport. Wanneer congestie op de wegen kan leiden tot aanzienlijke vertragingen, is intermodaal transport wel in staat om zijn concurrentiekracht opnieuw te verhogen. Bovendien is voor goederen met een lagere tijdswaardering intermodaal transport in veel meer gevallen een goedkoper transportalternatief, waardoor er in dit marktsegment een groter potentieel voor intermodaal transport bestaat. Bovendien biedt intermodaal transport bijkomende voordelen wanneer de terminal gebruikt wordt als depot voor lege containers en wanneer de transportafstand (en –tijd) van het natransport beperkt blijft. Dit kan onder meer door natransport buiten de piekuren te organiseren. Op die manier kan ook de betrouwbaarheid van de transporttijd toenemen.

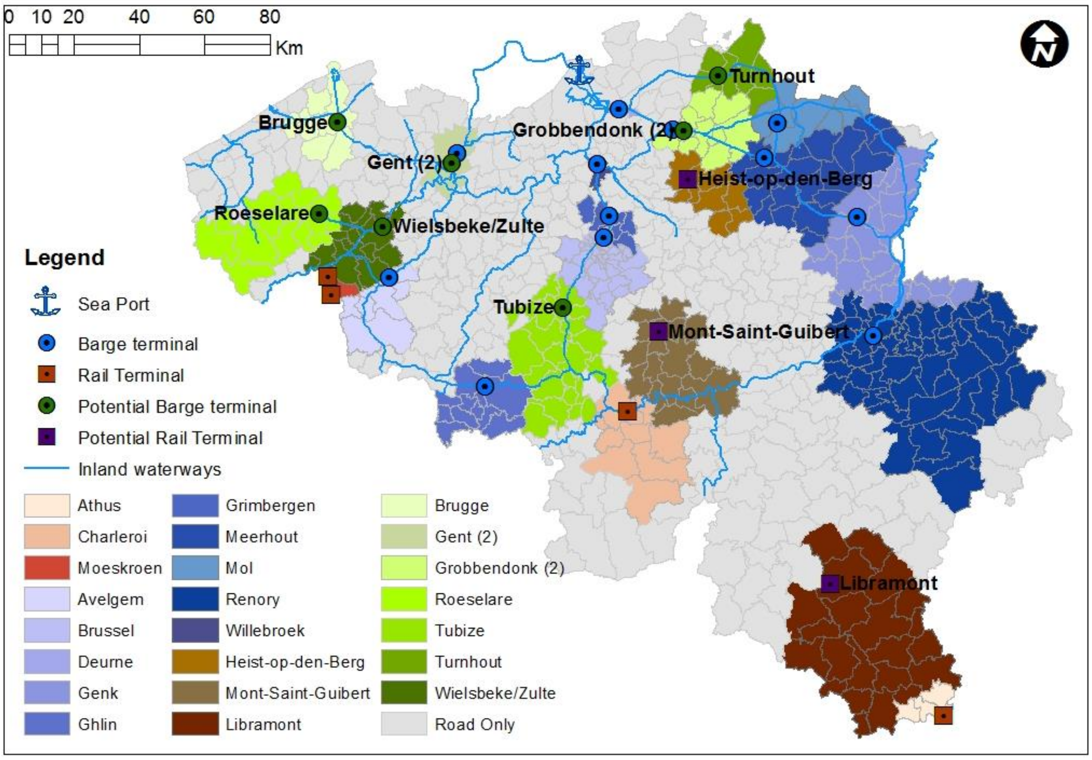
Optimale locatie nieuwe terminalinitiatieven

In het onderzoek naar de optimale locaties voor nieuwe terminals in Vlaanderen, werd gezocht naar de locaties met het grootste potentiële overslagvolume voor containertransport van/naar Antwerpen. Deze volumes geven een indicatie over het potentieel dat er bestaat voor modale verschuiving binnen het geografische marktgebied dat een nieuwe terminal kan beslaan. De methodologie die gebruikt werd, berekent de optimale locaties voor overslagterminals met als doel het totale intermodale overslagvolume te maximaliseren vanuit een netwerkregiefunctie. Om concurrentie met de bestaande terminals te voorkomen, werden de containerstromen van/naar de marktgebieden van deze terminals gaan buiten beschouwing gelaten. Figuur 2 geeft een indicatie van de potentiële overslagvolumes van de mogelijke terminallocaties die in deze studie beschouwd werden. De figuur geeft zo de locaties weer die in aanmerking komen als terminallocatie, zonder in concurrentie te treden met bestaande terminals. De in deze studie beschreven locaties vormen echter geen complete lijst van alle locaties die een kritisch overslagvolume kunnen realiseren (zoals in Figuur 2 weergegeven), maar wel een lijst van locaties die samen het totale intermodale overslagvolume voor transport tussen de Haven van Antwerpen en het Belgische hinterland maximaliseren. Hierdoor werd er binnen elke regio met een voldoende groot overslagvolume telkens maar één locatie geselecteerd. Uit dit onderzoek blijkt dat een binnenvaartterminal in Wielsbeke/Zulte een groot potentieel heeft voor de overslag van deze containers. De locatie van de vroegere River terminal Wielsbeke komt hiervoor in aanmerking, waardoor de heropstart van deze terminallocatie dus een groot potentieel marktgebied lijkt te hebben. Van de tien locaties die samen het totale intermodale overslagvolume in België maximaliseren, zijn er zeven in Vlaanderen gelegen (Figuur 3). De locatie met het tweede grootste potentieel volume is een railterminal in Heist-op-den-Berg. Verder werden ook een aantal locaties geselecteerd in de nabijheid van bestaande terminals (Gent, Grobbendonk). Dit toont aan dat er in deze regio's nog groeipotentieel bestaat voor intermodaal transport en dat de bestaande terminals hun marktgebied mogelijk nog kunnen vergroten door beperkte prijsveranderingen in het voordeel van intermodaal transport. Het is zelfs mogelijk dat in de realiteit de marktgebieden van de bestaande terminals het marktgebied van deze nieuwe locaties al (deels) bestrijken. Een te dicht terminalnetwerk loopt echter het risico overcapaciteit te creëren als de volumes in de marktgebieden van de terminals te klein worden.



Figuur 2 Mogelijke terminallocaties voor intermodale overslag van transport van/naar de Haven van Antwerpen, met een indicatie van hun potentiële overslagvolumes, op basis van analyse 5.3.1 voor goederen zonder tijdswaardering. (Bron: eigen opmaak)

Mogelijk zijn andere locaties die niet in deze studie werden opgenomen, ook geschikt als overslaglocatie in Vlaanderen. Zo zijn er locaties in de regio's van de hier beschreven locaties die ook een voldoende overslagpotentieel kunnen aantrekken, als op de hier beschreven locaties geen terminal wordt opgericht. Ook werd hier alleen gekeken naar containerstromen van en naar Antwerpen die in 2010 over de weg plaatsvonden. Aangezien deze stromen niet constant zijn in de tijd, en ook stromen naar onder meer Rotterdam kunnen bijdragen aan voldoende grote overslagvolumes blijft het zinvol om, indien mogelijk, elke mogelijke locatie ook op deze criteria te toetsen. Vanwege een te beperkte gegevensbeschikbaarheid, werd dit echter niet gedaan binnen het kader van deze studie. Verder dienen ook de plaatselijke omstandigheden (o.a. juridische voorwaarden) in rekening gebracht te worden bij de definitieve locatiekeuze. De locaties die in deze studie naar voren geschoven worden, zijn immers theoretisch optimale locaties die in de praktijk niet noodzakelijk aan alle voorwaarden voldoen om er een intermodale terminal van te maken.



Figuur 3 De marktgebieden van de bestaande terminals en van tien geselecteerde terminallocaties met een groot potentieel voor modale verschuiving. (Bron: eigen opmaak)

1 INTRODUCTION

The efficient transport of goods and people is a key condition in our current society. An efficient transport system can enable economic prosperity and social cohesion. But, the strong growth of movements, in particular in Flanders, has led to a list of challenges. A wide range of measures and actions have been set up to tackle the external effects of our current transport system. Some of the most important negative externalities are: the consequences of emissions (e.g. climate change, air pollution and health impacts), accidents, noise, soil contamination, damage to infrastructure, interference in the ecological system, visual nuisance and by all means: congestion. A modal shift from road-only transport to intermodal barge/road and intermodal rail/road transport is often stated as (part of) the solution, as intermodal transport is considered to be more attractive in terms of energy use, efficiency, external costs and it can reduce congestion problems on the road (Kreutzberger et al., 2006). For instance the European Union, in their 2011 White Paper, set the goal of shifting 50% of road freight over 300 km to rail and waterborne transport by 2050 (European Commission, 2011). But also on shorter distances, a modal shift can lead to severe reductions in external transport costs. Therefore, several policy initiatives have been set up to increase the market share of intermodal transport.

However, the full potential of intermodal transport in Flanders has not yet been fully exploited (Macharis et al., 2012a). Still, lots of possibilities and barriers for the use of intermodal transport in Flanders remain. Several reasons contribute to this situation. One important reason is that it's difficult for intermodal transport to compete with road-only transport, especially on the short distances (Bärthel and Woxenius, 2004). Another problem is the information gap, as described by Macharis et al. (2012a). To identify these problems, the Location Analysis Model for Belgian Intermodal Terminals (LAMBIT) has been developed by Macharis (see Macharis & Pekin, 2009; Macharis et al., 2010). This model has been used for policy analyses related to the intermodal sector and is now further extended.

Here we describe two new applications, developed within the LAMBIT framework. The first one includes the introduction of transport time as a second modal choice variable, next to transport cost, in the model. This extension of the model with a second modal choice variable, allows making more accurate simulations. As a part of this extension, the impact of road congestion was considered, to check the impact of moderate and severe road congestion on modal choice and on the market areas of the current intermodal terminals in Flanders. It is found that considering transport time as a modal choice variable, doesn't benefit intermodal transport because of the slower modes used. But as road congestion can create serious delays, intermodal transport is able to (re)gain important parts of market area. Second, an analysis was performed to investigate the need for the setup of new terminals. In regions where enough potential exists for the setup of a new terminal, the optimal locations were calculated. The analysis shows that potential for new terminals exists in inter alia Wielsbeke/Zulte (West Flanders) and Heist-op-den-Berg (Antwerp).

2 INTERMODAL FREIGHT TRANSPORT

Intermodal transport is the combination of at least two modes of transport in a single transport chain, without a change of container for the goods, with most of the route travelled by rail, inland waterway or ocean-going vessel and with the shortest possible initial and final journeys by road (Macharis and Bontekoning, 2004). An intermodal transport chain includes various types of transport, but in this case we focus on maritime-based chains using containers as loading units. The main haul is performed by rail-, barge- or short sea transport, while the post-haul is done by truck (Figure 4). The reverse direction, where road is used for pre-haulage, is also considered.

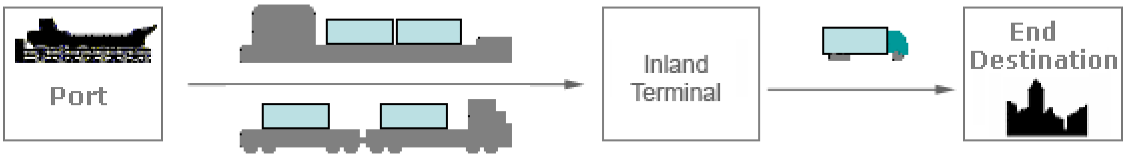


Figure 4 The intermodal maritime-based transport chain. (Source: Macharis et al., 2012a)

In this section, the current Belgian terminal landscape is discussed. Next, the cost structure of intermodal transport is discussed, as this is the basis of the LAMBIT-model that is used for the analyses described below. The LAMBIT-model itself is discussed in the next section.

2.1 Intermodal terminals and services

As an important enabler for the growth of intermodal transport in Flanders, many new intermodal terminals were set up during the last two decades. Three types of terminals exist: barge/road terminals, rail/road terminals and trimodal terminals. In trimodal terminals, transhipment between barge and road and between rail and road is possible. The number of rail/road terminals has been stable for the last years, but the number of inland waterways/road terminals has risen considerable, currently leading to a dense terminal landscape (Figure 5). Especially in the provinces of Antwerp and Limburg the terminal landscape is very dense.

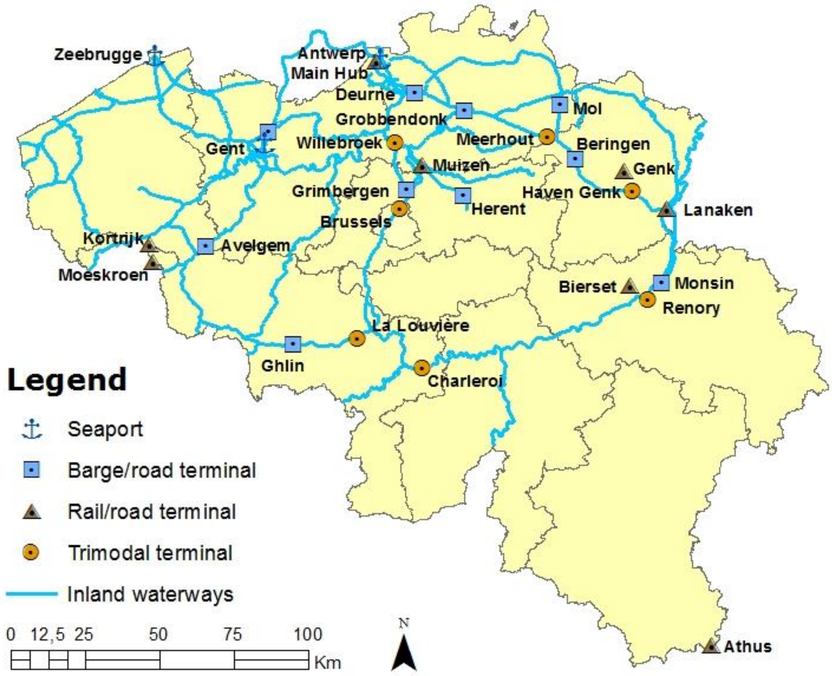


Figure 5 The intermodal terminal landscape anno 2012. (Source: own composition)

Although the terminal landscape became denser, not all terminals offer daily services to the Port of Antwerp. For instance the BATOP terminal between Herent and Antwerp is only servicing one client: the malting company Cargill (Macharis et al., 2011). Next, some terminals focus (only) on international connections. For instance the terminal of Renory offers three weekly connections to Italy, while no regular rail services within Belgium are offered. In the case of Renory, barge services connect the terminal with other terminals and deep sea ports within Belgium and the Netherlands (Liège Container terminal, 2012). In this analysis, only the terminals offering services to/from the port of Antwerp were included. It should also be noted that the possibility to offer trimodal transhipments, doesn't imply that (regular) rail or barge services are organised to and from this terminal. In Flanders, as in Wallonia, also new terminal initiatives are starting up (section 5.3.4).

For the analyses in this paper, the transferium of Grobbendonk (Antwerp East Port) was included. Although the function of a container transferium is not the same as the one of a terminal, it can perform the same role (Macharis et al., 2012b).

2.2 Cost structure

When for instance a carrier chooses a transport chain for a specific transport, different mode-route combinations are available. When comparing these combinations for a specific transport, different variables can influence the final decision. These variables are named modal choice variables. Studies have been conducted to identify these modal choice variables and their (relative) importance. Several studies point to cost/price as the attribute ranked highest in modal choice (Cullinane and Toy, 2000; or Vannieuwenhuyse, 2003 for the case of Flanders).

To analyse the market area of existing intermodal terminals, or the profitability of a new one, insight is needed in the cost structure of intermodal transport trajectories. As intermodal transport chains involve more actors (and modes) than unimodal road transport chains, also the cost structure of intermodal transport is more complex in comparison to unimodal road transport. In order to capture the benefits of intermodal transport, the critical cost items that constitute the total price are explained.

Taking a maritime-based transport chain, this cost function allows the calculation of the total intermodal transport cost between the sea port and the final destination. The total cost of a specific intermodal trajectory, contains the fixed cost of transhipment in the sea port to a wagon or barge, the variable cost of the intermodal main haul by barge or rail, the fixed cost of transhipment and the variable cost of post-haulage (Figure 6). The inverse logic goes for an intermodal transport from the hinterland to a sea port. At the sea port, intermodal transport has larger handling costs in comparison to unimodal road transport. This is due to the type of cranes that are being used for the transhipment. It is obvious that intermodal transport gains its advantage from the smaller cost per unit transported for the main haul. This is due to the economies of scale, obtained by the number of units that can be transported at the same time. The transhipment at the inland terminal compensates for the lower costs of the main haul. Related to the nature of pre- and post-haulage transport, its cost function is steeper than the one of unimodal road transport. This means that longer main haulage distances and shorter post-haulage distances favour intermodal transport in comparison to unimodal road transport. For intermodal transport to become competitive with unimodal road transport, certain conditions need to be fulfilled: sufficient volumes need to be transported to obtain the economies of scale and the total distance of the intermodal trajectory needs to exceed a critical distance in order to compensate for the additional fixed costs. The cost of intermodal transport basically depends on the length of the main haul, the length of pre- and post-haulage, the balance of traffics and the location of the inland terminal (Niérat, 1997). The total intermodal transport cost is obtained by adding all of the mentioned fixed and variable costs.

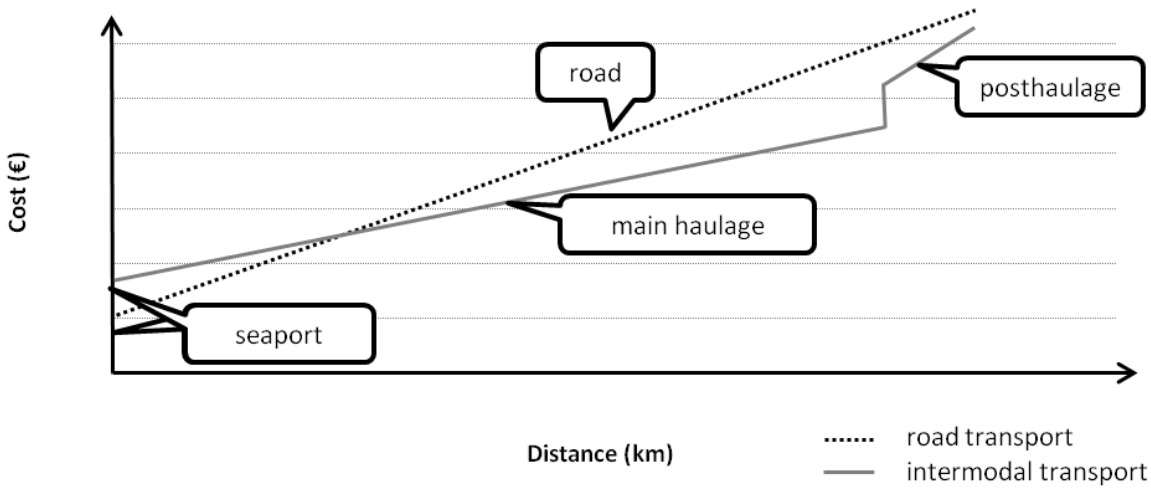


Figure 6 Maritime-based unimodal and intermodal transport cost functions. (Source: Pekin et al., 2013)

This leads to the following cost function, per kilometre per TEU (based on Pekin et al., 2013):

$$P_M = T_s^i + (p_m^i * d_m) + T_t^i + P_p^i + (p_p^i * d_{ph}) \qquad (1)$$

Where P_M is the total price of intermodal transport; T_s^i is the price of a container transhipment in the sea port; $p_m^i(d)$ is the price of the main haulage by barge or rail as a function of the distance of the main haul: d_m; T_t^i is the price of a container transhipment in the inland container terminal; P_p^i is the fixed cost of the post-haulage by road; p_p^i is the price per kilometre for the post-haulage by road, as d_{ph} is the distance of post-haulage by road.

3 LAMBIT METHODOLOGY

The LAMBIT-model is used to analyse both the impact of transport time on the market area of intermodal terminals and for the search for new suitable terminal locations in Flanders. Therefore, the current LAMBIT-model is firstly described in detail. In the subsequent two sections, both analyses are elaborated and their addition to the current model is discussed.

