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Are additional intermodal terminals still desirable? An analysis for Belgium

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Recently, the number of intermodal barge/road and rail/road terminals in Western Europe has boomed, facilitating a growth of more sustainable hinterland freight transport. But currently, the question is raised if additional intermodal terminals are still desirable, if they can operate in an economically viable way and where they should be located in the existing transport network. The goal of this research was to find optimal terminal locations from a terminal operators' perspective, maximizing the potential transhipment volumes in Belgium, without competing with the already established terminals. The developed methodology was tested for the Belgium infrastructure network, but can be applied to any network. Different locations are selected in a meta-analysis, but local conditions such as land availability and stakeholder approval should be investigated prior to setting up new terminal initiatives. In addition, the analysis shows that the selection of optimal terminal locations is highly influenced by the inclusion of transport time, next to market price, as a selection criterion.

Keywords: *intermodal terminal, intermodal transport, optimal location, value of time.*

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1. Introduction

Since decades, the European Commission aims to make the continental freight transport system more sustainable (e.g. European Commission, 2001, 2011). In their latest White Paper, the Commission sets the goal to reduce the transport-related greenhouse gas emissions by 60% by 2050 compared to 1990 levels. An important objective of the Commission therefore is to increase the share of intermodal rail and barge transport through an efficient use of co-modality. Regarding long distance transport, more than 50% of road freight should shift to more environmentally friendly modes such as rail and waterborne transport. But also on shorter distances intermodal transport can prove to be cheaper in certain cases, decreasing the external effects caused by freight transport (Macharis et al., 2012).

We consider intermodal transport as the combination of two transport modes in one transport chain, without a change of loading unit for the goods, and with the post- and/or the pre-haulage performed by truck (definition based on Macharis and Bontekoning, 2004). Transhipments take place in intermodal terminals and therefore the choice of their location is crucial for the organization of regional logistics. Hence, modal shift policies should aim for the creation of an efficient terminal network, as certain regions are still remote from the current inland terminals. A denser terminal network can reduce the use of road-only transport considerably, but an oversupply of terminals in a region can lead to severe competition and can decrease the profitability of an individual terminal (Visser et al., 2012). To provide policy tools to analyse the effect of an intermodal terminal on modal shift and to compare different possible terminal

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locations, simulation instruments are necessary. Therefore, the aim of this paper is to develop a methodology to find the most appropriate terminal locations for new intermodal terminals, within this Western European context. The proposed methodology is tested in a case study for Belgium, but is applicable to any network.

Solving the optimal location problem is particularly crucial for regions with low levels of intermodality (Vidović et al., 2011), but it's challenging to search for the optimal locations in an existing transport network where terminals are already (unevenly) spread across space, like in Belgium (Figure 2). This paper adds to the existing literature by, in light of the European Commission's sustainability goals, solving a hub covering problem in intermodal transport from a terminal operators' perspective by maximizing the intermodal market share with the addition of as few terminals as possible for a real-world transport network. In this paper the term intermodal terminal is used rather than intermodal hub, but when network typologies or location type problems are discussed, the broader term hub is still used. Second, we also evaluate rail and barge terminals simultaneously, while other scholars mainly focus on minimizing the total transport costs, by adding a single type of hubs to the network (Alumur and Kara, 2008). By linking the location decision to modal choice behaviour, we also account for the impact of evaluating an additional modal choice variable, next to market price, on the optimal terminal locations. To solve the optimal location problem, we developed a Geographic Information System (GIS)-based optimal location module. The regions with the highest potential for modal shift are identified and the locations with the highest potential transhipment volume are selected, while avoiding competition with existing terminals. Two separate optimization sub modules are discussed, to link the chosen methodology with possible implementation strategies.

This paper is organized as follows. Section 2 presents a concise literature overview of the intermodal terminal location problem. The proposed methodology, including two optimization sub modules, is described in section 3 and applied to the case of intermodal transport in Belgium. Section 4 elaborates on the results of the case study and discusses the use of the two sub modules. Section 5 gives concluding remarks.