The Location Analysis Model for Belgian Intermodal Terminals (LAMBIT) is a Geographic Information System (GIS)-based model, developed to evaluate the location of intermodal terminals. This tool was originally developed by Macharis (2000) to measure the effect of different policy measures related to intermodal transport. This model allows the visualization of the geographic market areas of the existing intermodal terminals in Belgium. The calculation of these market areas is based on the market price of the transport cost of all possible transport chains (unimodal road versus intermodal barge/rail). The market area of an intermodal terminal is constituted of the municipalities[1] in which the market price for intermodal transport is lower than the market price of road-only transport. The overall LAMBIT framework is depicted in Figure 7. The new additions are depicted in green.

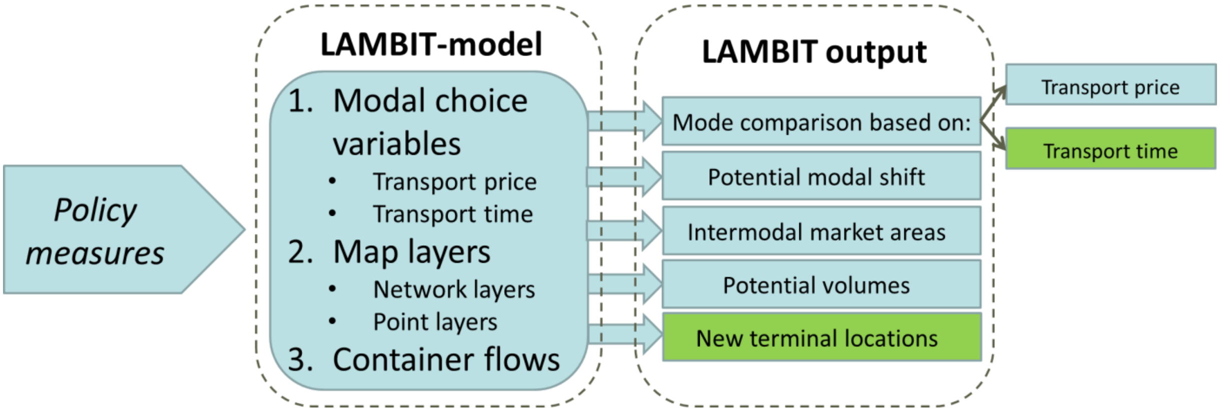


Figure 7 General LAMBIT framework. (Source: own composition, based on Pekin, 2010)

An All-Or-Nothing approach is used to highlight municipalities, meaning that a municipality is within a terminal's market area or not. Two approaches can be employed to relax this approach. A first possibility is the use of price ratios, to visualise the degree to which intermodal transport is more

[1] Municipalities are allocated to the market area of a terminal if the intermodal transport to its centre (i.e. this is the location of the main church of the municipality) is cheaper than the price of the road-only alternative.

favourable than road transport. This ratio divides the market price of intermodal transport by the price of the unimodal road transport market price. This methodology was tested by Pekin et al. (2013). A second approach is a sensitivity analysis, which is used to determine how the uncertainty in the output of the model can be distributed among the different input variables. Both approaches were tested in this paper.

LAMBIT consists of three main inputs: map layers, modal choice variables and container flows (Figure 7). The three inputs are described in the next subsections.

3.1 LAMBIT map layers

The LAMBIT-model consists of four different map layers: three network layers, each representing a transport mode (road, rail and barge) and one point layer containing all the municipalities within Belgium (Figure 8). These municipalities serve as the origins or destinations of the transport chains. Additionally also the intermodal terminals are added, connecting the different network layers with one another, as containers can there be transhipped from one mode to another.

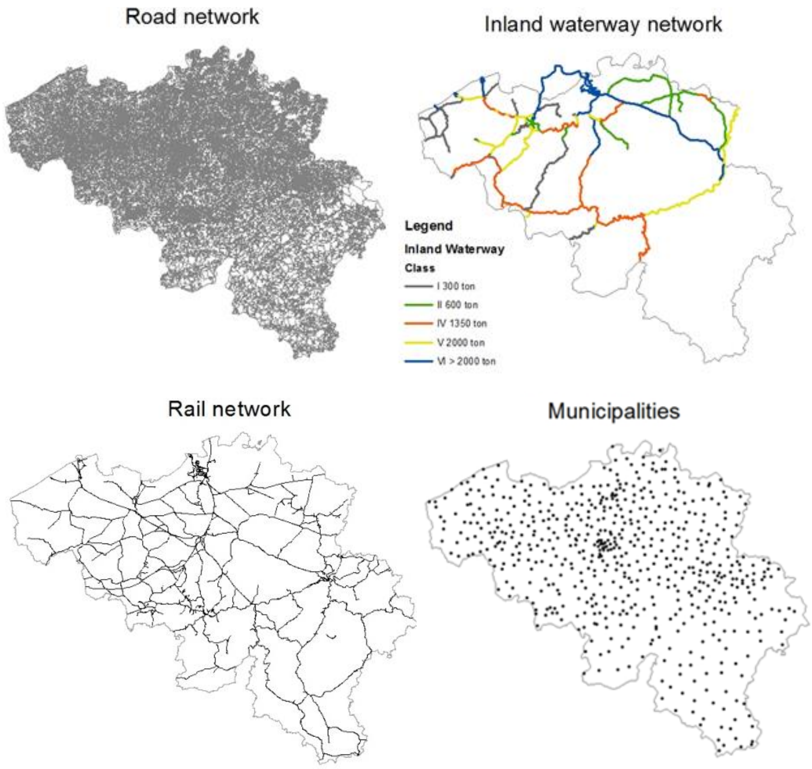


Figure 8 Representation of the network layers in ArcGIS. (Source: own composition)

The network for Belgium is built by combining the following digital databases:

- The inland waterways layer and the rail network layer are extracted from the ESRI (Environmental Systems Research Institute) dataset for Europe.
- The road layer and the municipality layer are obtained from the MultiNet database of Tele Atlas.
- The locations of the intermodal terminals were derived from a literature research and afterwards geocoded in ArcGIS.

3.2 LAMBIT modal choice variables

Once the networks are set up, the modal choice variables can be linked to these network elements (i.e. point and line elements). Initially only transport cost was included as a modal choice variable. This paper describes the addition of transport time to the model, as a second modal choice variable.

The transport prices for each mode were calculated, based on the real world market prices. These transport price data were obtained from transport companies, inland barge terminals and rail operators. The relation between price and cost is not one-to-one, but prices will follow cost in the longer term, even though transport prices are volatile depending on the market conditions. Therefore, we use the price and the cost terms together. All parts of the transport chain were included in the cost functions of unimodal road -, intermodal barge - and intermodal rail transport. The intermodal cost functions were already described above. The variable costs are linked to the respective line segments in the different transport networks. This is because they will vary with the distance travelled. The fixed costs are related to the nodes in the network, and therefore linked to the sea port and the intermodal terminals.

It is clear that using general cost functions is a simplification of reality. In practice, transport prices will depend on several conditions: e.g. fuel costs, load factors, the rate of empty hauls, discounts etc. which are not constant in time and space. Although, by averaging out different prices obtained from practice, the prices used in the model give a good approximation of average market prices.

3.3 Container flows

To provide an accurate estimate of the current container transport within Belgium, we use data of 2010, collected by the Algemene Directie Statistiek en Economische Informatie (ADSEI, 2010). For every origin-destination (OD) couple, these data contain information on the package of the goods transported (i.e. containers, pallets, bulk…), the tonnage transported, the number of kilometres and the number of ton-kilometres. These data are specified on municipality level. International transport is also included, but no information is available on the origin/destination municipality abroad. Therefore, these data are not included in this analysis.

The ADSEI data are obtained by a weekly at random sample of 1000 trucks or trailers. All vehicles with a capacity of 1 ton or more are included, with the exception of agricultural, military and public vehicles. Every truck or trailer can only be included once a year. The trailers are exhaustively questioned once a year, the trucks are on average questioned once every 2 years. The ADSEI data are thereby a clear indicator of the transport movements in Belgium and their tonnage (Mommens and Macharis, 2013). But since samples are used to obtain the data, under- or overestimations might occur locally. As the ADSEI data only account for road transport, they can give a clear indication of the potential for a modal shift from unimodal road to intermodal rail and barge transport. But as data on foreign transport companies is not included, international container transport cannot be (fully) accounted for.

In the LAMBIT-model, only the freight flows to/from the Port of Antwerp from/to the different Belgian municipalities are considered. Second, only the intermodal terminals with shuttles to the Port of Antwerp are considered in the model. Therefore, not all terminals as depicted in Figure 5 are included in the analyses. Only for the terminals with regular services, the market area is depicted in the LAMBIT output maps. A parallel output can be obtained for container transport to and from other Belgian sea ports such as the Port of Zeebrugge[2].

It is clear that the majority of containers transported to/from the port of Antwerp from/to its Belgian hinterland have their origin/destination in Flanders, mostly in the proximity of inland waterways infrastructure (Figure 9). Regarding the Belgian hinterland transport, 88% is transported to/from Flanders, while transport to Wallonia accounts for 11% and to/from Brussels for less than 1% (Figure 10).

[2] A separate study to visualise and analyse the market areas of intermodal transport to and from the ports of Zeebrugge and Ghent, was commissioned by the Department Mobiliteit en Openbare Werken of the Flemish Government.

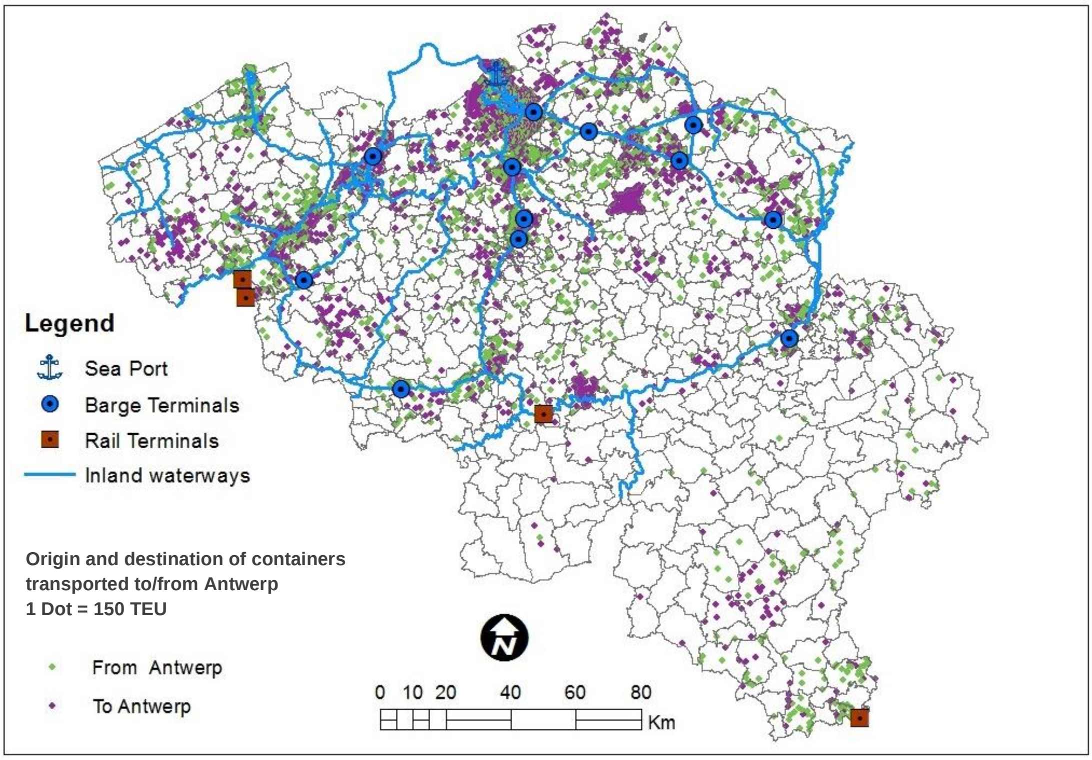
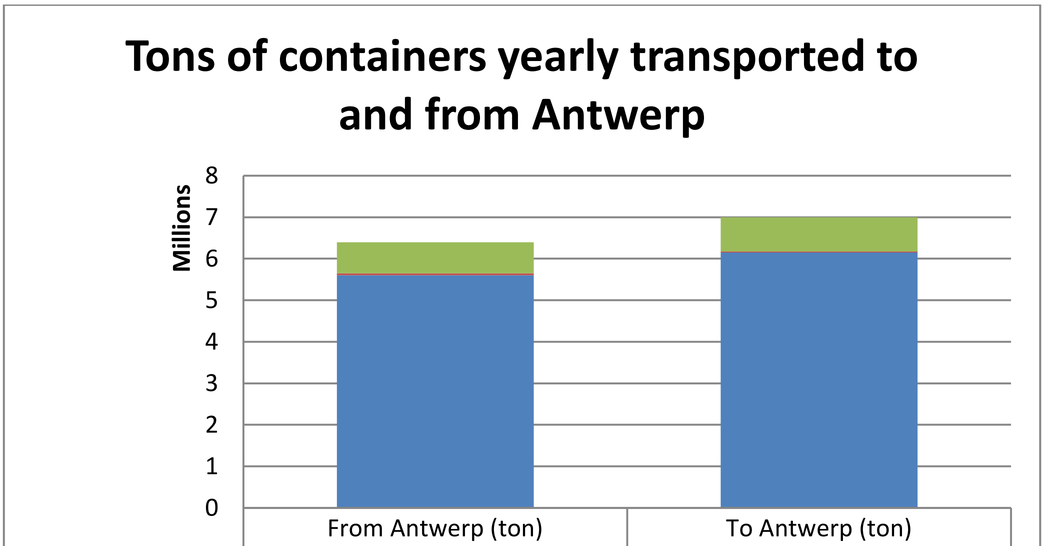


Figure 9 Belgian origin and destination of containers transported by road to and from the Port of Antwerp.

(Source: own composition based on ADSEI data, 2010)



	From Antwerp (ton)	To Antwerp (ton)
Total Wallonia	749000	821221
Total Brussels	43900	24015
Total Flanders	5602893	6148097

Figure 10 Belgian origin and destination of containers transported by road to and from the Port of Antwerp.

(Source: own composition based on ADSEI data, 2010)

To calculate the different possible route-mode combinations, an optimization approach is applied. A shortest path algorithm is used to calculate the paths that are considered for the mode comparison in a later stage of the analysis. To calculate these shortest paths, the algorithm of Dijkstra (1959) is used to minimise the transport cost. In a later stage, when transportation time is considered as a modal choice variable in the model, this approach is slightly altered (see below). When computing these different routes, also a road hierarchy aspect is taken into account. A basic shortest path algorithm would allow the calculation of the shortest paths, navigating trucks through local roads and small villages. This hierarchy aspect, takes into account the road categorization (highways, N-roads, local roads etc.) with a preference for highways.

When the three mode-route combinations with the lowest generalized cost are selected (one unimodal road, one intermodal inland waterways/road and one intermodal rail/road), these costs are compared for every municipality and the cheapest option is selected and displayed. The LAMBIT map output than visualizes the market area of every single intermodal terminal, while the municipalities which are served the cheapest by road, all have the same colour. As a next step, the potential additional volume of every inland terminal can be derived, by aggregating the total number of containers that are currently transported by road to/from the municipalities which are located in a terminal's market area.

4 VALUE OF TIME

To further enhance the LAMBIT-model and make it more realistic, transport time was considered as a second modal choice variable for decision making within the model. A first step towards the introduction of transport time in the LAMBIT-model was already performed by Pekin et al. (2013), but road congestion was not taken accounted for. Also differential speed limits on the road network were not taken into account, calculating the total transport time for road transport only with average speeds. Including the effects of congestion and differential speed limits enhances the realism of the model considerably.

In this research, we want to answer the following questions:

- How does transport time impact the market areas of intermodal terminals?
- How does road congestion impact the market areas of intermodal terminals?

Subsection 4.1 deals with the importance of transport time and congestion in modal choice. Subsection 4.2 explains the methodology that was used to adapt the existing LAMBIT-model. Subsection 4.3 provides the results of the new analyses, while subsection 4.4 concludes this section.

4.1 Introduction

Next to transport cost/price, also transport time is often stated as an important modal choice variable. For instance Beuthe and Bouffioux (2008), in their study on qualitative attributes of freight transport in Belgium, find that cost is the dominant factor with a weight of 63.7%, while transport time is ranked second with 16%. Therefore, time and hence also distance are important factors of competitiveness of intermodal transport, as in practice, intermodal transport can never compete with the speed and flexibility of unimodal road transport. This is a consequence of lower maximum speeds, waiting and transit times in intermodal transport. The time of a door-to-door intermodal journey consists of the time of the main haul, the time for pre- and post-haulage (if applicable), as well as waiting - and transhipment times. On the other hand, the transport time of unimodal road transport can also be influenced by external factors. Next to a truck breakdown, the main variable influencing this is traffic and in case of under capacity of the road network or traffic accidents, possibly congestion.

Traffic congestion not only impacts the total transport time of a truck, reducing the average speed of road transport, also the other users of the same infrastructure will lose time due to an additional vehicle on the network. Besides the longer transport time, also the transport cost will increase. First, transport will become more expensive due to increased energy consumption. Second, the time lost in congestion also has a value as opportunity costs. Besides, congestion might also lead to delays and late arrivals, increased external effects such as emissions, wear and tear of vehicles, impact on people's health, a negative image of a region etc. In case of pre-haulage, also intermodal transport can suffer from congestion, leading to the additional problem of missed connections. This problem can be solved by the use of an intermodal terminal as a temporary depot where users can deposit their containers in advance of the actual transport. In order to compare the importance of transport time to transport cost in modal choice, transport time can by valorised using a Value Of Time (VOT) factor.

4.2 Methodology

Transport time is a variable which is easy measurable for a specific transport. Although, collecting time-related data on a wider scale is more difficult. Transport time can be modelled using a Value Of Time (VOT) factor (for example, see Pekin et al., 2013). Accurate estimations of this VOT are needed for the assessment and comparison of different freight transport chains.

Some dispersion exists between the VOT's available in literature (Kreutzberger, 2008). A wide range of values exist, ranging from 0.03-2 euro per hour per ton transported. This range can be related to the type of goods transported, the type of decision maker, transport attributes and differences in survey methods. Indeed, different estimation methods can be used to compute the VOT (Feo-Valero et al., 2011). Currently there doesn't seem to be agreement among researchers over the size and the specific nature of the VOT. In Europe, only few studies have been performed to estimate the VOT in freight transport, and only very few pay attention to intermodal transport (de Jong, 1996). Also, different values per mode are found in literature.

A study of Beuthe and Bouffoux (2008) provides estimates on the value of time, based on the analysis of a stated preference experiment. Their study is based on experiments with Belgian shippers and therefore we use their values in this research. They calculate different VOT's for different types of goods, concluding that shippers of different commodity types have different preferences for modal choice variables. High value goods are usually transported by road while lower value goods can be transported by intermodal rail or barge transport. Although, different types of goods can be stuffed in a container. Therefore, it seems impossible to use only one VOT which is indicative for all freight transport. The lower VOTs hardly have an impact on modal choice, compared to the importance of price/cost (Pekin et al., 2013). But the higher values can impact the market areas in LAMBIT drastically. Beuthe and Bouffioux (2008) define their time attribute as door-to-door transport time, including loading and unloading. The VOT we applied in this case is: 2.23 euro, per TEU (twenty foot equivalent unit), per hour. This value is used as an upper value. Depending on the type of goods (low, medium or high value goods), the output image of LAMBIT will change between the figure were no VOT is taken into account – meaning the VOT in the cost function is zero – and the output image of LAMBIT were a high value of time is taken into account. Comparing to Pekin et al. (2013), this means that only low and average value goods are considered in this analysis.

To include the time attribute in the total cost function, total transport times have to be calculated, using the LAMBIT-model (subsection 4.2.1). Additionally the route calculation was altered, since transport time is considered as a modal choice variable, next to price (subsection 4.2.2).

4.2.1 Calculation of transport times

To integrate transport time as a modal choice variable in route/mode decision making, the different networks had to be adapted, meaning that the specific time it takes a transport mode to drive a section had to be assigned to the corresponding network segment. As we wanted to take into account the effect of road congestion, this means that different time attributes had to be assigned to the segments, depending on the level of congestion.

For the inland waterway and the rail networks, no congestion was accounted for. Average speeds of 11 km/h for inland waterways transport and 25 km/h for rail transport were used, based on numbers provided by ECMT (2006). Dividing the length of every inland waterway and rail segment respectively by these average speeds provides the total time these modes spend on a specific network link. These time attributes can be multiplied by the relevant VOT, to obtain the time cost on every segment.