2. Literature

In this section, the main factors influencing terminal location decisions are addressed. These variables are used as input for solving different terminal location problems. Subsequently, the existing literature on terminal location problems is discussed.

2.1 Factors influencing terminal location

The main strength of intermodality is the combination of the advantages of different transport modes. Rail and barge transport get more interesting for transporting over longer distances and for larger quantities, while truck transport is often preferred for short distances and small quantities (Vidović et al., 2011). In this perspective, the optimal location of intermodal terminals can be related to variables influencing the modal choice. If a new terminal is set up, a carrier can reconsider his available transport alternatives, evaluating his alternatives based on the importance he attains to different modal choice variables. If a new terminal can directly influence his modal choice criteria, he might opt for a modal shift. For intermodal transport to be competitive, certain threshold volumes should be transported to profit from economies of scale and critical distances should be covered. So the cost of an intermodal transport therefore depends on the traffic balance and the location of the terminals (Niérat, 1997). But, next to price, also quality-related variables, such as transport time and reliability can influence the choice between transport modes, although the importance attached to transport time in modal choice will vary strongly on the type of goods transported (Beuthe and Bouffioux, 2008).

A main problem, when searching for the optimal terminal location is the choice of which objectives to optimize. Notable examples are: minimizing the total transport cost on the network, maximizing a new terminal's profitability, maximizing the modal shift, minimizing transport costs on the links, minimizing drayage distances and costs etc. (Bontekoning et al., 2004). This is related to the fact that the location choice impacts different stakeholders, including investors, policy makers, infrastructure providers, terminal operators, users and the community (Sirikijpanichkul et al., 2007). The chosen perspective will also influence (the trade-offs between) the included variables. A transport operator might aim to minimize his total transport costs, but to keep his shipper satisfied he might also try to accommodate his price and quality requirements. Governments on the other hand often evaluate infrastructural projects in for instance a social cost benefit analysis. This paper takes the perspective of the terminal operators and therefore the aim of the proposed methodology is to maximize the volume transported by intermodal transport.

A first type of criteria for terminal location selection is economic: e.g. distance, time and the potential modal shift volume. But also variables related to external transport effects, can be included (e.g. Bergqvist and Tornberg, 2008). In this paper we will use the first type of constraints (transport distance, - time and - price and relative network location) to calculate the feasibility of intermodal connections and the transhipment volume and market area sizes to calculate the locations with the highest potential transhipment volume. Environmental constraints are only considered implicitly, assuming that large volumes, shifted from the road will decrease the total external effects of the transport system.

2.2 Optimal location problem

The interest in the optimal location problem increased due to its vital role in the field of freight transport (Campbell and O'Kelly, 2012). The aim is to find the best locations for hubs and to allocate the demand nodes to these hubs (Alumur et al., 2012). So the relative location of these demand nodes in respect to the possible hub locations is crucial. The topic of locating hubs is therefore very relevant in the field of intermodal network design (Caris et al., 2013). SteadieSeifi et al. (2013) review strategic planning problems related to investment decisions on the existing infrastructure. They find that most scholars focus on hub-and-spoke type of networks when studying hub location problems (see Woxenius (2007) for a typology of different network types). Many scholars approach the problem of locating hubs in a network as a (variant of the) hub median problem. The objective of the p-hub median problem is to minimize the total transportation cost within the transport network to serve the given transport flows and the number of hubs to allocate (p) (Alumur and Kara, 2008). A second type is the hub centre problem, where the maximum distance or cost between origin-destination pairs is minimized (SteadieSeifi et al., 2013). A third approach is the hub covering problem where the number of served spokes is maximized. Alumur and Kara (2008) find that this is an under-researched problem. Model formulations for this type of problems can be found in Wagner (2008). A variant of this problem is elaborated in this research, as the aim of the methodology suggested is to increase the share of intermodal transport by the addition of as few terminals as possible. By searching for the possible locations with the highest potential transhipment volume, the intermodal market share is maximized.