For the calculation of the time attributes of the road network links, data from the Traffic Centre Flanders (Verkeercentrum Vlaanderen, 2010) were used. This dataset contains point speed data, collected from double detection loops for the highway network in Flanders. To include only data for trucks, the category 'trucks & buses' was selected. Average values for every point are available on hourly basis. It is clear that these points don't provide a full coverage of the complete road network (Figure 11). Therefore, these data had to be extrapolated to the rest of the highway network. Where there is a greater density of detection loops (for instance around Antwerp), the accuracy of these extrapolations will be better than were this density is less (for instance the E313 and E314 in Limburg). To simulate for working days only: data for weekends, public holidays and the months of

July and August were left out of the analysis. For the rest of the road network, average congestion values were used based on the relative speed reductions on the highway network.

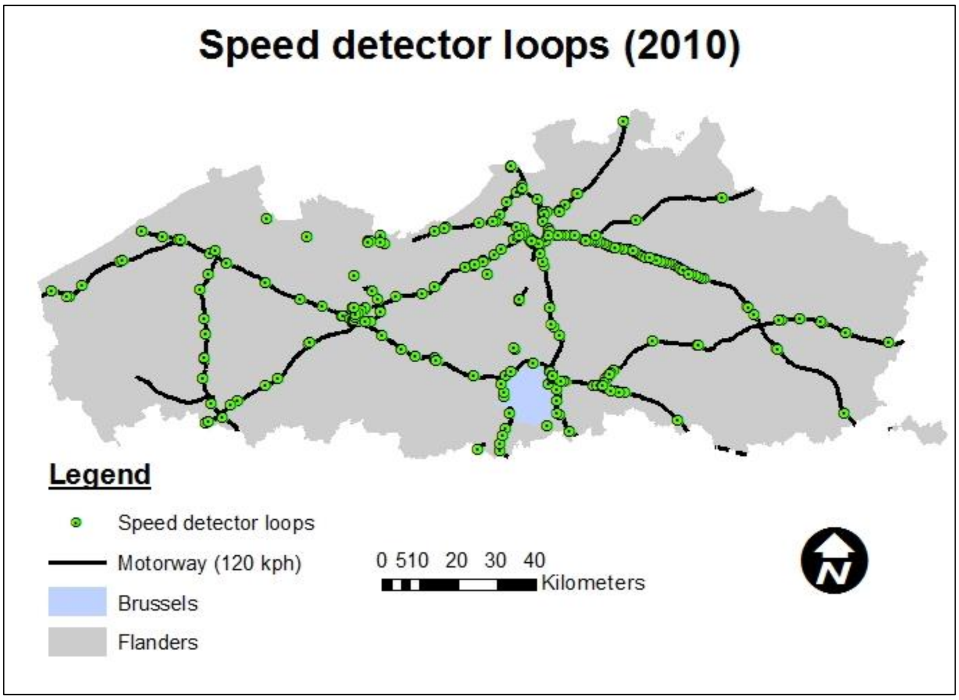


Figure 11 Spatial distribution of speed detector loops in Flanders. (Source: own setup)

For this analysis, we considered four different levels of congestion, leading to four separate scenarios:

- **Scenario 1**: In this scenario, free flow speeds are attached to the network segments. This provides an output situation where there is no congestion and all trucks drive at a constant speed, which is the same as the actual speed limit. This scenario can serve as a reference for an optimal flow situation.
- **Scenario 2**: This scenario is based on an average situation. For every segment, the average speed between 7.00 and 8.00 AM is calculated. This scenario serves as the average situation.
- **Scenario 3**: This scenario is calculated as the average speed of the 5 lowest values of every detection loop in the 7.00 till 8.00 AM time interval. So this scenario provides an average of severe congestion levels, during the morning peak. Although, these values are still based on hourly averages, smoothing the extreme peaks of severe congestion.
- **Scenario 4**: This scenario provides input for a severe congestion situation. These values are calculated as the average of the three lowest unique values of every detection loop in the

year 2010. Like in the other scenarios, these values are based on hourly averages. Second, the detection loops don't provide a 24/24, 7/7, 365/365 input, so this scenario provides an average of the most extreme values, that were measured. For the detection loops with insufficient useful measurements, an extrapolation was done, based on the detection loops in their vicinity.

For every scenario, a time attribute was calculated for each road network link. Afterwards, the routes for every OD couple could be calculated.

4.2.2 Route calculation using VOT

Previously, routes were calculated based on the Dijkstra (1959) algorithm, minimising the total cost of each route. Therefore, the LAMBIT cost function had to be adapted, to account for transport time. A new cost function was developed, based on Pekin et al. (2013):

$$TC = P_M + P_T \quad (2)$$

$$P_T(\mathrm{t}) = (t^i + t^t)V_T \quad (3)$$

The P_M (price of intermodal transport) function was already explained in a previous section. The *TC* (Total Cost) adds the value of the time function (P_T) to this price of intermodal transport. The same logic goes for unimodal road transport. P_T is a function of the transport time t. The total value of time is than the sum of the travel time by intermodal transport (t^i), be it intermodal rail or barge, and the post haulage travel time by truck (t^t), multiplied by the value of time for containers (V_T) factor, derived from Beuthe and Bouffioux (2008).

This new total cost functions, allows a new optimal route calculation, based on minimising the total cost of each route, including the value of time. For each possible trajectory the following total cost functions are minimised:

$$TC_{RO} = T_s^{ro} + (p_m^{ro}(d) * d_m) + (t^t * V_T) \quad (4)$$

$$TC_{IR} = T_s^{ir} + (p_m^{ir}(d) * d_m) + T_t^{ir} + P_p^{ir} + (p_p^{ir} * d_{ph}) + ((t^{ir} + t^t)V_T) \quad (5)$$

$$TC_{IB} = T_s^{ib} + (p_m^{ib}(d) * d_m) + T_t^{ib} + P_p^{ib} + (p_p^{ib} * d_{ph}) + ((t^{ib} + t^t)V_T) \quad (6)$$

Where: TC_{RO} is the total cost of unimodal road transport, TC_{IR} is the total cost of intermodal rail transport and TC_{IB} is the total cost of intermodal barge transport. This new, adapted route selection mechanism was developed to calculate the 'cheapest' routes, taking into account the time attribute.

4.3 Results

Based on this new cost function and route calculation algorithm, the market areas of the intermodal terminals are calculated for the different scenarios, to visualise the potential effect of congestion. For every scenario, two maps are shown. The first one gives a visualisation of the market areas, where the VOT is not taken into account. Here the VOT is left out the cost function, but routes are still calculated taking into account congestion. Therefore, this image can alter a little between the different scenarios. The second map shows a LAMBIT output image, where the VOT has a value of 2.23 €/TEU/h, which is included in the route calculation and the total cost function. Depending on the type of goods transported, the market area of the intermodal terminals will vary between both images. Third, a table is shown were the total tonnage that is yearly transported by road between the municipalities in this market area and the Port of Antwerp. This table provides an indication for the potential for modal shift within these market areas, comparing both sub scenarios. Subsection 4.3.5 provides a comparison of the four scenarios and elaborates on the difference in tonnage between them.

4.3.1 Scenario 1: Free Flow

This first scenario serves as a reference scenario. In the first map image, no congestion and no transport time are taken into account (Figure 12). It's clear that the terminals in the east of Flanders have reasonably sized market areas, while the west of Flanders is dominated by road-only transport. Also the terminals in the central north-south axis (WIllebroek, Grimbergen, Brussels) are able to catch a certain market area.

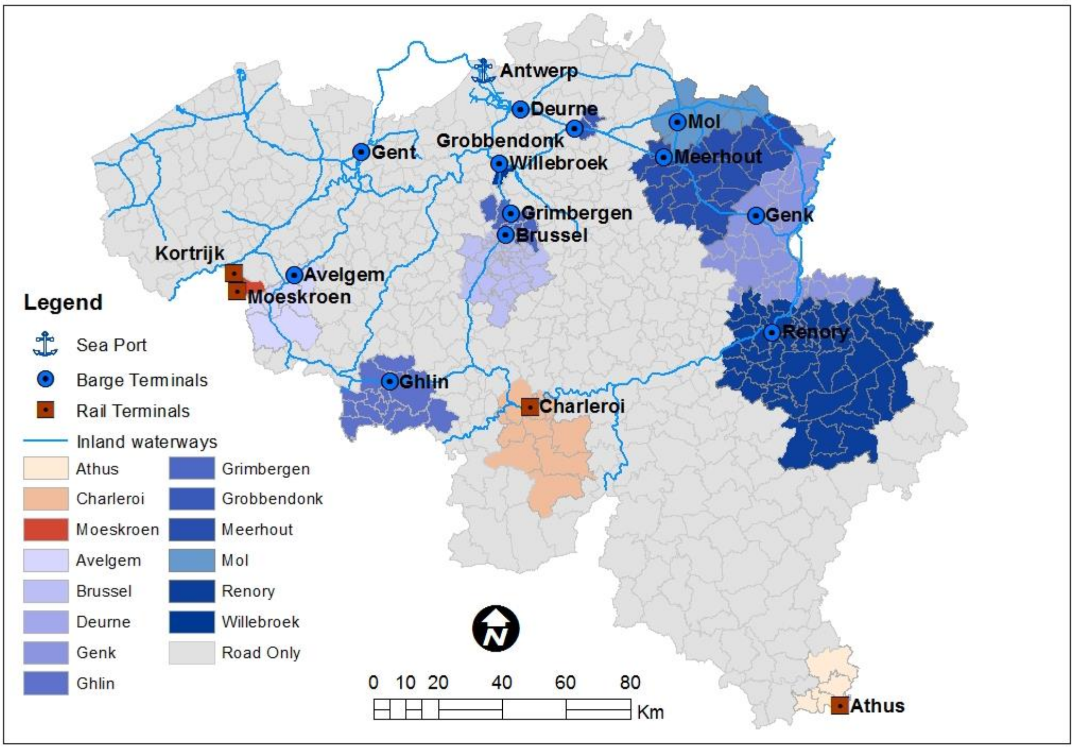


Figure 12 Market areas of intermodal terminals, for free flow speeds and no VOT included. (Source: own composition)

The next map shows the same scenario, but with inclusion of transport time as modal choice variable (Figure 13). The market areas of all terminals shrink considerably in comparison to the previous image. This is a logical consequence of the fact that road transport is in all cases faster than intermodal transport. The greater the share of transport time in the total cost function, the more municipalities that will be preferably served by road-only transport.

The difference in total volume transported to and from the market areas of the terminals between both map images is displayed in Figure 14. All terminals clearly lose potential volume in the scenario were VOT is included. Some terminals (e.g. Genk and Mol) retain a large share of their original potential volume, while the potential of other terminals completely disappears (e.g. Willebroek and Avelgem). The former group also loses market area but the municipalities with a high potential are retained, while the latter group loses the municipalities with the largest potential volume.

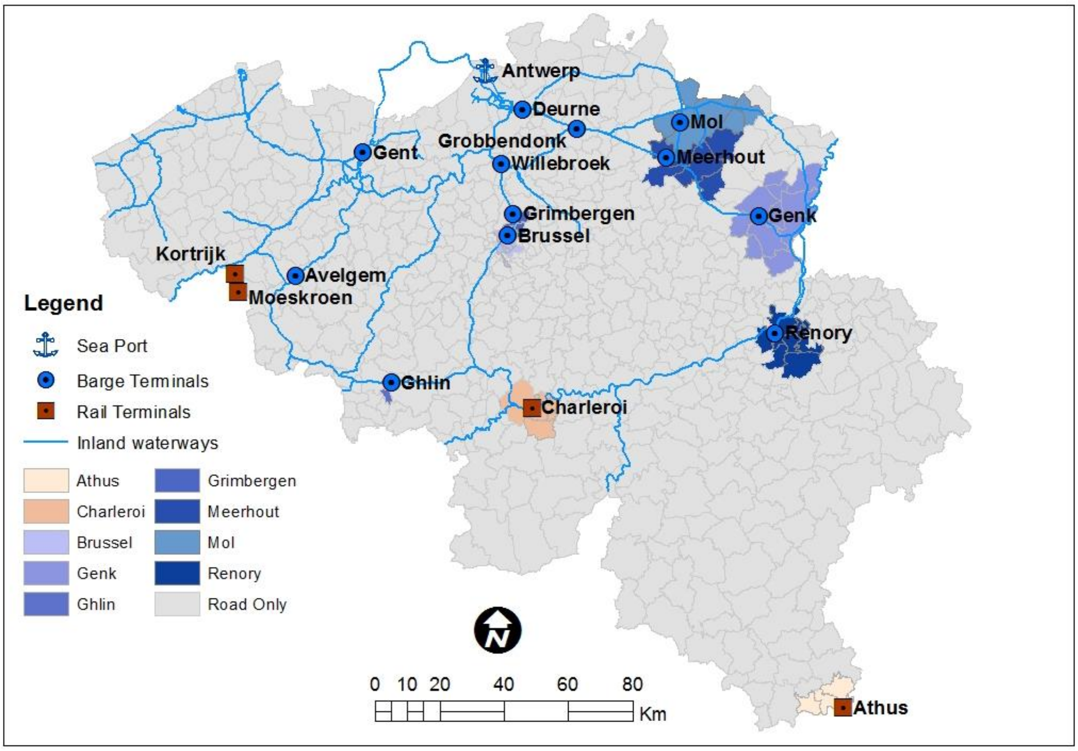


Figure 13 Market areas of intermodal terminals, for free flow speeds with VOT included. (Source: own composition)

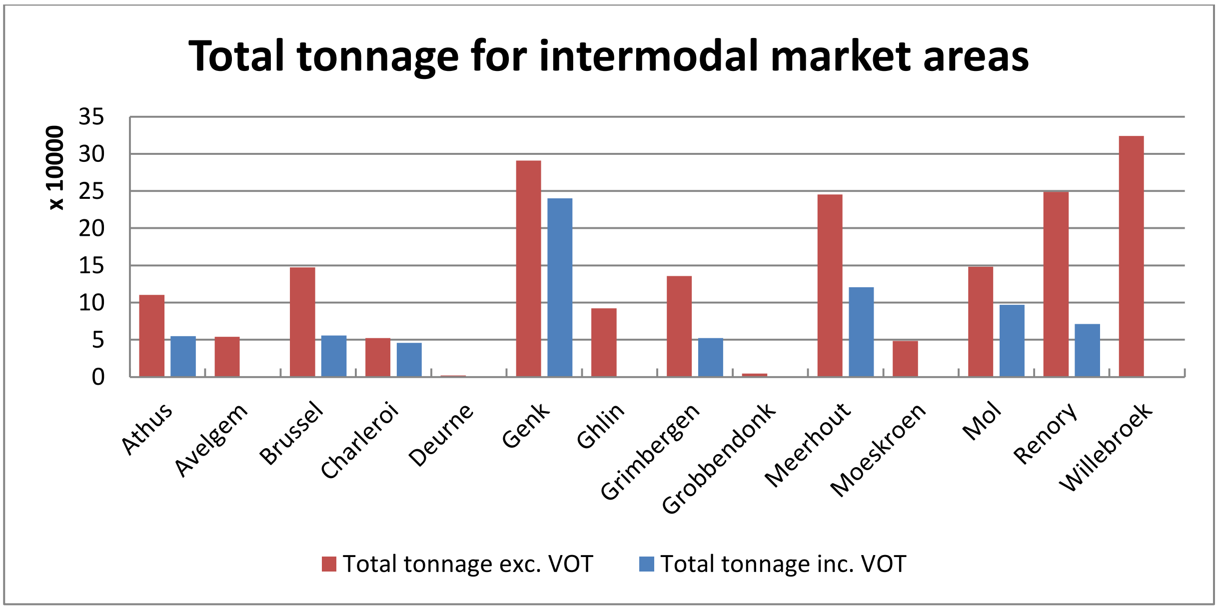


Figure 14 Comparison of both sub scenarios of scenario 1. (Source: own setup, based on ADSEI data)

4.3.2 Scenario 2: Average Traffic

The second scenario, simulating an average traffic situation, provides two output images which are very similar to the first ones. Comparing the first sub scenario (Figure 15) of an average traffic level to the corresponding sub scenario of free flow traffic (Figure 12), only shows a difference in market area for the terminal of Renory, where in the average traffic scenario one municipality is added to its market area.

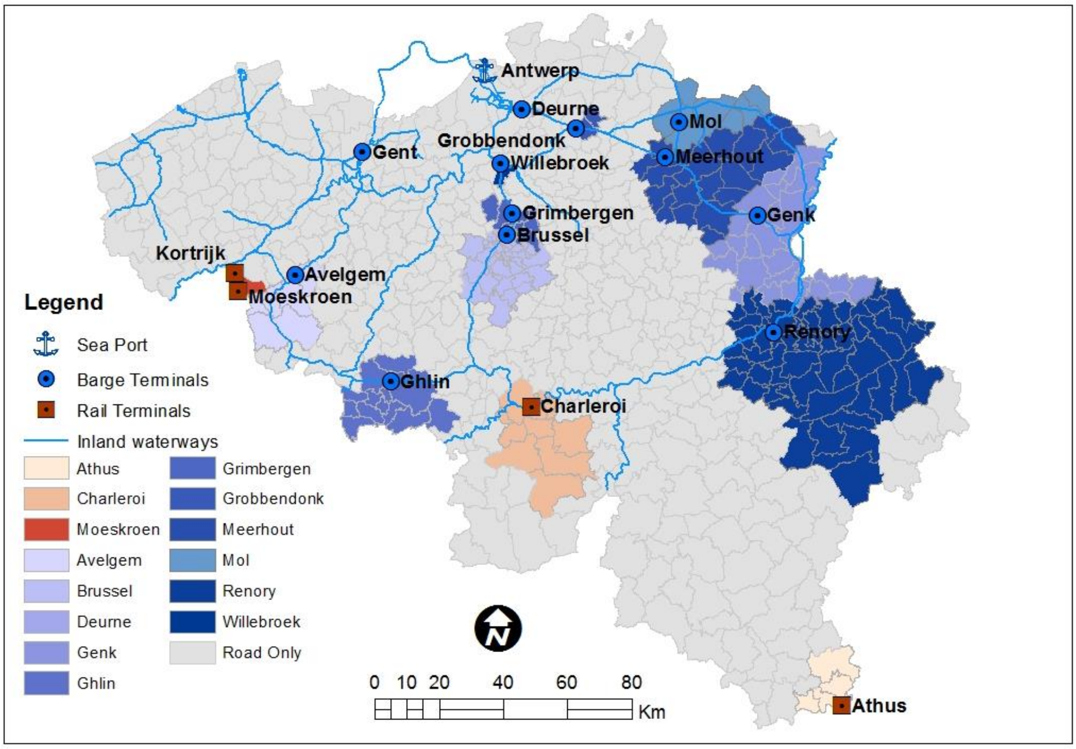


Figure 15 Market areas of intermodal terminals, for average speeds and no VOT included. (Source: own composition)

The sub scenario where the VOT is included (Figure 16) can also be compared to the corresponding sub scenario 1 (Figure 13). In comparison to scenario 1, the market areas in scenario 2 lose less market area size, when the VOT is accounted for. In particular, the terminals of Meerhout, Grimbergen, Brussel, Ghlin and Charleroi have a larger market area, than can be observed in the corresponding sub scenario 1. The difference in speed between both scenarios doesn't impact the transport time drastically, but still some terminals profit from lower transport times by road (Figure 17).

This scenario of average traffic shows that in contrast to the first scenario, the market area for higher value goods (i.e. goods for which the transport time is more important) is larger. For the case of

Grimbergen, the potential volume only decreases slightly and also the potential for Meerhout increases when compared to scenario 1.