Different authors already tried to solve the terminal location problem in intermodal transport, often for specific cases: van Duin and van Ham (1998) use a three-stage modelling approach to identify optimal terminal locations. First, a linear programming model searches for the rough optimal locations, starting from the existing terminals. A second model searches for the exact location within the identified region, supported by a cost model. Arnold et al. (2004) use an integer programming model and heuristics to locate rail-road terminals by minimizing the total transportation cost. Racunica and Wynter (2005) introduced a non-linear concave cost function, to account for economies of scale in their development of an optimization model, to increase the share of intermodal rail transport in a hub-and-spoke network, while Rahimi et al. (2008) apply a location-allocation method to determine the optimal locations (and number) of dry ports in the same type of network. Limbourg and Jourquin (2009) propose an iterative procedure based on the single allocation *p*-hub median problem and the multimodal assignment problem to locate rail-road terminals in a European hub-and-spoke network. Their approach allows for the assignment of transport flows over different transport modes.

Bergqvist and Tornberg (2008) evaluate a set of inland intermodal terminal locations in Sweden, based on considerations set by the identified relevant actors. They use a GIS-supported approach to evaluate locations based on economic, environmental and quality considerations. Additionally they attempt to integrate external transport effects. Sirikijpanichkul et al. (2007) propose a multi-criteria decision analysis (MCDA) approach, taking into account different stakeholders: terminal owners or operators, infrastructure providers, users and the community. An agent-based modelling approach is suggested, to allow for negotiation between stakeholders. Macharis (2000, 2004) used a multi-actor multi-criteria analysis (MAMCA) approach to examine potential terminal sites in Belgium, by involving multiple stakeholders (users, operators, investors and the community).

Ishfaq and Sox (2011) criticize older models that are solely based on minimizing logistics costs. They extend the *p*-hub median problem for locating rail-road terminals, by using an incapacitated hub location model that includes service time constraints. Vidović et al. (2011) combine two approaches, namely a multiple assignment *p*-hub network location model with a simulation model. The *p*-hub model is extended to include terminal catchment areas, while the simulation modelling approach estimates economic, time and environmental performance. Meng and Wang (2011) propose a mathematical program for the design of an intermodal hub-and-spoke network. Their model can account for multiple stakeholders and multi-type containers and includes different service levels. Also Alumur et al. (2012) include different types of service levels and costs, while addressing a multimodal terminal location and terminal network design problem. Still the aim is to minimize the total cost, including set-up costs for the terminal network.

To conclude, SteadieSeifi et al. (2013) list different factors to compare different hub location problems in intermodal transport, including: transport modes considered, allocation type, capacitated terminals etc. The methodology proposed in this paper adds to this existing literature as it considers a hub covering type problem where the objective is the maximization of the total intermodal transhipment volume of the transport system instead of minimizing the total transport costs, while avoiding competition with the existing terminals. Besides, we evaluate the addition of rail/road and barge/road terminals simultaneously, instead of only rail/road terminals. We argue that a GIS-based approach is well suited for calculating the optimal terminal locations, even on a very detailed level. Finally, the impact of differences in the monetary valuation of travel time in modal choice is simulated to account for the impact on the optimal terminal location, as is described in the next section.

3. Methodology

This methodological section consists of two main parts. First, we describe the Location Analysis Model for Belgian Intermodal Terminals (LAMBIT), developed by Macharis (2000), which was used as the base model in this paper. We discuss its general framework, the different input data and the route calculation algorithm. Next, we describe how the LAMBIT-model was extended with the optimal location module. The module consists of a common body, while two sub modules were developed for the optimization itself.

3.1 LAMBIT

General framework

Our proposed optimal location module is an extension of the LAMBIT-model (Figure 1), developed to evaluate the location of intermodal terminals and to measure the effect of policy measures impacting the use of intermodal transport (Macharis, 2000). LAMBIT visualises the market area of intermodal terminals, consisting of the municipalities for which the market price of intermodal transport is lower than the one of road-only transport. Municipalities are allocated to the market area of a terminal if intermodal transport to its centroid is cheaper than the price of the road-only alternative. An All-Or-Nothing approach is used to highlight municipalities, meaning that a municipality is within a terminal's market area or not. In the LAMBIT-model, intermodal transport chains are limited to maritime-based chains using containers as loading units. The main haul is performed by rail or barge, while the post-haul is done by truck. LAMBIT requires three input types, described below.

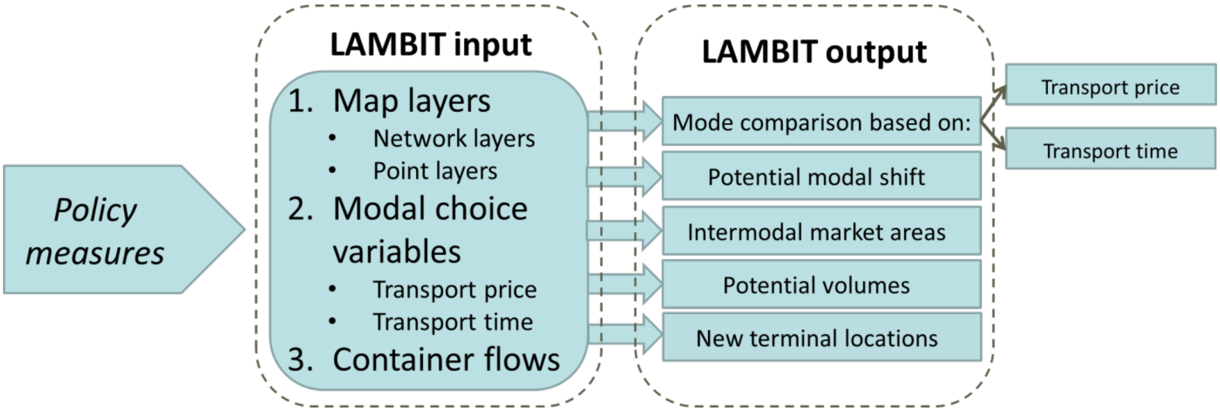

Figure 1. General LAMBIT framework (based on Pekin, 2010)

Data input

The LAMBIT-model consists of different geographically referenced map layers: network layers, representing the transport networks of a specific mode and point layers containing the intermodal terminals and the municipalities within Belgium. These municipalities serve as the origins or destinations of the transport chains, depending on the direction of the transport flows. Once the different networks are set up, modal choice variables are linked to the network elements. This means that to every node and link in these networks, the price and time to travel to the node or link are attached. To better simulate the modal choice behaviour, we use price data instead of cost data. The transport prices for each mode were calculated, based on real world market prices. Transport price data were obtained from transport operators and used as input for the price functions. Nevertheless, it is clear that using generalised price functions is a simplification of reality. In practice, transport prices will depend on several conditions: e.g. fuel prices, load factors, the rate of empty hauls, discounts etc. which are not constant in time and space. Although, by averaging out the different prices obtained, the prices used in the model give a good approximation of average market prices. The price functions include a fixed component for the transhipment(s) and variable components relative to the transport distances of each part of the transport chain. For more elaborate information on the price function used, see Pekin et al. (2012).