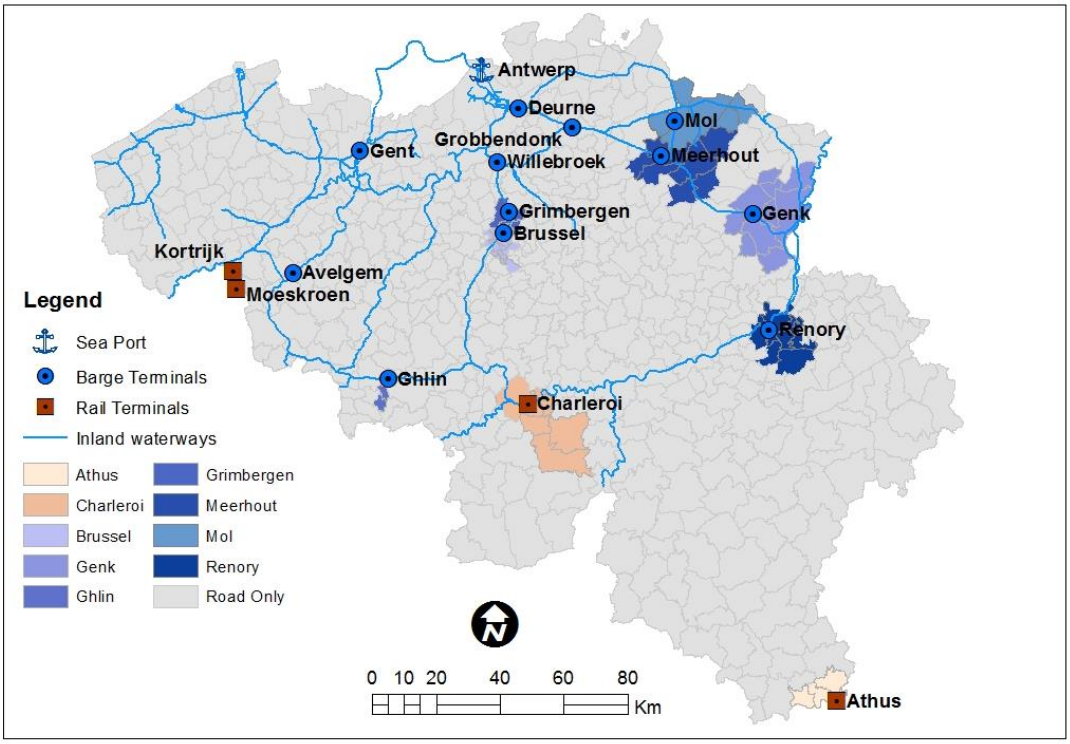


Figure 16 Market areas of intermodal terminals, for average speeds with VOT included. (Source: own composition)

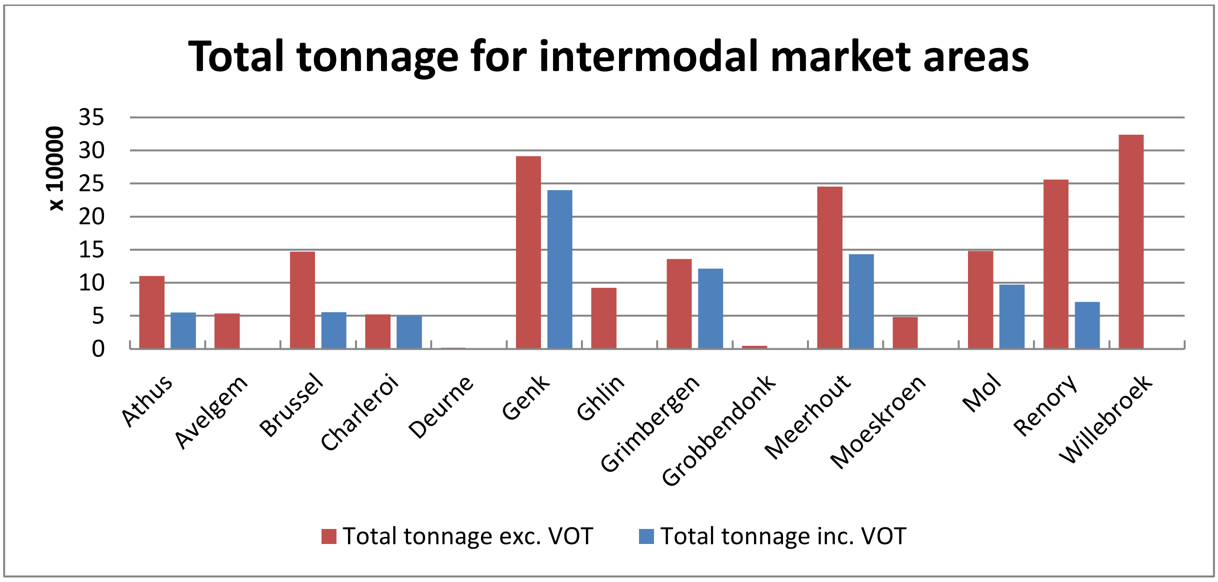


Figure 17 Comparison of both sub scenarios of scenario 2. (Source: own setup, based on ADSEI data)

4.3.3 Scenario 3: Average morning congestion

Scenario 3 simulates the intermodal market areas for a situation of average morning congestion. Again, this scenario can be compared to the previous ones. In the case that no VOT is included (Figure 18), no market area changes occur in comparison to scenario 2. For this sub scenario, the situation of average morning congestion doesn't seem to impact the market area of the intermodal terminals. Only the terminal of Brussels gains an extra municipality to its market area.

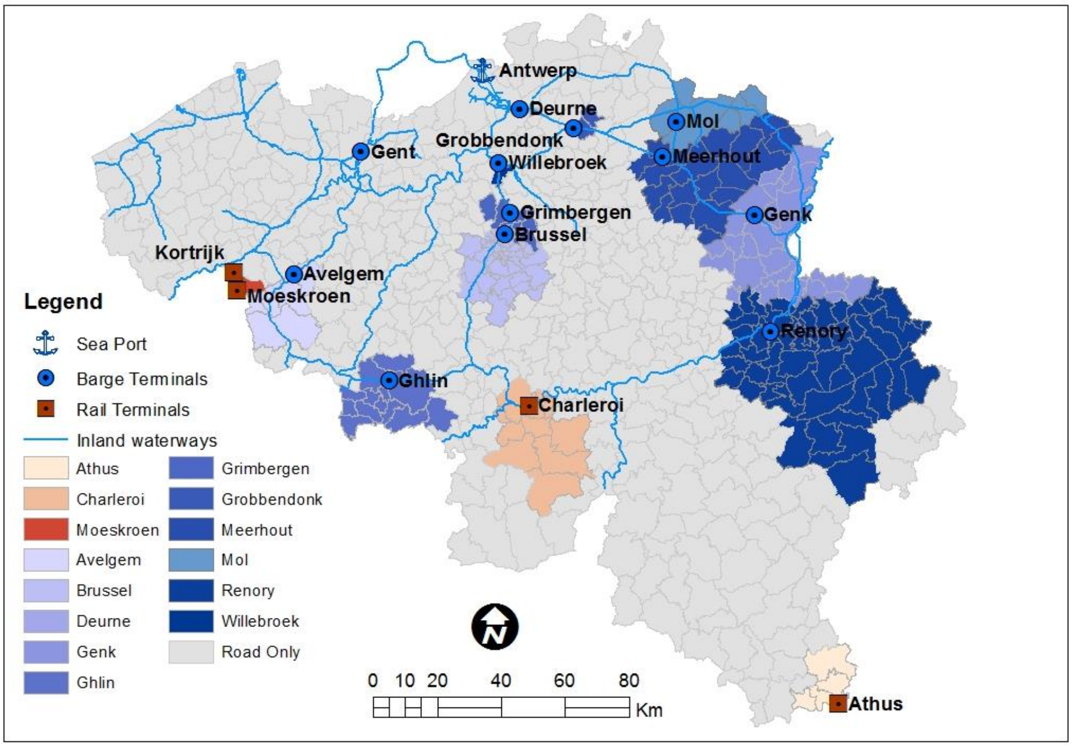


Figure 18 Market areas of intermodal terminals, for average morning congestion and no VOT included. (Source: own composition)

The case where the VOT is included in the cost function (Figure 19) can again be compared to the previous scenario. Only three terminals seem to profit from this increased congestion, increasing the market area of the terminals of Brussels, Renory and Charleroi. The terminals don't seem to profit considerably when a situation of average congestion occurs.

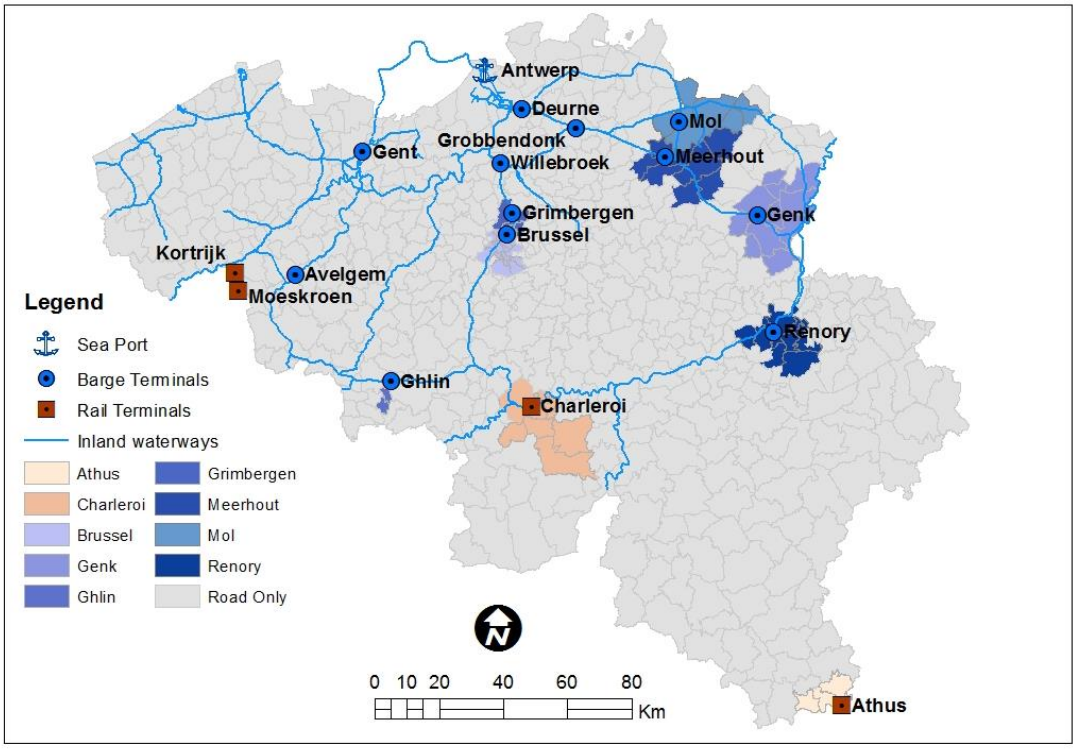


Figure 19 Market areas of intermodal terminals, for average morning congestion with VOT included. (Source: own composition)

In comparison to the previous scenario, not much seems to be changed, when comparing the map image where the VOT is included and where it's excluded (Figure 20). Considering the case where VOT is included in situations of average morning congestion, some terminals still can't take any market area: i.e. the terminals of Avelgem, Deurne, Ghlin, Grobbendonk, Moeskroen and Willebroek. For the terminals of Deurne, Grobbendonk and Willebroek, this can be related to the short distance to the Port of Antwerp. Even though the intermodal transport times are rather short, their inclusion in the cost function will make the total cost higher compared to road-only transport. This is the consequence of short main haul distances, so the variable cost of transport cannot compensate for the fixed costs in intermodal transport.

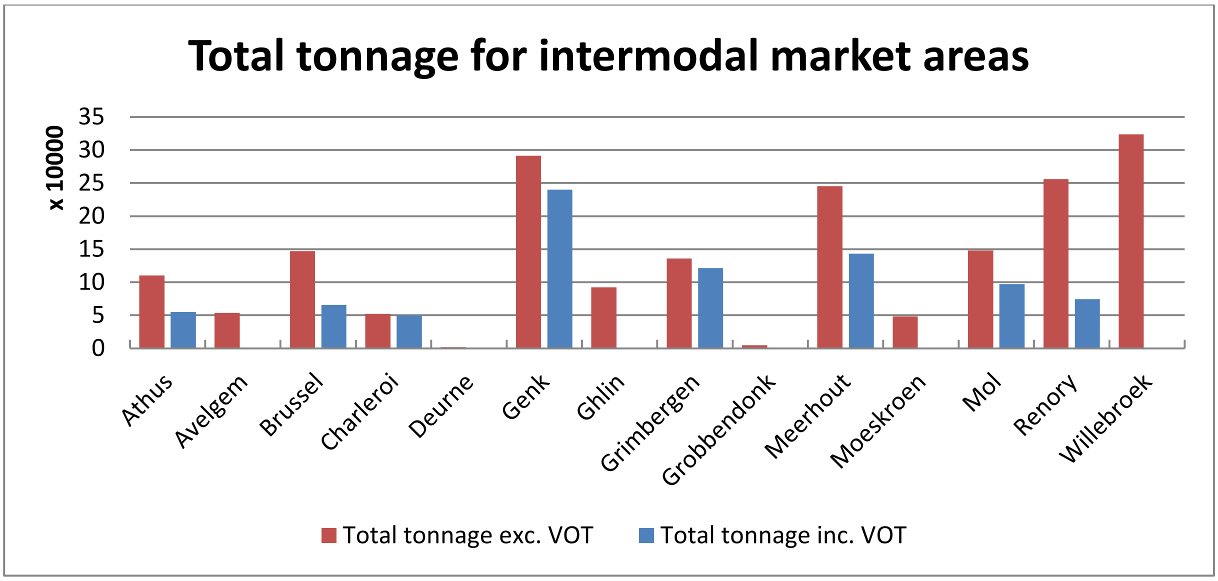


Figure 20 Comparison of both sub scenarios of scenario 3. (Source: own setup, based on ADSEI data)

4.3.4 Scenario 4: Severe congestion

This last scenario shows the intermodal market areas in case of severe road congestion. Again, more market areas grow as the transport time for the road-only alternative increases. In the first sub scenario (Figure 21), the market areas of the terminals of Avelgem, Meerhout, Genk, Ghlin, Athus and Renory increase in size.

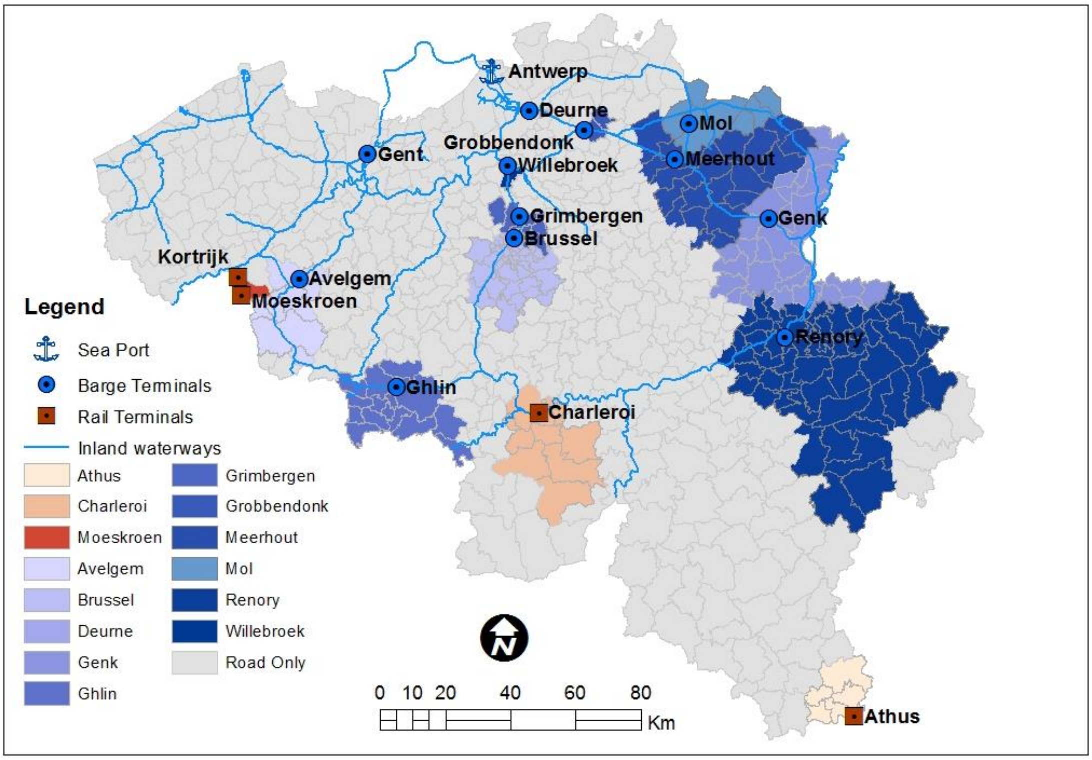


Figure 21 Market areas of intermodal terminals, for severe congestion and no VOT included. (Source: own composition)

The second sub scenario is the most interesting one. In comparison to the same sub scenario of scenario 3, the market areas of all terminals have increased considerably in size, showing a big potential for intermodal transport (Figure 22). In comparison to the sub scenario where no VOT is considered (Figure 21) some market areas even increased in size, meaning that intermodal transport can be faster for these municipalities (e.g. Brussels, Grimbergen, Willebroek, Kortrijk). Especially rail terminals seem to favour, as intermodal rail transport is on average significantly faster than intermodal barge transport. Other terminals see their market area decrease in size (e.g. Renory, Avelgem) as one would expect intuitively.

In fact, this map visualises a condition of very severe road congestion on the complete network. As it will never be the case that the whole network is severely saturated at one time (except for instance for extreme weather conditions of very severe snowfall, leading to traffic jams in the whole country), this map shows only the possibilities for individual trajectories, which are severely saturated at a time.

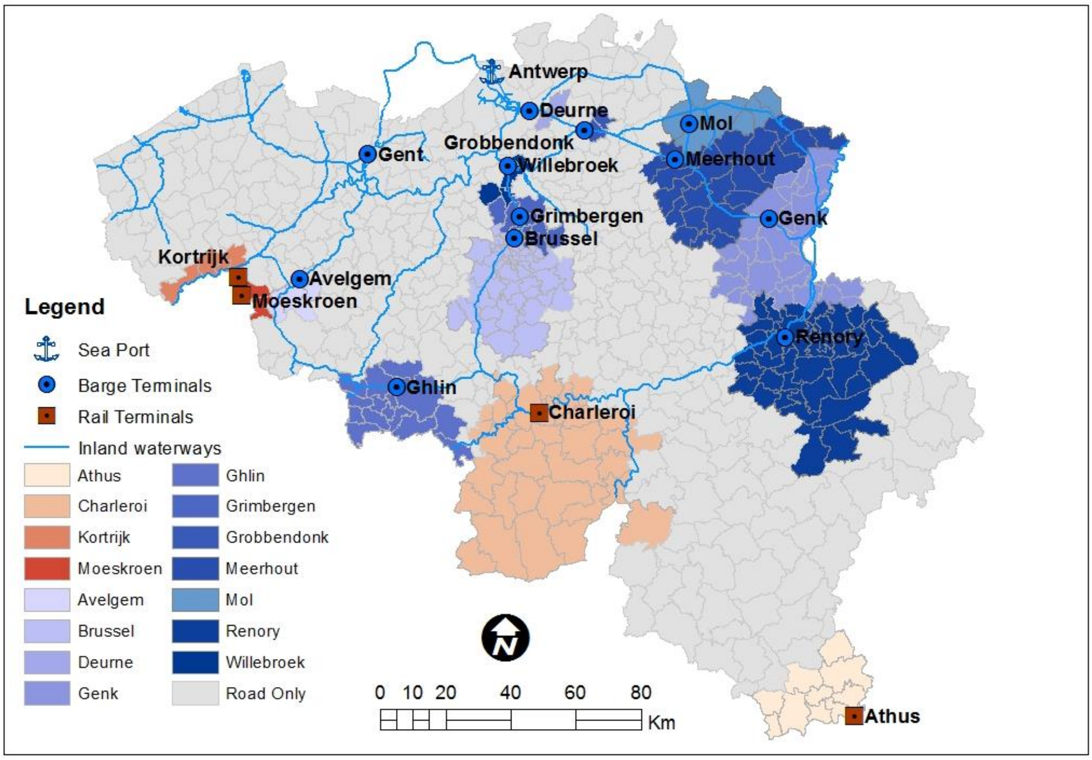


Figure 22 Market areas of intermodal terminals, for severe congestion with VOT included. (Source: own composition)

This last scenario shows that severe road congestion can favour the use of intermodal transport (Figure 23). Most of the terminals' market shares increase when the VOT is taken into account, except for Avelgem, Genk, Meerhout and Renory. This strong difference in reaction to the inclusion of VOT in the total cost function can be related to the locations suffering more from situations of extreme congestion. The market areas of the terminals in the central axis gain the most potential volume (Willebroek, Grimbergen, Brussel, Charleroi, Athus) as in this case, transport will have to cross Brussels, known for its congestion problems.