In an elaborate total price function, next to market price, also transport times are included. A first step towards the introduction of transport time in the LAMBIT-model was already performed by Pekin et al. (2012), but now also the effect of road congestion and differential speed limits are taken into account. Transport time is considered as the door-to-door transport time. This door-to-door transport time does not include other time-related components which might impact modal choice behaviour such as the frequency of service or the reliability of on-time delivery. These latter variables have to be monetized using a Value Of Frequency and a Value Of Reliability, and were not included in the total price function due to difficulties arising in their monetization and modelling and the lack of suitable data on the variance in transport time. In this case, transport time was modelled using a Value Of Time (VOT) factor. Accurate estimations of the VOT are needed for the assessment and comparison of different freight transport chains (Kreutzberger, 2008). This range of values can be related to the type of goods transported, the type of decision maker and transport attributes. The values used in this paper are derived from a study of Beuthe and Bouffioux (2008), based on stated preference experiments with Belgian shippers. The VOT we applied in this case is: 2.23 euro, per TEU, per hour. This VOT component is multiplied by the door-to-door transport time of each transport chain. For the calculation of the time attributes on the road network links, a dataset from the Traffic Centre Flanders (Verkeerscentrum Vlaanderen, 2010) was used, containing point speed data, collected from double detection loops for the highway network in Flanders. As these points do not provide a full coverage of the complete road network, these data had to be extrapolated to the rest of the highway network. For the rest of the road network, average congestion values were used, based on the relative speed reductions on the highway network. For this analysis we considered a scenario based on an average morning situation. For every segment, the average speed on working days between 7.00 and 8.00 AM is calculated. A time attribute was calculated for each road network link to calculate total transport times. For the calculation of the transport times of the intermodal main haul, average speed data were used for barge transport (11km/h) and for rail transport (25km/h) (ECMT, 2006). The total transport time of an intermodal transport chain was calculated as the sum of the transport time of the main haul by barge or rail and the transport time of the post-haulage by truck. The waiting- and transhipment time of the container at the inland terminal, was included in the average transport speed. In practice, container pick-up and delivery is usually scheduled to suit the clients' specific requirements, providing an improved reliability. This was not included in the transport time as such, assuming that the container can be picked up at arrival.

As a third type of input, the LAMBIT-model uses container flow data. To provide an accurate estimation of the current container transport within Belgium, data collected by the Directorate General Statistics and Economic Information (DGSEI, 2010) are used. These data are available on municipality level and therefore allow analyses on a very detailed scale level. International transport is not included in this analysis as no information is available on the origin/destination municipalities abroad. In the LAMBIT-model, only the freight flows to/from the Belgian sea ports from/to the different Belgian municipalities are considered and only for the terminals with regular services to/from the sea ports, the market areas are depicted (Figure 2). The main container flows in Belgium are between the Port of Antwerp and its Belgian hinterland and especially for barge services the focus is on transport to and from this port. Some rail terminals focus solely on international transport, without having services to/from the Port of Antwerp. An analysis of the optimal terminal location for continental transport could be performed in addition, when data are made available on a detailed level.