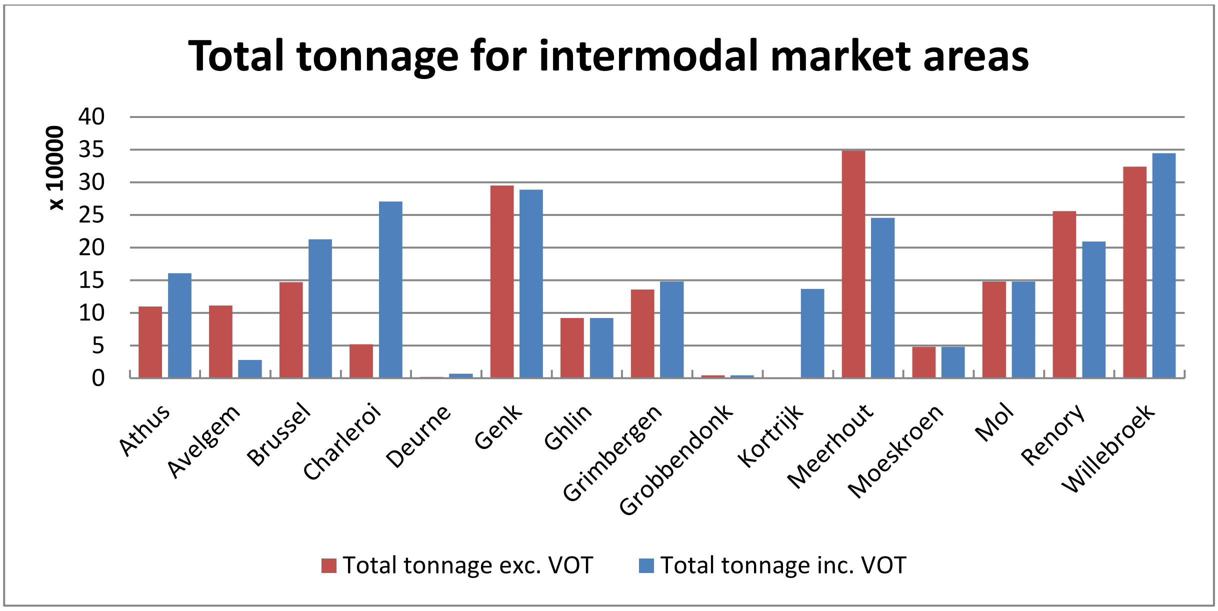


Figure 23 Comparison of both sub scenarios of scenario 4. (Source: own setup, based on ADSEI data)

4.3.5 Scenario comparison

Comparing the four different scenarios, allows us to evaluate the impact of congestion on the market area of intermodal terminals. The impact of congestion is very limited if transport time is only considered in route calculation (sub scenarios 1) but is not included in the cost function. Some terminals observe an increase in tonnage transported to and from their market area in the fourth scenario. This is a consequence, of slightly different routing due to congestion. For instance the terminal of Meerhout observes a significant increase in potential volume, while only two extra municipalities were added to its market area. When taking transport time into account for route and mode choice (sub scenarios 2), we see a clear impact on the market areas of intermodal terminals (Figure 24). Especially in the last scenario, potential volumes rise spectacularly for most terminals (Table 12 and Table 13 in appendix).

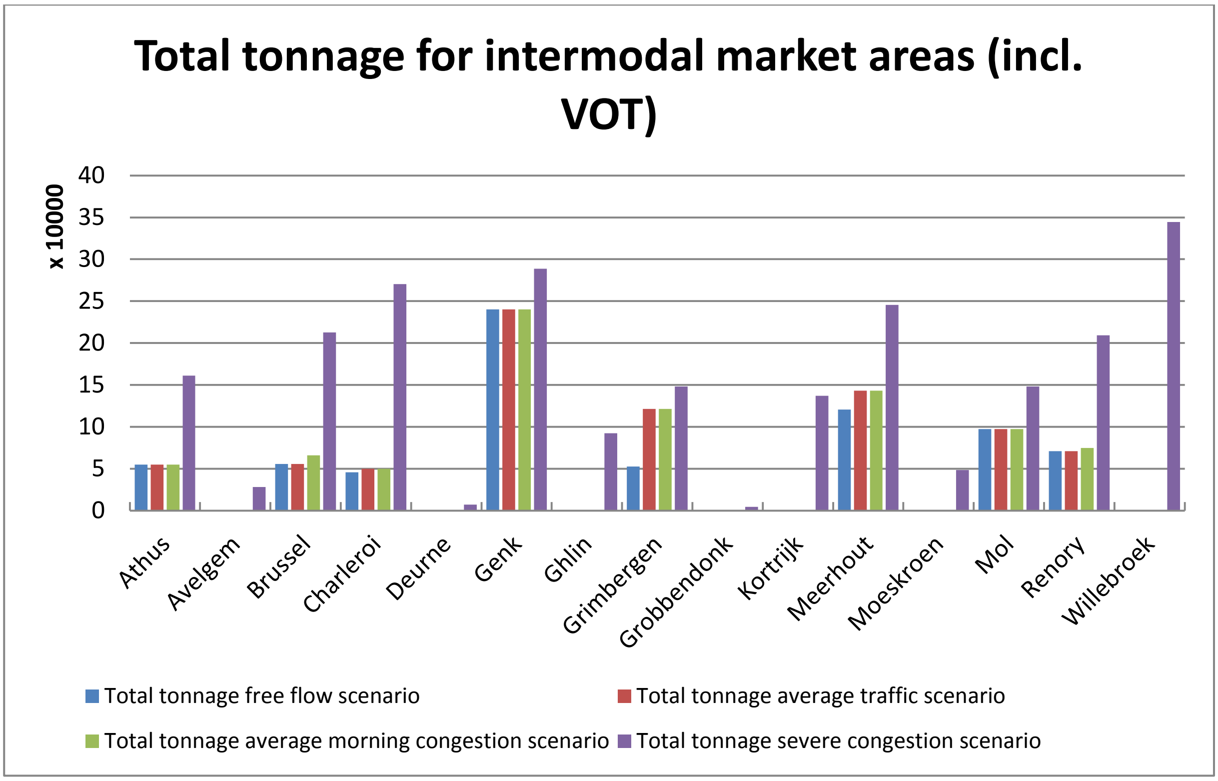


Figure 24 The impact of congestion on the potential volumes is clear, when transport time is considered in route calculation and in the total cost function. (Source: own setup based on ADSEI data)

To relax the All-Or-Nothing approach dealt with in this paper, a ratio analysis was performed on one scenario. The ratio analysis suggested here, could also be performed on the other scenarios elaborated in this paper. A comparison is made between the ratio when the VOT was excluded (Figure 25) and included (Figure 26) in the modal choice of scenario 2. A ratio higher than one means that unimodal is the preferred mode for a municipality, while a ratio lower than one means that intermodal transport is preferred. This approach takes into account smaller differences in preference between the alternatives. Further away from the terminals, unimodal has a strong market position, while closer to the terminals, small differences in price levels and/or transport times could benefit the intermodal alternative. Also the oval shape, with the terminal closer to the origin of the transport becomes visible. This ratio introduces a more realistic image of a terminal's market area (Pekin et al., 2013).

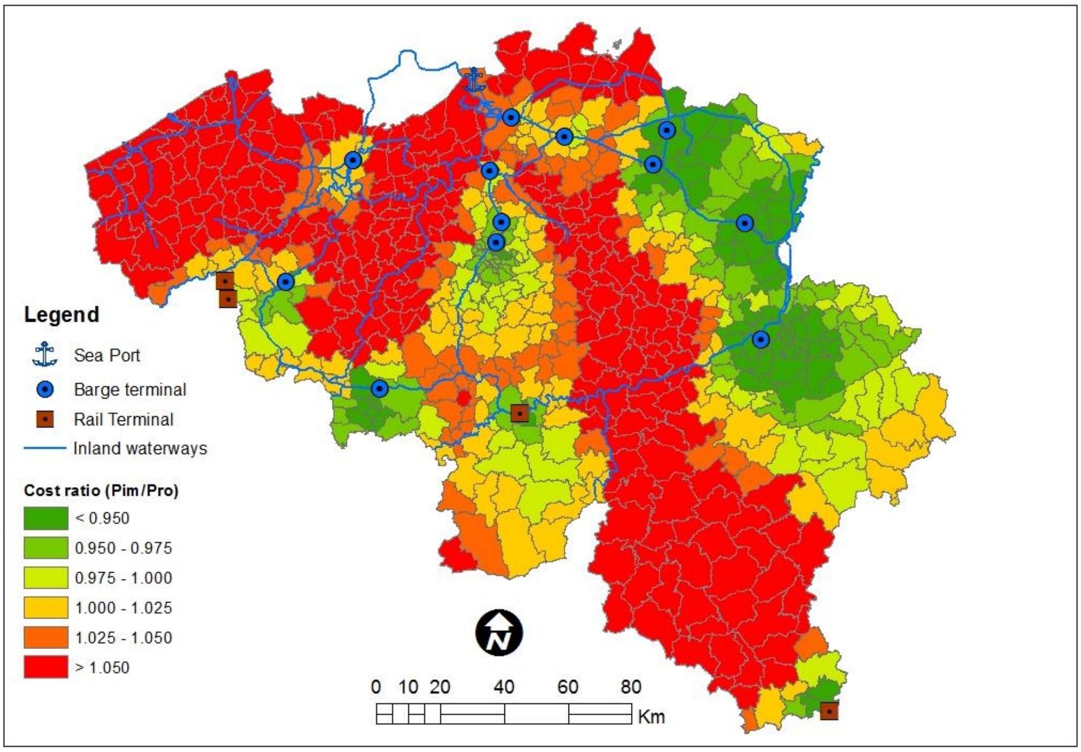


Figure 25 Transport cost ratio (excl. VOT) shows potential for additional intermodal transport, especially in the yellow-coloured areas. (Source: own setup)

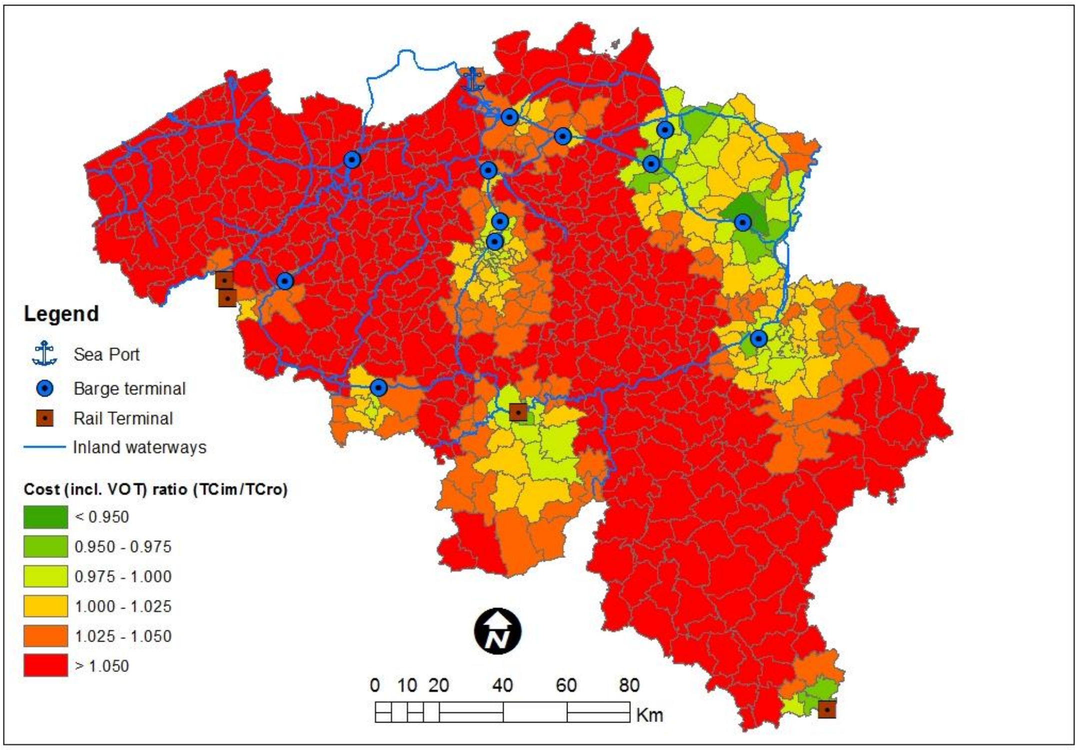


Figure 26 Transport cost ratio (incl. VOT) shows potential for modal shift. Especially the terminals In Limburg, Brussels, Charleroi and Liège can profit from small price differences. (Source: own setup)

4.4 Conclusions

By adding the value of time and the impact of congestion to the LAMBIT-model, it becomes more integrated and comprehensive. It can make a difference between goods (or users) who value time differently, resulting in different market areas for intermodal transport.

The previous results show that road congestion provides opportunities for intermodal transport. Although, when the importance of transport time in modal choice increases, intermodal transport will become a less interesting alternative. But the more congested the road network is, the more the difference in transport time between unimodal and intermodal transport will decrease. In this way, also goods with a higher valuation of time can be transported intermodal when the difference in price compensates for the longer transport time. Scenario 4 also proves that there is an obvious relation with the location of road congestion.

Some additional opportunities arise for intermodal transport:

- The post-haulage in intermodal transport can be performed in off-peak hours, when transport time is less of an issue. In this way, the expected delivery time can be better approximated, increasing the reliability and the on-time delivery rate of a transport considerably. If intermodal terminals serve as a temporary depot, where shippers can pick up their containers when they want (within a certain time after arrival), on time delivery will increase and the arrival of new goods can be fit in better in the total logistic chain and/or warehousing operations.
- Next, a terminal can also serve as a depot for empty containers, where shippers can pick up an additional container. This can happen when due to temporal fluctuations, not always an empty container is available on the spot. A second option to reduce the total cost function is using intermodal transport for the return of empty containers (Pekin et al., 2013).

Concluding from this section, it would be useful to distinguish the markets were transport time is of less importance (e.g. low value goods, longer distances). Intermodal transport policies therefore have more potential for sectors with low time valuations. Better estimations of the impact of road congestion on terminal market area size would be possible, when origin-destination transport times for different speed regimes are available, instead of the aggregated transport times used here. Also more specific transport times for the other modes could improve the reliability of this analysis.

5 LOCATION ANALYSIS

In this part of the study, we present a module to determine the optimal locations for new intermodal terminals (rail/road or barge/road). Based on the existing road traffic volumes, we determine the potential location(s) for the setup of a new terminal in Flanders for transport to/from the Port of Antwerp. The location analysis model is formulated as a discrete mathematical program. We will look at two facets of location, the first being relative location and the second being the absolute location. Absolute location is related to the specific site characteristics. The relative location of a terminal is its location in the terminal and sea port network and its accessibility to the different transport modes (Pekin, 2010). Both absolute and relative location of terminals, determine the competition between unimodal road- and intermodal transport.

In this study, we focus on terminals with a regional service function. Next to this type of terminals, Visser et al. (2012) distinguish three other types of terminals. First, there are terminals in the main sea ports (e.g. Main Hub and Zomerweg in Antwerp). Second, there are hub terminals which are connected to sea ports and also have international connections to other hubs in Europe (e.g. Renory in Liège). In addition, these terminals can also have a regional service area. Third, there are the container transferia, in the close vicinity of sea ports, aimed at decongesting the port area (Macharis et al., 2012b).

The market areas of intermodal terminals do not cover the full territory of Flanders. Certain regions in Flanders are too remote from the current intermodal container terminals and can be considered as white spots on the terminal market area map. Figure 27 provides service areas of the current intermodal terminals, based on driving distance by truck. When considering the break-even distance of intermodal transport, a maximum post-haulage distance of 20 km from the terminal is often considered (Pekin, 2010). According to Hofstra, 75% of the costumers of a terminal are located within a service area of 25 km (Hofstra, 2010). It is clear from the map that the terminal density is higher in the east of Flanders and in the central axis Antwerp-Brussels. In contrast to this figure, our LAMBIT analysis calculates the real market areas of intermodal terminals for transport to/from the Port of Antwerp. Maximum post-haulage distances will vary with the total distance from the origin, leaving smaller areas for terminals closer to the Port of Antwerp (see Figure 15 as reference). The LAMBIT analysis which is discussed below will identify the real 'white spots' within Flanders, i.e. the regions located outside the present terminal's market areas for transport to/from the Port of Antwerp. Based on this analysis, new terminal locations will be proposed. On the other hand, also privately exploited terminals exist within Flanders, which could increase the density of the current terminal network and lead to quick-wins if they are publicly accessible.

Recently, the number of inland terminals has grown considerably (see Figure 5) and still, initiatives for the implementation of new terminals arise. A denser terminal network can reduce the use of road-only transport considerably, but as freight flows become thinner, shuttle services cannot be kept viable as economies of scale decrease (Rutten, 1998). An oversupply of intermodal terminals could harm the sector, when the capacity of terminals is underutilized. An abundance of terminals in a region can lead to severe competition and can affect the profitability of each individual terminal (Visser et al., 2012). Therefore, the future inland terminal network has to be linked closely to the future freight demand and supply within the region. Parallel, when new terminal locations are considered, the potential competition with existing terminals has to be accounted for. An uncontrolled sprawl of terminals has to be avoided.

In this research we want to answer the following questions:

- Is there market potential for new inland terminals in Flanders?
- Which is/are the optimal location(s) to implement (a) new inland terminal(s)?

For the selection of potential terminal locations, the LAMBIT-model was used and altered. The use of GIS software for site selection is rather common, as GIS are used to analyse and integrate spatial data from multiple sources. Common techniques used are: overlaying, buffering, merging and extracting (Barnett and Okoruwa, 1993) and in addition distance-related analyses.

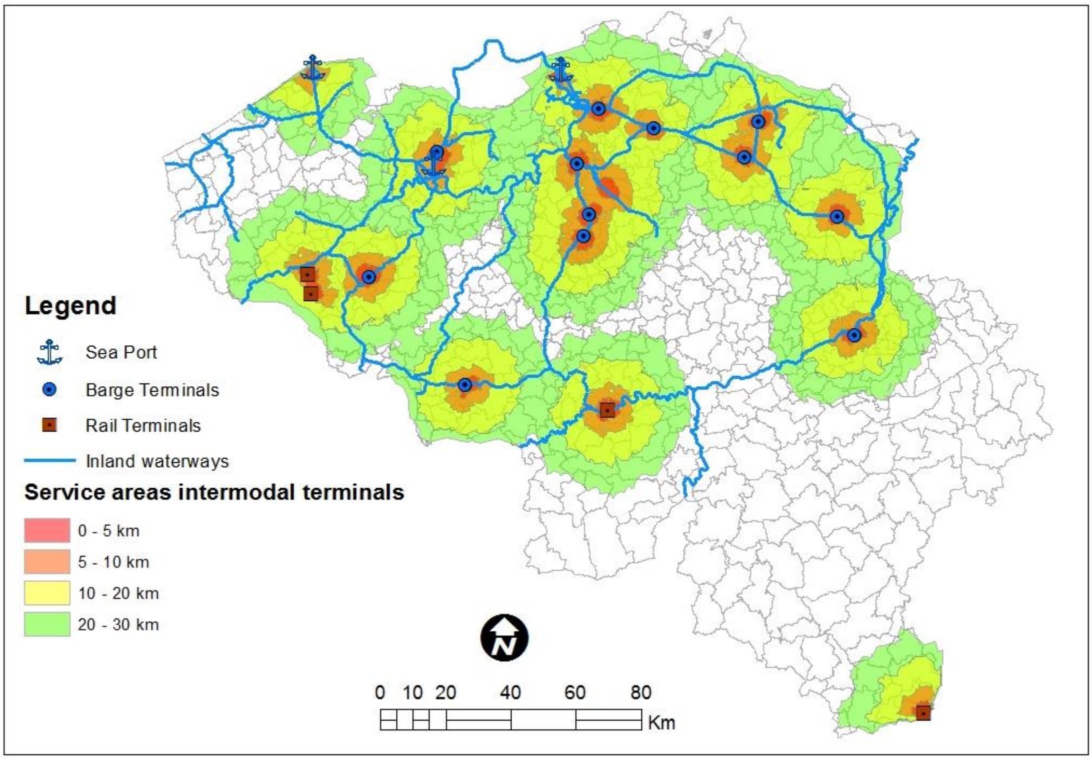


Figure 27 Service areas of Belgian intermodal terminals, based on distance. (Source: own setup)

Subsection 5.1 introduces the search for the optimal terminal location. Subsection 5.2 explains the methodology that was used to adapt the existing LAMBIT-model. Subsection 5.3 provides the results of the new analyses, while subsection 5.4 concludes this section.

5.1 Introduction

When potential locations for intermodal terminals are considered, a close link to the potential for modal shift within its market area is required. The nodes should be located in the terminal network on places with a good accessibility and where a sufficient potential volume exists that can be transported cheaper by intermodal transport than by road-only transport. Since there are only a limited number of access points for containers to the rail and inland waterway network, these access points should be located in order to minimize post-haulage distances and maximize potential volumes. The modal choice is highly related to the relative position of potential users to these access points (Niérat, 1997). Too small volumes cannot optimally benefit from economies of scale, and therefore transport prices will increase. Depending on the size of a terminal, the yearly required transhipment volume estimates are within a broad range.

In practice, the shape of an intermodal market area is not a circle with the terminal as its centre, but rather an ellipse. The theoretical shape of a market area is influenced by diverse (geographic) barriers and enablers (e.g. the course of a river, speed restrictions…). The size of a market area is depending on the cost of unimodal and intermodal transport and the distance to/from the sea port. In general will terminals further from sea ports have greater market areas, than the ones located closer to sea ports. Indeed, on longer trajectories intermodal transport can benefit more from the economies of scale as the intermodal leg increases in length. Therefore the pre- and/or post-haulage distance within market areas can differ from a few to tens of kilometres.

Previously, different research projects already aimed at selecting the most appropriate locations to start up new terminal initiatives. In the EMOLITE project for instance, an evaluation model for the optimal location of intermodal terminals in Europe was developed. This was a simulation model, aimed for decision-makers who could weigh relevant criteria for the terminal selection (Moreira et al., 1998). Rutten (1998) developed the TERMINET model to determine the location and the capacity of rail/road terminals, where all rail/road intersections were considered as potential locations. Bottani and Rizzi (2007) developed a methodology to estimate the potential volume that is likely to be diverted from road only transport to intermodal rail/road transport. These potentials are derived from an index which is a function of: the transport distance of the main leg, the transport time of the short leg and the aptitude of the goods to be transhipped towards intermodal transport. The REFORM project identified six elements to assess the potential freight volume of a terminal: transport time and distance to the terminal, the kind of goods transported, space available for transhipment, the facilities established on site and the existing transport mode and technology (Bottani and Rizzi, 2007; European Commission, 1998). Bergqvist and Tornberg (2008) provide a framework for the evaluation of potential terminal locations on the basis of economic and quality-related considerations, in contrast to traditional methods that often focus either on economic, environmental or quality aspects in exclusion of each other. Sirikijpanichkul and Ferreira (2005) and Sirikijpanichkul et al. (2007) use a multi-objective methodology to evaluate the terminal locations, trying to incorporate different stakeholders by taking into account externalities. Limbourg and Jourquin (2009) approach our research question as a *p*-hub median problem in a hub-and-spoke network in Europe. Also the LAMBIT-model was previously used in finding the best locations, but only existing terminal initiatives were considered (Macharis et al., 2011). The criteria mentioned in most studies are thus: distance and time of main- and post-haulage (infrastructural, spatial and capacity constraints), potential volume to be shifted to intermodal transport (economic constraints) and possibly also variables related to external effects (community related constraints). Limpscomb et al. (2011) add to this: land availability, government and industry support and labour supply. In our analysis we take abstraction of the land availability and the supply of (skilled) labour, support is indirectly included in transport price.

5.2 Methodology

The LAMBIT-model was used and altered to analyse the optimal locations for new intermodal terminals within Flanders. The data applied and the methods used to calculate distances, transport times and prices are described in section 3. An optimization approach was used to maximize the total potential volume transported by intermodal transport. ADSEI data (2010) were used as the estimates for the volumes transported between Antwerp and the hinterland, which is in this case the municipalities within Belgium. Terminals as international hubs were not discussed due to data restrictions. Transport volumes to regions and ports abroad are not considered. Therefore, the volumes discussed below present underestimations of the total volumes as for instance transport to/from the Port of Rotterdam is not taken into consideration.

We want to select the potential locations with the highest potential volume for modal shift. Therefore we don't want to minimize the total transportation cost of the full network, but we want to maximize the volume (i.e. the total potential volume, not the potential market area size) that can be transported cheaper intermodal than by unimodal barge, by adding only viable new terminals. This search is limited by the fact that we don't want to compete with existing terminal initiatives, limiting the list of optimal terminal locations. The list of optimal terminals described below is not a full list of all suitable locations, but a list of the optimal locations to maximise the total potential transhipment volume of the intermodal network. An example can clarify this: two locations in each other's vicinity might be attracting very similar high potential transhipment volumes. But, as only the location with the highest potential transhipment volume is selected, this second best location is neglected. As the market areas of these terminals will probably overlap, the second terminal will not be added to the terminal network in a later stage as the potential transhipment volume of the full network will not be maximised. Therefore, the selected locations will be at certain distances from one another.

For a new terminal to be viable and to cover costs, in the sector, 10.000 TEU is used as a rule of thumb, but this hasn't been proven for the case of Flanders. In the literature, the minimal required transhipments volumes vary between 5.000 TEU (Sirikijpanichkul and Ferreira, 2005) and go up to 20.000 containers (Decisio, 2002), depending on the size and capacity of the terminal (Table 1). Other estimations exist, based on the type of connections and the ship size (Konings et al., 2006). For 90 TEU barges with 5 services per week in both directions and a load factor of 85%, they vary from 8320 TEU/year (line, hub-and-spoke or collect-and-distribute) to 25.012 TEU/year (point-to-point connections) and for intermodal rail transport from 4.680 TEU/year (a 400m train in hub-and-spoke networks) to 21.216 TEU/year (a 600m train in point-to-point connections). This is because potential for modal shift from road to intermodal only exists when traffic flows reach a certain threshold value, as intermodal transport of small flows is not viable (Trip and Bontekoning, 2002). If we assume that these volumes can be attained once a threshold potential volume is reached, we can assume that economies of scale will influence the transport prices. If these volumes are not reached for a certain location, benefits due to economies of scale will be eliminated and prices will increase, leading to a smaller share in modal shift. Therefore, only locations, able to catch a certain potential volume will be retained, otherwise the price function used, would have to be adapted (Arnold et al., 2004).

Table 1 Classification of intermodal freight terminals. (Adapted from Sirikijpanichkul and Ferreira, 2005, adapted from Sd+D, 2004)

Terminal size	Transhipment potential
- **Small**	- Less than 5.000 TEU
- **Medium**	- 5.000 to 20.000 TEU
- **Large**	- 20.000 to 40.000 TEU
- **Super**	- Over 40.000 TEU

In our analyses we take into account the criteria: distance and time of main- and post-haulage, total transport cost, relative location with respect to the Port of Antwerp and the existing terminals, the minimal transhipment volume that has to be shifted and the size of the market areas of the existing terminals. Other criteria where left out due to data limitations and/or time constraints: external effects of transport, land availability, the supply of skilled labour and the current and potential future capacity of the existing terminals.

The first step was the selection of the potential terminal locations. In first instance, we considered every location next to a navigable inland waterway or adjacent to a railway within Belgium. As this leads to a continuous space of potential locations, discrete locations were retained with an interval of 5 km between two consecutive point locations. In a later stadium, the true optimal location could be approximated. 1066 potential locations were selected as a subset, to reduce computation time and to keep the dataset manageable, as has been done in Limbourg and Jourquin (2009). Three types of sampling can be used for the choice of potential location (Sirikijpanichkul and Ferreira, 2005). The first one is continuous sampling, where it is assumed that a terminal can be located anywhere in space. Therefore, a raster of potential locations is placed on top of the selected territory. The second, the network methodology, only considers locations on (or next to) the network. The third methodology, discrete modelling, uses a list of pre-selected sites (Figure 28). Such a selection can be based on previous experiences, the availability or ownership of sites, preferences etc. For this study, the network methodology is used. The idea was to start with a subset of good potential locations, while after, the final selection is done on a smaller scale.

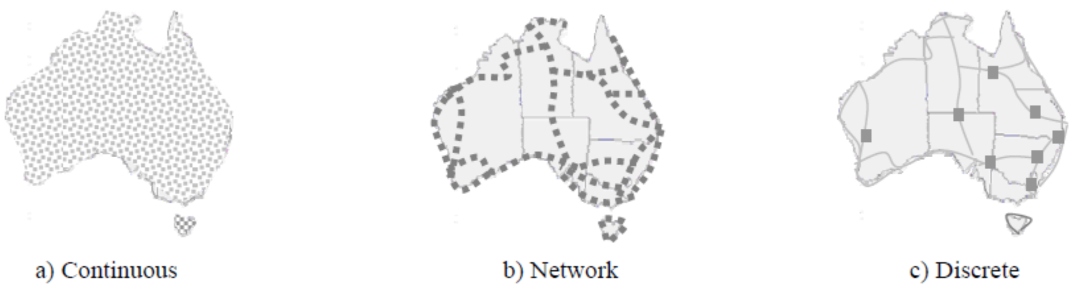


Figure 28 Continuous, network and discrete location sampling models. (Source: Sirikijpanichkul and Ferreira, 2005)

As was previously done for the existing terminals, also for all potential locations, the potential market area was calculated using the LAMBIT-model. The distances and transport times were calculated, starting from the average traffic scenario, described in section 4.3.2. When the potential volume of all municipalities in each potential market area is summed, the total potential of a location is known. Two methodologies are tested, to calculate the optimal terminal network configuration:

1. *Optimal single coverage*

   First, all municipalities in the market areas of the existing terminals are excluded. This is done to reduce the chance on potential competition between new and existing terminals. Thus can the new selected terminals create their own market area without 'stealing' municipalities from existing terminals. This approach also allows efficiently filling up the existing 'white spots'. This scenario maximises the total potential volume of every extra terminal. In every iteration, only the one terminal with the highest potential volume is added to the current terminal landscape. After every iteration, all the municipalities within the market area of the extra terminal are removed from the database before a next terminal is selected. This methodology is very useful if one terminal at a time is added to the current terminal network. This methodology was applied to the current terminal landscape when VOT was included and excluded, leaving two parallel analyses. This methodology was applied until the market share needed to obtain a transhipment potential of 5.000 TEU was 37.5% or 75% for 10.000 TEU.[3]

2. *Optimal total coverage*

   This scenario maximises the total volume of the added terminals. The sum of their potentials is maximised for the number of new terminals=*p*. This means that if for instance *p* equals two, none of the selected terminals might be the same as in the case that p equals one. This is due to potential overlap (Figure 29). In scenario 1, the intermodal market area with the highest potential volume (terminal i) has no spatial overlap with the market area of the second biggest potential volume (terminal j). For *p* equals two, the optimal terminal locations would be i and j. In scenario 2, both terminals have a certain spatial overlap of their market areas. In this case, the sum of the potential volume of both market areas (i and j) minus the potential volume in the overlapping area, might be smaller than the sum of the potential volume of two other terminals whose individual market areas might have a smaller potential volume (terminals k and l).

[3] 37.5% and 75% were used as arbitrary limits.

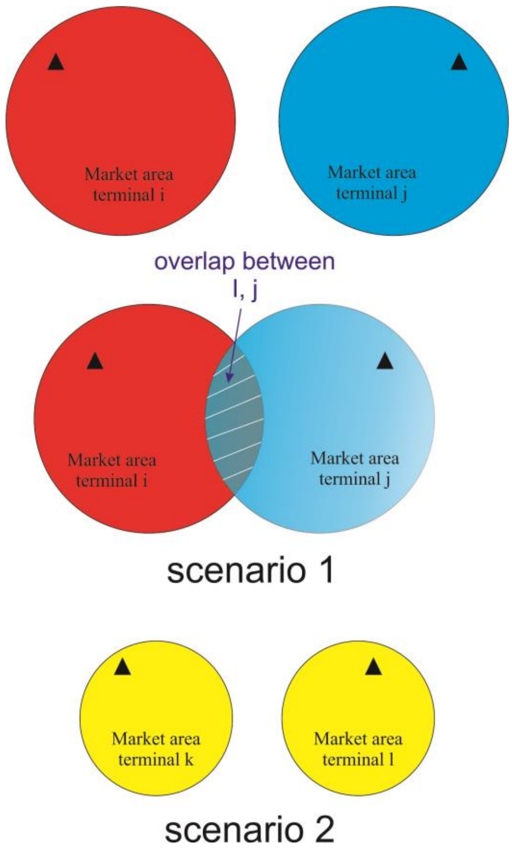


Figure 29 Possible terminal configurations, the triangles mark the location of a terminal. (Source: own setup)

5.3 Results

5.3.1 Optimal location for new terminals: optimal single coverage

If the first methodology is applied, seven new terminal locations are selected within Flanders that can potentially attract transhipment volumes exceeding 175.000 ton per year (Table 2). Except for one, all the terminals are barge/road terminals, as it's easier for intermodal barge transport to be competitive on shorter distances than for intermodal rail/road transport.

Table 3 displays the market shares needed to achieve transhipment threshold values of 5.000 or 10.000 TEU per year. For instance for the case of Wielsbeke/Zulte, 12 % of the total containers currently transported to/from the market area of this potential terminal should shift to intermodal to obtain a yearly transhipment volume of 5.000 TEU. It is clear that only very limited potential exists for medium-sized terminals within Flanders. Three other potential locations are in the Walloon region, and are not further discussed in this analysis.

Table 2 Additional terminals[4] and their potential market potential (excl. VOT).[5]

Number of additional terminals	Location	Transhipment	Number of municipalities in market area	Potential volume in market area (ton)
1	Wielsbeke/Zulte	Barge/Road	18	540.360
2	Heist-op-den-Berg	Rail/Road	11	439.154
3	Gent	Barge/Road	2	375.068
4	*Mont-Saint-Guibert*	Rail/Road	17	259.015
5	Brugge	Barge/Road	6	256.561
6	Grobbendonk	Barge/Road	7	242.492
7	Roeselare	Barge/Road	13	239.799
8	*Tubize*	Barge/Road	20	224.046
9	Turnhout	Barge/Road	8	218.380
10	*Libramont*	Rail/Road	20	175.379

Table 3 Market share needed to have a potential turnover of 5.000 or 10.000 TEU for the implementation of additional terminals (excl. VOT).

Number of additional terminals	Location	Market share needed to totalize 5.000 TEU (%)	Market share needed to totalize 10.000 TEU (%)
1	Wielsbeke/Zulte	12,0	24,1
2	Heist-op-den-Berg	14,8	29,6
3	Gent	17,3	34,7
4	*Mont-Saint-Guibert*	25,1	50,2
5	Brugge	25,3	50,7
6	Grobbendonk	26,8	53,6
7	Roeselare	27,1	54,2
8	*Tubize*	29,0	58,0
9	Turnhout	29,8	59,5
10	*Libramont*	37,1	74,1

These potential locations and their respective market areas can also be displayed on maps (Figure 30). The location with the highest potential volume is located next to the Leie River, on the border of Wielsbeke and Zulte, which is also the border between West Flanders and East Flanders. Compared

[4] Locations marked in italics are located outside Flanders, but within the Walloon Region.

[5] In the appendix the list of decimal coordinates of these terminals is added.

to the reference output for the same traffic intensity scenario (Figure 15), it is clear that the existing terminals don't lose market area in favour of this new terminal.

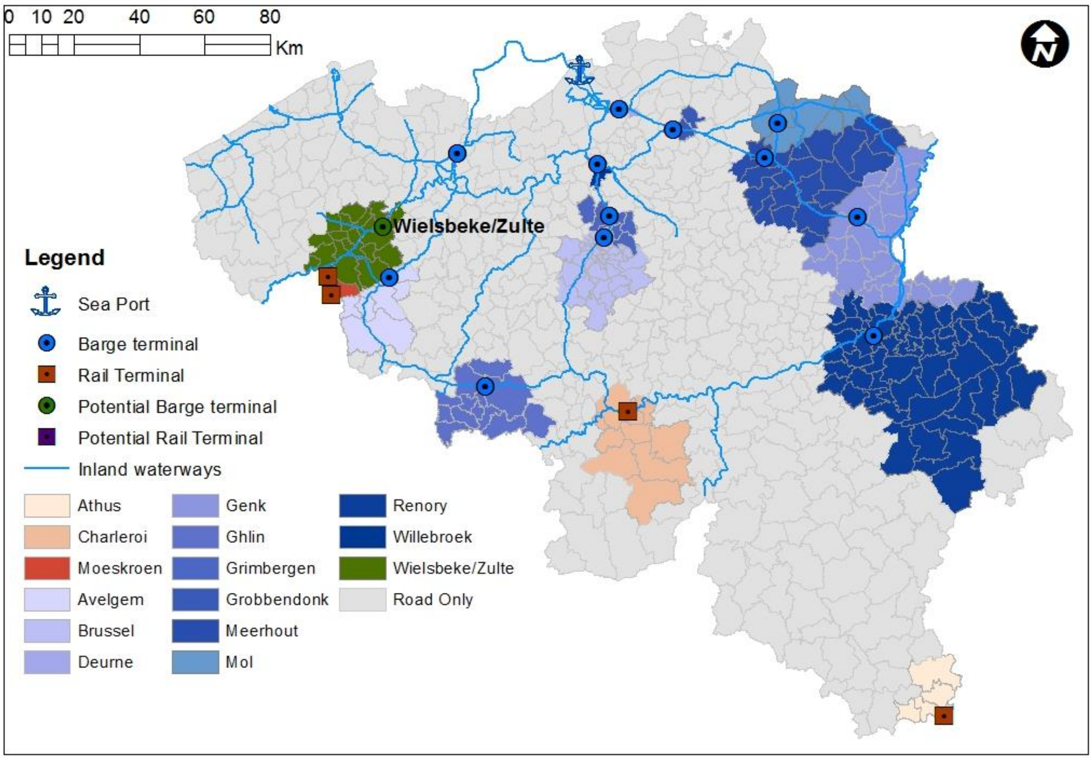


Figure 30 The optimal location for a new terminal is in Wielsbeke/Zulte. (Source: own composition)

The ten terminals resulting from the analysis can also be mapped at the same time (Figure 31). It is clear that not all white spots are covered by the introduction of these seven new intermodal terminals in Flanders. For the resulting white spots, intermodal transport cannot be organised catching a sufficient potential volume when these 10 terminals are set up. This can be due to a weak competitive position compared to unimodal road transport and/or the lack of sufficient volumes to/from Antwerp. But when new terminals are implemented incrementally, these locations could still prove interesting, especially when the other selected locations are not included in the existing terminal network. All new optimal locations within Flanders are shortly evaluated and where quick-wins are possible, they are mentioned. It should be noted that for intermodal rail transport currently subsidy schemes exist. However, the elimination or the adjustment of support for intermodal rail transport can impact the market area of rail terminals (cf. sensitivity analysis). When this analysis was performed for intermodal barge transport only, similar locations result from the simulation (Table 4).

- *Wielsbeke/Zulte*: This terminal is able to catch the highest potential volume for transport to/from Antwerp. It's striking that this optimal location is only 5 km east of the River terminal

WIelsbeke (RTW), which can be reopened after it was closed in 2009. Therefore, it would be necessary to overcome the reasons for the previous shut-down of this terminal.