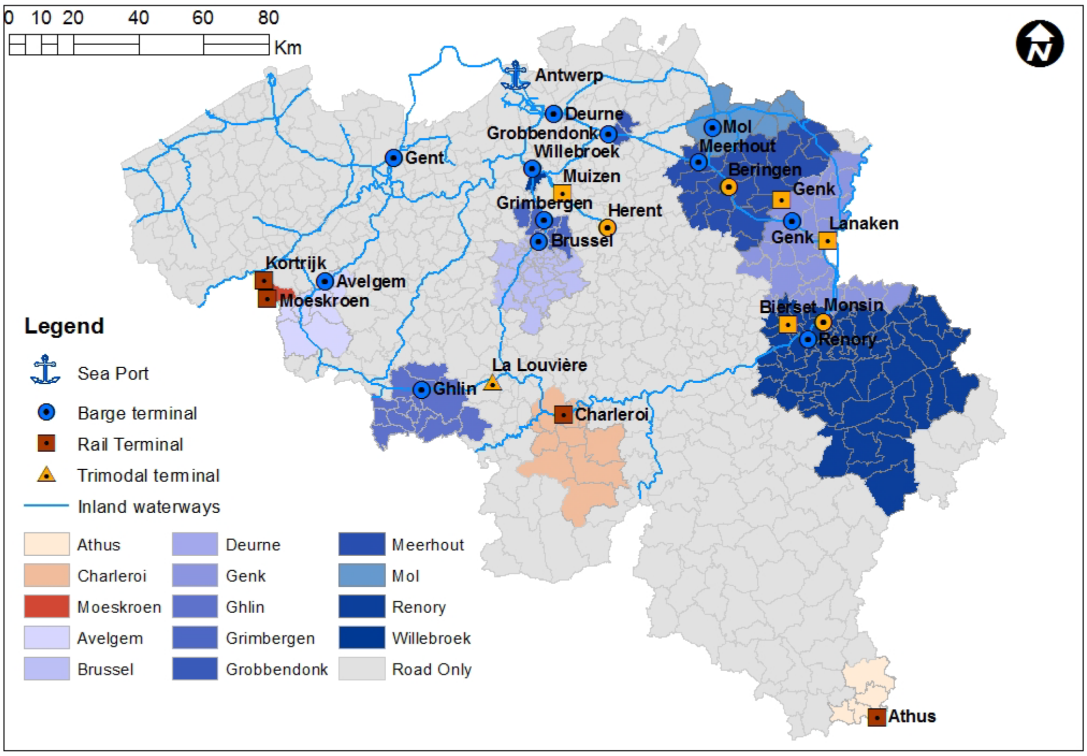

Figure 2. LAMBIT reference output, depicting the market areas of existing intermodal terminals for transport to/from Antwerp. The terminals depicted in orange do not have regular services to/from Antwerp.

Route calculation

To compare the available transport alternatives, the different possible route-mode combinations that are considered for the mode comparison are calculated using a shortest path algorithm (Dijkstra,1959). When computing these different real network routes, road hierarchy is taken into account, preferring highways. To account for transport price and transport time at the same time, the total price (transport price plus the monetized transport time) is minimized in route calculation. The total price function again is the same as presented in Pekin et al. (2012). When the three mode-route combinations with the lowest total price are selected and compared for every O/D combination, the cheapest option is retained.

3.2 Optimal terminal location module

In this section, we present the module to determine the optimal locations for new intermodal terminals (rail/road or barge/road) with a regional service function. For the selection of potential terminal locations, the LAMBIT-model was used and altered.

When potential locations for intermodal terminals are considered, a close link to the potential for modal shift within its potential market area is required (Trip and Bontekoning, 2002). The terminals should be located on places in the terminal network with a good accessibility and where a sufficient potential volume exists that can be transported cheaper by intermodal transport than by road-only transport. These access points should be located in order to minimize post-haulage distances and maximize potential transhipment volumes, as the modal choice is highly related to the relative position of potential users to these access points (Niérat, 1997). If the total ton-km of the complete transport network is minimized, the transhipment volumes on every additional terminal location will be lower on average. Too small volumes cannot optimally benefit from economies of scale, and therefore transport prices will increase. The LAMBIT-model assesses the potential market area of all possible terminal locations in parallel and evaluates the critical transhipment values ex ante. The potential intermodal transhipment volume of every possible location is maximized and estimated. Investors need good estimates of these transhipment potentials, as they will be a major factor influencing the investment decision (Bergqvist and Tornberg, 2008). A single allocation is used to allocate potential intermodal flows. This approach was tested on the Belgian transport network using the LAMBIT input data. The module developed to search for the optimal terminal location consists of 7 steps (Figure 3).