- *Heist-op-den-berg*: This rail/road terminal also has a large potential for intermodal transport. Although, rail services can only be profitable if they are introduced as hubs in a larger network, where the hub is only a single stop in a longer trajectory.
- *Gent*: Also in Ghent a large potential remains, as large volumes are available. Currently there is already a terminal in Ghent, but for the current scenario it was not able to catch the same market area as the proposed location. Both locations are only approximately 7,5 km from one another, so a quick-win could be easily realised. The reason why the existing terminal doesn't catch a market area and the new one does, relates to a very small price difference between road-only and intermodal. This means that the existing terminal is not capable of catching market area only just, while the proposed one is only just able to catch it. A small difference in price setting in favour of intermodal would make the existing location already able to catch the same market area, as the proposed location.
- *Brugge*: This location is 16 km south of the Port of Zeebrugge. Between Antwerp and Zeebrugge, 39 round trips a week are organised, so it would be possible to transport containers from Antwerp to Zeebrugge by rail, while the post-haulage is done by truck. In this case, the Port of Zeebrugge would act as a hub and would probably compete with this location for market area. So partially, this potential market area could be covered by a quick-win. Another problem with the connection Antwerp-Bruges, is the capacity of the canal Gent-Oostende, therefore it would be appropriate to use short sea shipping, passing the Port of Zeebrugge.
- *Grobbendonk*: Again, the proposed location is in the close vicinity of an existing terminal: the container transferium of Grobbendonk (3 km). In the previous analysis, this terminal was not able to catch the same market area as the proposed location. The new terminal also captures the market area of the current terminal. Again, as pricing changes a little in favour of intermodal barge transport, the existing terminal will incorporate the market area of the proposed terminal, leading to a quick-win.
- *Roeselare*: This proposed location is able to include 13 municipalities in its market area, but this also implies taking two municipalities from the market area of the Wielsbeke/Zulte terminal: Ledegem and Izegem. But still, this terminal is able to catch a significant market area in a 'white spot' area and therefore seems an interesting location.
- *Turnhout*: This location is located next to the canal Dessel-Turnhout-Schoten, a canal with a very limited maximum capacity (600 ton barges). Therefore it's more difficult to obtain

economies of scale, and to transport an equal volume, more regular services have to be organised. This location does eliminate the white spots in the regions East-Antwerp and Limburg.

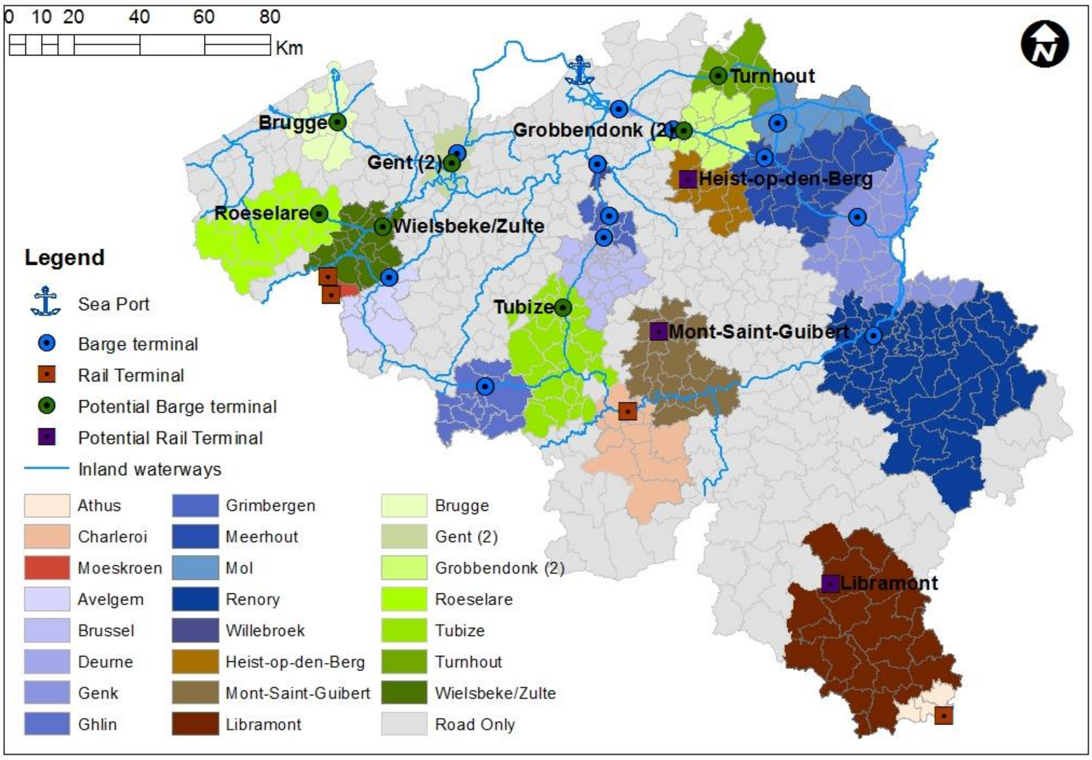


Figure 31 Ten potential terminal locations in Belgium with the greatest total potential transhipment volume. (Source: own composition)

Table 4 Additional terminals when only intermodal barge transport is considered (excl. VOT).[6]

Number of additional terminals	Location
1	Wielsbeke/Zulte
2	Grobbendonk
3	Gent
4	Izegem (close to Roeselare)
5	Brugge
6	Turnhout
7	Halle (close to Tubize)
8	Deinze

[6] In this case, the optimal terminal locations in Wallonia were not considered.

A parallel analysis was performed, including the Value Of Time as a modal choice variable (Table 5). It is clear that different terminals have been selected as the terminals with the highest potential, except for the terminal in Heist-op-den-Berg. As transport time disadvantages slower modes, and mainly barge, only one barge/road terminal was selected. The number of rail/road terminals suited could also diminish when the support for intermodal rail transport declines. Only five terminals, of which three are located in Flanders, have enough potential volume (Table 6). Again, also different locations could prove interesting if other transport flows are accounted for or when the selected locations are not added to the existing terminal network.

In practice, for the transport of goods with a higher valuation of time, faster modes will usually be preferred, unless also other factors will get more important in model choice. For instance (travel time) reliability, or the risk on damage might reincrease the interest for slower modes again.

Table 5 Additional terminals[7] and their potential market potential (incl. VOT)

Number of additional terminals	Location	Transhipment	Number of municipalities in market area	Potential volume in market area (ton)
1	Heist-op-den-Berg	Rail/Road	6	352.692
2	Herentals	Barge/Road	5	326.840
3	Willebroek	Rail/Road	1	283.270
4	*Gembloux*	Rail/Road	10	232.716
5	*Braine-Le-Comte*	Rail/Road	11	203.340

Table 6 Market share needed to have a potential turnover of 5.000 or 10.000 TEU for the implementation of additional terminals (incl. VOT)

Number of additional terminals	Location	Market share needed to totalize 5.000 TEU (%)	Market share needed to totalize 10.000 TEU (%)
1	Heist-op-den-Berg	18,4	36,9
2	Herentals	19,9	39,8
3	Willebroek	22,9	45,9
4	*Gembloux*	27,9	55,9
5	*Braine-Le-Comte*	32,0	63,9

[7] Locations marked in italics are located outside Flanders, within the Walloon Region.

Again, the best suited terminals are mapped (Figure 32). This image can be compared to the reference image for the same speed scenario (Figure 16). It is clear that these five terminals cannot fill the identified white spots. The three identified terminal locations in Flanders are located close to the Port of Antwerp, filling white spots in the province of Antwerp. Some locations which were selected in the previous analysis disappear as for longer transport times, intermodal transport is less competitive when accounting for the VOT. The terminals proposed in Flanders, are discussed below:

- *Heist-op-den-Berg*: see above. This terminal has also potential for the intermodal transport of goods with a higher valuation of time. Although the market area shrank in comparison to the previous analysis, the market area still catches enough potential volume.
- *Herentals*: This location is only 6.5 km removed from the previously proposed location in Grobbendonk (see above). This location and the one in Heist-op-den-Berg show that there is still potential for terminals in a region, where the terminal density is already rather dense.
- *Willebroek*: This location was selected due to the fact that the barge/road terminal in Willebroek has no market area in the analysis where VOT is included. And as there is a large potential volume in Willebroek, this location was chosen. Both locations are only 3.5 km removed of one another. Setting up a new rail terminal in the close vicinity of the existing terminal would bring competition for the goods with a lower valuation of time.

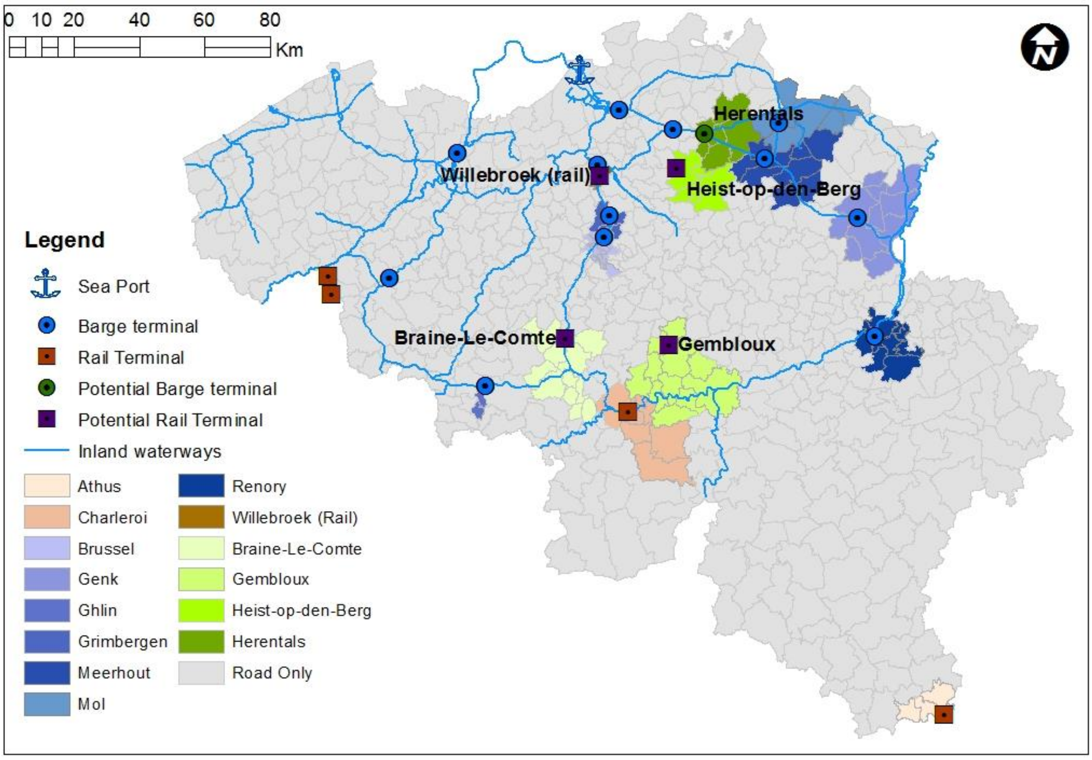


Figure 32 Five potential terminal locations with the greatest potential volume (incl. VOT). (Source: own composition)

As a cross-check, we can also simulate the impact of including VOT in decision making, when the terminals from the initial analysis are loaded to the network (Figure 33). The results are dramatic for most terminals, except (off course) Heist-op-den-Berg, Grobbendonk and Herentals. The rail terminals (as a faster mode) are better able to retain a part of their original market areas. It is clear that optimal locations change drastically, depending on the importance attached to transport time in modal choice. The same could be true for the inclusion of other additional modal choice variables.

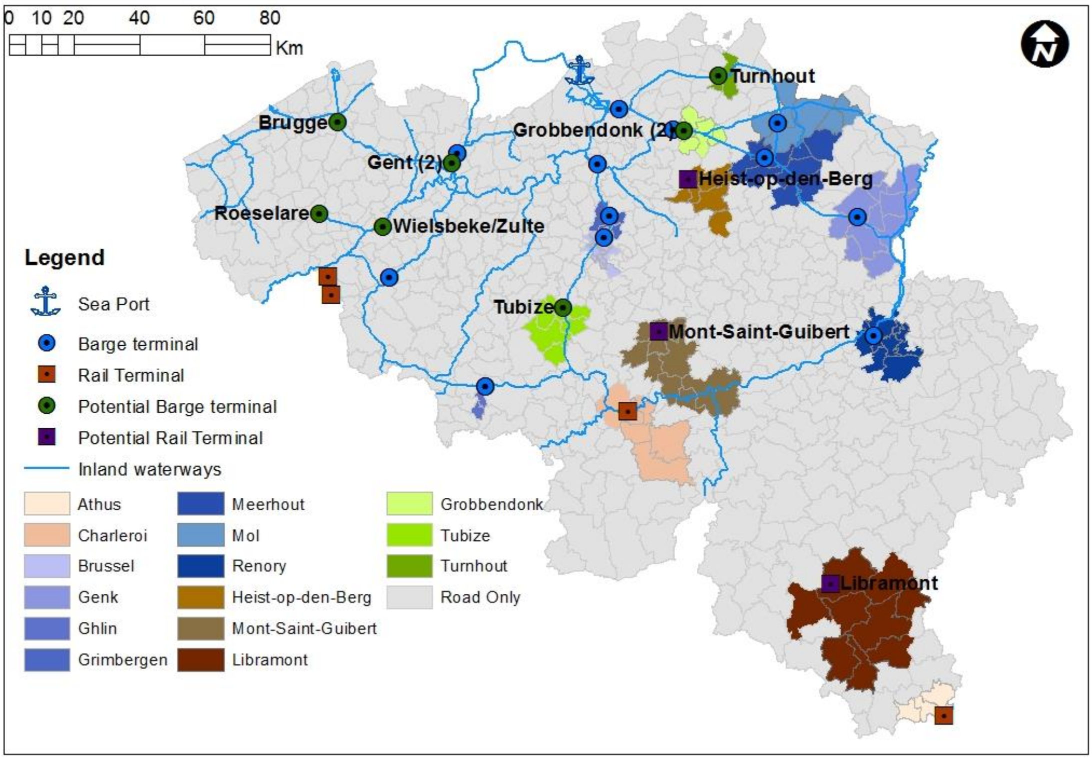


Figure 33 Simulation of the initially added terminals, when transport time is considered as modal choice variable. (Source: own composition)

5.3.2 Optimal location for new terminals: optimal total coverage

This second methodology can have a different output than the first one, as a different kind of maximization approach is used. The first methodology aims to maximise the potential of every single terminal added to the network, facilitating an incremental introduction of extra terminals. This means that when the best location is chosen, for the second iteration, this terminal is considered as an existing terminal. Therefore, new terminals aim not to compete with this existing terminal. This second methodology aims to maximise the total potential volume added. This means that if one wants to add *p* terminals to a network, the terminals selected in the previous iteration are not automatically added to the existing terminal network. As stated before, this is due to potential overlap in market areas between suited locations (Figure 29). The first methodology is preferred when one terminal at a time is introduced, while the second is preferred when a number of terminals (*p*) are added to the network at the same time.

The programming for these iterations was performed in MATLAB, but due to computing constraints the optimal configuration was only calculated up to p=3 new terminal locations. The outcome of this methodology was compared to the previous outcome (Table 7). For p=1 both methods logically have the same outcome as only one terminal is added to the existing network. For p=2, the total potential market area volume of all terminal combinations of two terminals was calculated. The possibility of overlap between two market areas was accounted for. When overlap between market areas occurred, the potential volume of two market areas was summed and the overlapping volume was subtracted from the total. As for the previous methodology, the selected terminals were Wielsbeke/Zulte and Heist-op-den-Berg.

For the optimal location of three new terminals (p=3), two types of overlapping market areas were identified: (1) overlap between two market areas (between i and j, i and k etc.), (2) overlap between three terminals (between i, j and k, see Figure 34). The first type of overlap between two market areas was already considered in the previous model (p=2) while the second type of overlap between the three market was solved in the model, by subtracting the overlapping volume twice from the sum of the three potential volumes. Still the same locations are preferred as in the first methodology tested. This confirms the potential of these locations (for p<4).

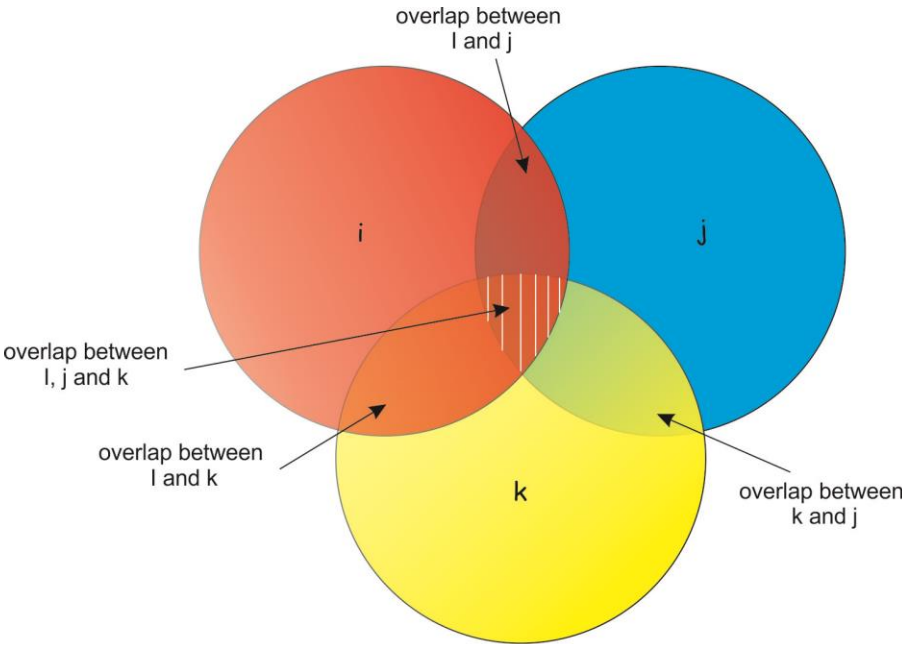


Figure 34 Potential overlap between three terminals' market area. (Source: own setup)

Table 7 Comparison of optimal locations for both methodologies.[8]

# terminals added	Methodology 1	Methodology 2
***p*=1**	W/Z	W/Z
***p*=2**	W/Z; HB	W/Z; HB
***p*=3**	W/Z; HB; G	W/Z; HB; G

5.3.3 Sensitivity analysis

A sensitivity analysis was performed for the outcome of methodology one, to investigate the impact of price changes. The reference scenario is compared to scenarios in which the price of some input variables is altered (Table 8). For each scenario, three sub scenarios are considered to account for the impact of the added terminals (0, 1 or 10 terminals added).

The different scenarios are first applied on the sub scenario where no terminals are added to the current terminal landscape (Table 9). This analysis shows that even limited changes to transport prices can have a severe impact on the potential for intermodal transport combinations. It is clear that the changes in road transport and barge and rail transport (scenarios 4 and 7) have the biggest impact on the number of municipalities and the potential volumes. The impact of changes related to barge transport have a bigger impact than changes impacting rail transport, due to the greater potential of barge transport in Belgium (more terminals etc.). Changes related to transhipment costs and rail transport costs have smaller impacts. If the 10 extra terminals are added (Table 10) all ratios increase due to the larger potential for intermodality. Although the price ratio remains close to 1, the volume ratio shows a great variability. This proves that slight changes in transport prices might have a great impact on the competitiveness of the different modes.

Table 8 Overview sensitivity analysis scenarios

Scenario number	Scenario	Causes	Change
1	Reference scenario	/	/
2	Road pricing	Kilometre charge trucks	+0,15 € per TEU per km
3	Transhipment	Innovative techniques	± 5 % transhipments costs in port and terminal

[8] W/Z=Wielsbeke/Zulte; HB=Heist-op-den-Berg; G=Gent

4	Road transport	Tax structure change…	± 5 % transport costs (incl. post-haulage)
5	Rail transport	Capacity changes…	± 5 % transport costs
6	Barge transport	Capacity changes...	± 5 % transport costs
7	Barge and Rail transport	Capacity changes…	± 5 % transport costs

Table 9 Sensitivity analysis for the sub scenario where no extra terminals are added[9]

	S1	S2	S3A	S3B	S4A	S4B	S5A	S5B	S6A	S6B	S7A	S7B
Ratio municipalities Intermodal/Road Only	0,47	1,05	0,45	0,61	2,46	0,14	0,43	0,60	0,19	1,09	0,15	1,32
Ratio volume Intermodal/Road Only	0,17	0,31	0,17	0,19	2,99	0,07	0,15	0,22	0,09	2,64	0,07	3,04
Ratio average price Intermodal/Road Only[10]	1,03	0,99	1,03	1,02	0,99	1,08	1,03	1,02	1,06	0,99	1,07	0,98

Table 10 Sensitivity analysis for the sub scenario where 10 extra terminals are added

	S1	S2	S3A	S3B	S4A	S4B	S5A	S5B	S6A	S6B	S7A	S7B
Ratio municipalities Intermodal/Road Only	1,10	2,75	0,99	1,49	3,37	0,18	0,80	1,61	0,38	2,58	0,23	3,57
Ratio volume Intermodal/Road Only	0,53	0,67	0,51	0,55	8,01	0,07	0,40	0,57	0,20	7,39	0,11	7,97
Ratio average price Intermodal/Road Only[11]	1,00	0,96	1,00	0,99	0,96	1,05	1,01	0,99	1,03	0,97	1,04	0,96

A possible future scenario would be the combination of the introduction of a road pricing scheme, were road freight transport pays 0,15 €/km (scenario 2), combined with an increase of the fuel price, leading to another 5 % relative increase in the variable price of road transport (Figure 35). This is a

[9] The A scenarios simulate a 5% increase in prices, the B scenarios a 5% decrease.