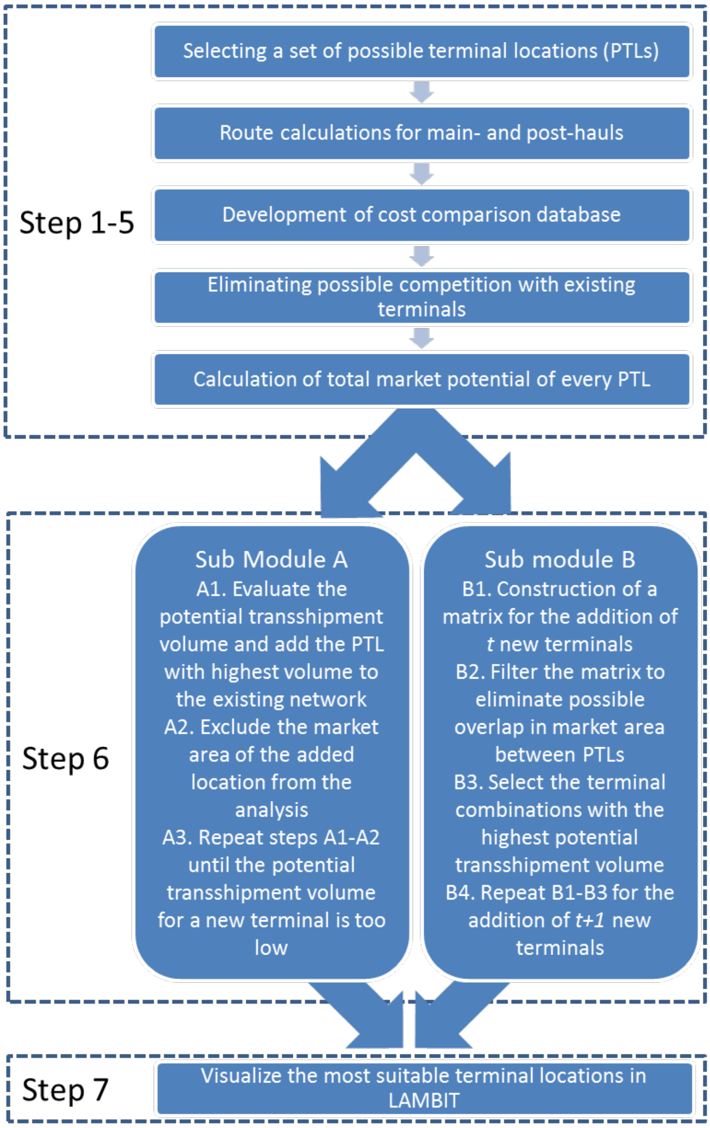

Figure 3. Optimal terminal location module framework.

Step 1 consists of selecting a set of possible terminal locations (PTLs), which will be evaluated and compared. Three types of sampling can be used for the choice of potential locations (Sirikijpanichkul and Ferreira, 2005). For continuous sampling, it is assumed that a terminal can be located anywhere in space, while network sampling only considers locations on (or next to) the network. The third methodology, discrete sampling, uses a list of pre-selected sites, for instance based on the availability or ownership of sites. For this study, a network sampling method is used (Figure 4). In first instance, we considered every location next to a navigable inland waterway or adjacent to a railway within Belgium. Both potential intermodal rail and – barge terminals were considered, as they compete for market area in Belgium, especially when subsidy schemes are involved (Macharis and Pekin, 2009). This leads to a continuous space of potential locations along network lines with an interval of 5 km between two consecutive point locations, leaving 1,066 potential locations to reduce computation time and keep the dataset manageable. These PTLs were not checked on land availability prior to the analysis. Nevertheless, the most appropriate PTLs should be evaluated on this criterion. In second instance, appropriate locations in the vicinity of the selected PTLs can be identified, before repeating the analysis for these newly selected PTLs.