[10] Here, the cheapest intermodal alternative is compared to the price of the road-only transport between all OD-couples.

[11] Here, the cheapest intermodal alternative is compared to the price of the road-only transport between all OD-couples.

favoured situation as it provides opportunities for intermodal transport, leading to lower external transport costs for the transport system.

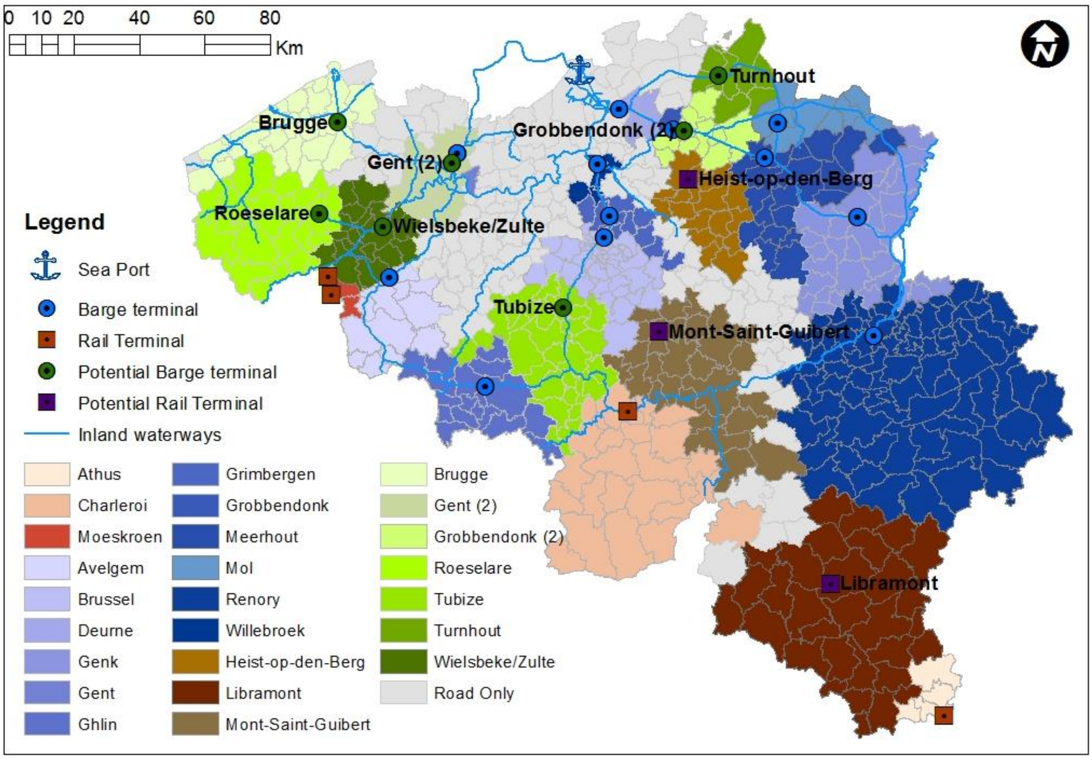


Figure 35 Simulation of the sensitivity analysis where road pricing is implemented and fuel prices increased. (Source: own composition)

5.3.4 Current terminal initiatives

In Aalter (Woestijne), there are plans to build a Regional Transhipment Centre[12] for the new industrial area, located next to the canal Ghent-Ostend (Waterwegen en Zeekanalen, 2010). Also in Aalst (Wijngaardveld), plans exist to develop a Regional Transhipment Centre. This centre will be located at the Dender River. A study was commissioned to research the market potential of this location (Waterwegen en Zeekanalen, 2012). In Roeselare, an analysis of the potential for intermodal transport was performed, for the development of a new water bound industrial area. This potential location is next to the canal Roeselare-Leie and would also include a rail connection (Rebel and Tri-Vizor, 2010). This location in Roeselare was also selected in the first analysis as a potential location

[12] Regionaal Overslag Centrum (ROC)

for a barge/road terminal. The other current initiatives are not in the vicinity of the proposed optimal locations as they are calculated in this analysis.

The three current initiatives are also mapped (Figure 36) and their market areas are calculated (Table 11). The initiative in Aalter has less potential for a container terminal than the locations in Roeselare and Aalst. Although the potential market area of Aalter is bigger than the one of Aalst, the potential transhipment volume is lower. The potential of these locations will even be more interesting if also pallets and bulk transport are considered.

The analysis of discrete locations therefore adds to the approach discussed in this paper. In this case, the potential of a single location can be calculated, while the presented approach calculates optimal locations when more than a single terminal is added. This doesn't mean that possible terminal locations which were not discussed in this paper are unsuitable.

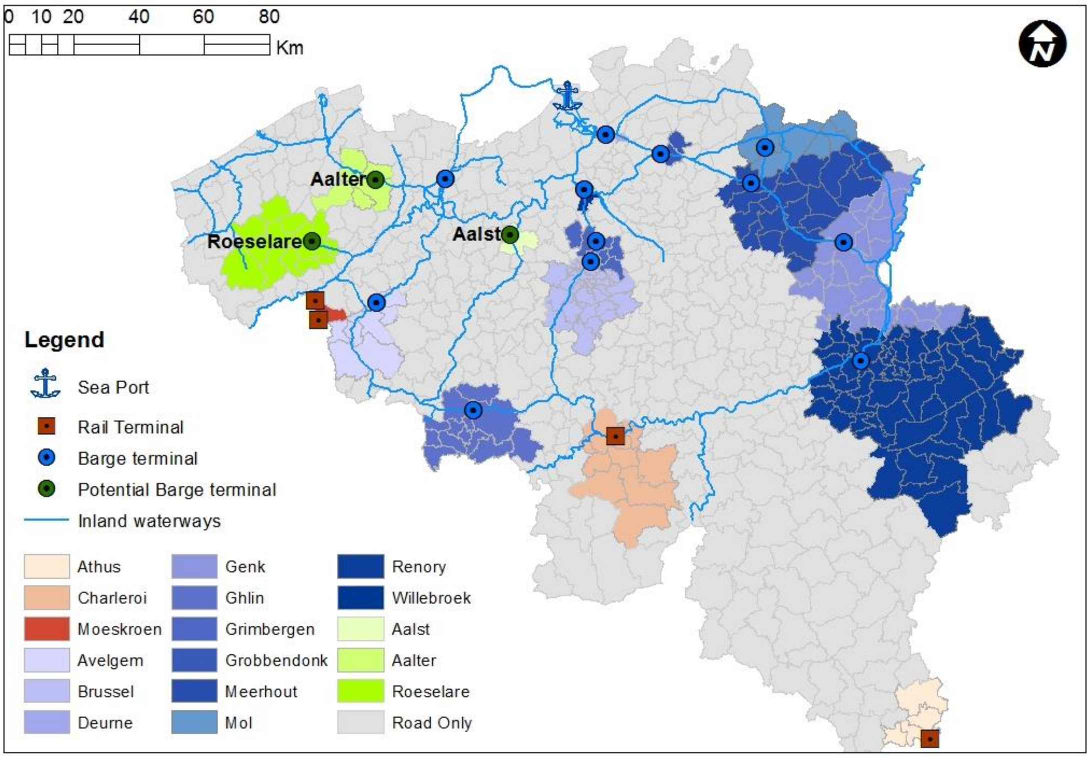


Figure 36 Market areas of current terminal initiatives for speed scenario 2 (excl. VOT). (Source: own composition)

Table 11 Potential of current terminal initiatives for container transport to and from Antwerp (excl. VOT).

Location	Transhipment	Number of municipalities in market area	Potential volume in market area (ton)
Aalst	Barge/Road	1	39.289
Aalter	Barge/Road	5	12.949
Roeselare	Trimodal	14	236.740

5.4 Conclusions

It seems that despite the current relatively high density of intermodal terminals, still potential exist for the setup of new terminal initiatives. Depending on the category of goods transported and the value attained to transport time in modal choice, different locations are suggested. The location of a barge terminal in Wielsbeke/Zulte has the highest potential of transhipping the biggest volume of containers to/from Antwerp. For the transhipment of goods, with a higher importance attached to fast transport, the optimal new terminal location is in Heist-op-den-Berg. However, changes in the support for intermodal rail transport can impact the profitability of rail terminals. In both analyses, locations in the vicinity of existing terminals were selected as suitable terminal locations (e.g. Grobbendonk, Willebroek (2)). But in practice, these locations are not preferable, as small fluctuations in price levels can enlarge the market areas of the existing terminals, making these initiatives unnecessary or resulting in competition between both terminals. The potential for international hub terminals is more difficult to estimate due to data limitations, while intermodal transport on longer distances (over 300 km) is a key objective of the European Commission.

Other locations which were not considered in this analysis can still prove interesting and be economically viable locations for intermodal transhipment terminals. Different reasons support this:

1. Only transport to/from Antwerp was included in this analysis. As only ADSEI data (2010) were included, only domestic flows were included, neglecting the possibilities of international transport to foreign ports and terminals. Therefore, the locations considered suitable in this study are presumably part of a longer list of suitable locations.

2. The methodology used in this paper aims to maximise the total transhipment volume of the terminal network. Other terminal locations could also yield similar transhipment volumes in discrete locations. The difference would only be that if several terminals are added, the total intermodal transhipment volumes will not be maximised. Figure 37 provides insight in the

transhipment potential of the considered locations when no extra terminals are added to the terminal network, and when no competition for market area with existing terminals is allowed. This figure gives an indication of the regions/clusters where potential remains for the set-up of new terminals. This figure shows that locations in the vicinity of the terminal locations mentioned in Table 2 often have similar potential transhipment volumes. Different 'clusters' mark the regions with the highest transhipment potentials for transport to/from the Port of Antwerp.

3. Due to the all-or-nothing approach dealt with in this analysis, no sensitivity is taken into account. Small difference in price between unimodal and intermodal could make different regions and terminals more or less interesting in terms of transhipment potential. Also, as no competition with existing terminals is allowed, some regions are excluded from the analysis and therefore not considered.

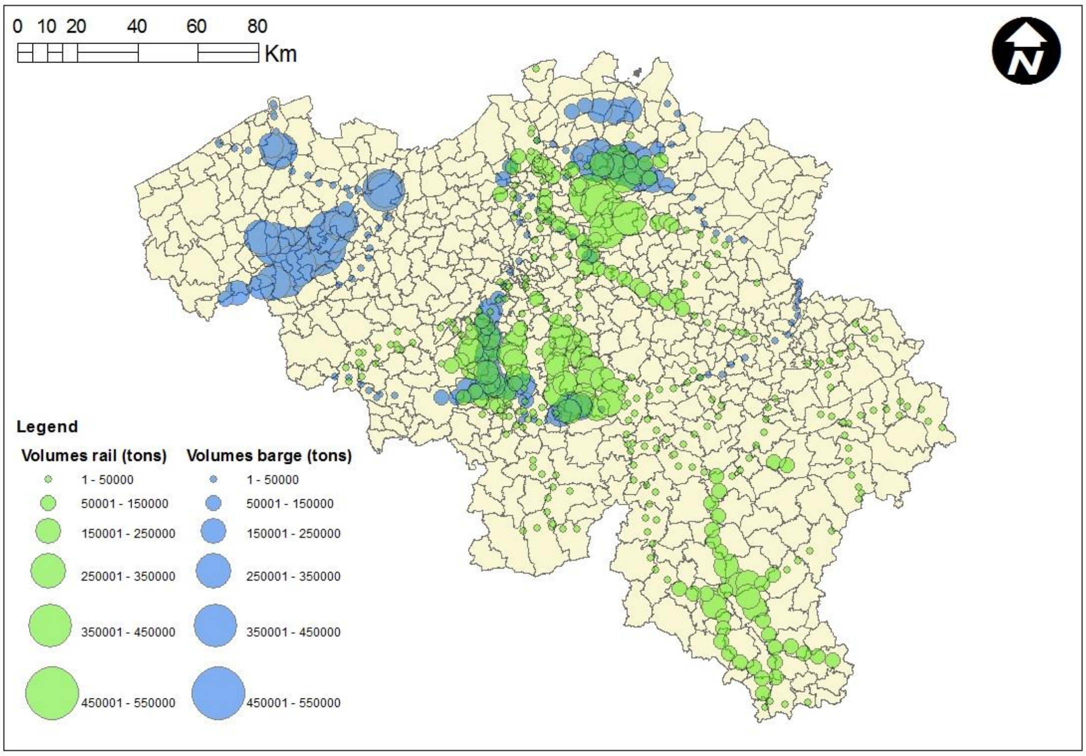


Figure 37 Possible terminal locations for intermodal transport to and from the Port of Antwerp, with an indication of potential transshipment volumes, based on analyses 5.3.1 with no VOT included. (Source: own composition)

The exact terminal locations can only be selected, by inclusion of their absolute location. Here, a first obstacle can be land availability and legal constraints. After, externalities should be evaluated for these possible locations, and also stakeholders can be included in decision making to create a wider support

6 CONCLUSION

It is clear from the analyses above that potential remains for intermodal transport within Flanders. But for intermodal policies to become successful, the behaviour of its (potential) users should be understood in detail. As modal choice doesn't only depend on transport price, transport time was added as a second variable to the LAMBIT-model. Despite the longer transport times of intermodal transport and the limited market area of intermodal terminals when transport time is included in modal choice, opportunities remain for the sector. It is clear that intermodal transport can benefit from congestion on the road network in terms of relative transport time and reliability. Especially when post-haulage can be performed during off-peak hours and over short distances, intermodal transport becomes more interesting. Additionally, terminals can also serve as depot for empty containers.

Regarding the setup of new terminal initiatives, possibilities remain. For transport to and from the Port of Antwerp different locations (and by extension regions) can possibly attract sufficient transhipment volumes to start up new terminals initiatives. The highest potential was allocated to a discrete location in Wielsbeke/Zulte. All the locations calculated in this study are theoretical locations, and therefore also local conditions (such as legal constraints, stakeholder opinions) should be accounted for in the final location decisions. Next to the locations mentioned is this study, also other locations could prove interesting, especially if international transport volumes are considered. The LAMBIT-model can be used to calculate optimal terminal locations starting from the optimization methodology described in this paper. Second, the model is also capable of evaluating discrete terminal locations (5.3.4). When additional information is available on international transport flows, also these data can be included in such an analysis. Also growth potential for the existing terminals remain, especially when the difference in transport price is very limited between unimodal road – and intermodal transport, the existing terminals can still enlarge their market area considerably. Therefore slight changes in the variables influencing transport price such as fuel taxes, internalization of external costs and intermodal subsidies can easily favour one mode over another.

Within the scope of the MOBILO research, additions to the LAMBIT-model will be made to enhance the credibility of the model and to provide new relevant recommendations. First, new modal choice variables will be added to the model next to transport price and transport time. Second, also the possible need for container transferia in Flanders will be investigated. Third, an external cost module will be included to account for several external effects of the different modal alternatives. Fourth, simulations for the introduction of eco-trucks on the Belgian road network will be performed. The focus will be on comparison of these new trucks with traditional unimodal road transport and intermodal barge/road – and rail/road transport. Outside the scope of the MOBILO research, a study was performed to analyse the competition and possible cooperation with intermodal terminals in the neighbouring countries. Additionally, the market areas of intermodal terminals connecting to the ports of Zeebrugge and Gent were investigated. The results of this study can be read in addition to this paper.

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8 APPENDIX

Table 12 Total volumes within each terminal's market area for different scenarios (in tons).

Terminal	Scenario 1			Scenario 2			Scenario 3			Scenario 4		
	Exc. VOT	Inc. VOT	Diff. (%)	Exc. VOT	Inc. VOT	Diff. (%)	Exc. VOT	Inc. VOT	Diff. (%)	Exc. VOT	Inc. VOT	Diff. (%)
Athus	110116	55002	-50	110116	55002	-50	110116	55002	-50	110116	161021	46
Avelgem	53766	0	-100	53766	0	-100	53766	0	-100	111291	28065	-75
Brussel	147218	55741	-62	147218	55741	-62	147218	65859	-55	147218	212805	45
Charleroi	52179	45740	-12	52179	49756	-5	52179	49756	-5	52179	270466	418
Deurne	2016	0	-100	2016	0	-100	2016	0	-100	2016	7123	253
Genk	291042	240118	-17	291042	240118	-17	291042	240118	-17	295090	288570	-2
Ghlin	92208	0	-100	92208	0	-100	92208	0	-100	92208	92208	0
Grimbergen	135817	52449	-61	135817	121427	-11	135817	121427	-11	135817	148270	9
Grobbendonk	4567	0	-100	4567	0	-100	4567	0	-100	4567	4567	0
Kortrijk	0	0	0	0	0	0	0	0	0	0	136856	/
Meerhout	245379	120429	-51	245379	143089	-42	245379	143089	-42	348360	245379	-30
Moeskroen	48439	0	-100	48439	0	-100	48439	0	-100	48439	48439	0
Mol	148205	97137	-34	148205	97137	-34	148205	97137	-34	148205	148205	0
Renory	248930	71112	-71	256004	71112	-72	256004	74571	-71	256004	209155	-18
Willebroek	323831	0	-100	323831	0	-100	323831	0	-100	323831	344541	6

Table 13 Total number of municipalities within each terminal's market area for different scenarios.

Terminal	Scenario 1			Scenario 2			Scenario 3			Scenario 4		
	Exc. VOT	Inc. VOT	Diff. (%)	Exc. VOT	Inc. VOT	Diff. (%)	Exc. VOT	Inc. VOT	Diff. (%)	Exc. VOT	Inc. VOT	Diff. (%)
Athus	4	3	-25	4	3	-25	4	3	-25	5	10	100
Avelgem	8	0	-100	8	0	-100	8	0	-100	10	5	-50
Brussel	34	6	-82	34	12	-65	35	15	-57	35	45	29
Charleroi	11	5	-55	11	7	-36	11	8	-27	11	35	218
Deurne	1	0	-100	1	0	-100	1	0	-100	1	4	300
Genk	26	11	-58	26	11	-58	26	11	-58	29	28	-3
Ghlin	13	1	-92	13	2	-85	13	2	-85	15	15	0
Grimbergen	6	2	-67	6	3	-50	6	3	-50	6	8	33
Grobbendonk	2	0	-100	2	0	-100	2	0	-100	2	2	0
Kortrijk	0	0	0	0	0	0	0	0	0	0	15	/
Meerhout	20	7	-65	20	9	-55	21	9	-57	23	23	0
Moeskroen	1	0	-100	1	0	-100	1	0	-100	1	2	100
Mol	7	5	-29	7	5	-29	7	5	-29	7	7	0
Renory	51	8	-84	53	9	-83	53	10	-81	56	42	-25
Willebroek	2	0	-100	2	0	-100	2	0	-100	2	5	150

Table 14 List of terminals (Table 2) and their decimal coordinates.

Number terminals	Location	Decimal coordinates
1	Wielsbeke/Zulte	50.913 – 3.426
2	Heist-op-den-Berg	51.046 – 4.760
3	Gent	51.092 – 3.726
4	*Mont-Saint-Guibert*	50.626 – 4.629
5	Brugge	51.196 – 3.227
6	Grobbendonk	51.181 – 4.743
7	Roeselare	50.945 – 3.150
8	*Tubize*	50.693 – 4.216
9	Turnhout	51.330 – 4.893
10	*Libramont*	49.927 – 5.359

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