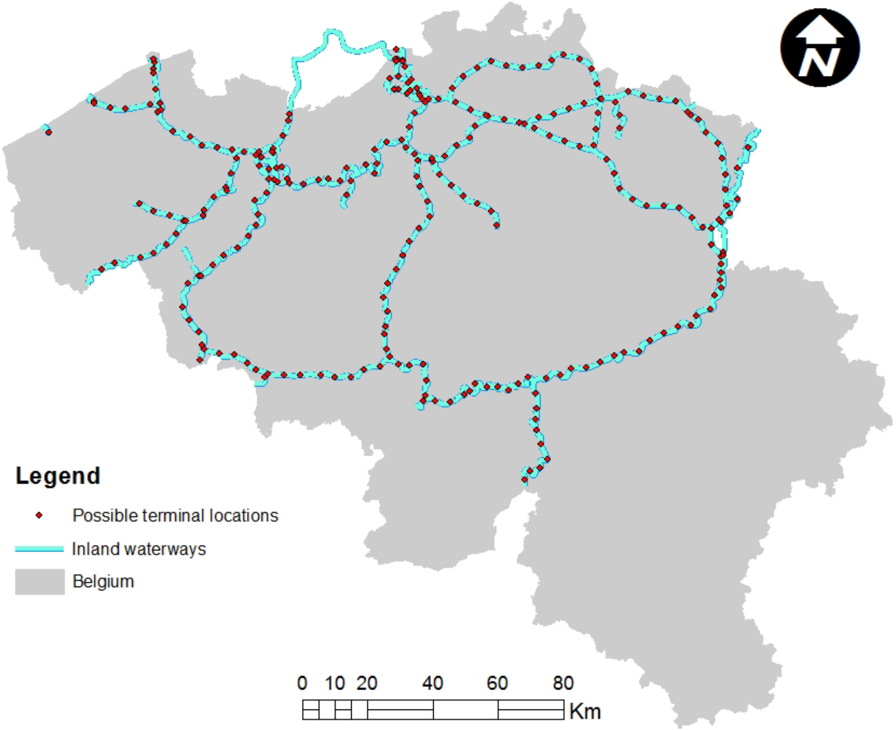

Figure 4. Possible terminal locations along inland waterways, using network sampling.

In a second step, route calculations are performed. LAMBIT already contains information on all route characteristics for transport from the Port of Antwerp to its Belgian hinterland, for all available modes and terminals. New routes are calculated for main hauls between the Port of Antwerp and all possible terminal locations (PTLs) and for post-haulage between the PTLs and all demand nodes (see section 3.1). Then, information is derived regarding total transport price, transport time and transport distance for the main- and the post-hauls.

In step 3, a database is set up to compare all modal alternatives (for all existing and potential terminal locations). This means that for every possible O/D combination, all transport alternatives are compared based on the price functions discussed above. This database serves as input for step 4. Step 4 is an optional step to exclude all container flows to the market area of existing terminals. This is done to reduce the risk on potential competition between new and existing terminals. This approach fits the aim of maximizing the total volume that can be transported cheaper by intermodal transport. In this way, the newly selected terminals can create their own market areas without 'stealing' it from existing terminals. This approach also allows efficiently filling up the existing 'white spots'. Another option would be to allow new terminals only to compete for a limited transhipment volume, so the existing terminals can retain a sufficient transhipment volume to operate profitably.

In step 5, the total market potential of every PTL is calculated. The DGSEI data (2010) were used as estimates for the volumes transported between Antwerp and all Belgian municipalities. By using this approach, one can easily identify the overlap of market areas of PTLs, which is very important in a later stage of this module. When the potential volumes of all municipalities in each potential market area are summed i.e. by means of single allocation, the total transhipment potential of a location is known. The DGSEI data provide an indication of the maximum potential, but the real potential for modal shift is only a proportion of this total potential, as not all goods can be transported intermodal. In analogy, it is also possible to calculate the terminal locations with the highest impact on decreasing the total transport prices of the infrastructure networks. The threshold volume required to start up a profitable intermodal terminal depends on the minimum transhipment volume and of the aptitude of the goods to be shifted to intermodal transport. 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. This potential is a function of i.a. the aptitude of the goods to be transhipped towards intermodal transport. For their case study in Italy, aptitude values range from 33.2-76.6%. When comparing the transhipment volumes of terminals to the total transport volumes within these terminals' market area that are transported by road and intermodal transport, one can also calculate aptitude values for existing Belgian terminals. Based on the available DGSEI data and the limited data on terminals' transhipment volumes, only the aptitude values for terminals with their complete market area within Belgium are calculated (e.g. Brussels). For two barge/road terminals the aptitude ranged between 55% and 60%, which corresponds well to the average data of Bottani and Rizzi (2007). Because of data unavailability on the transhipment volume of certain terminals and international transport volumes in border crossing market areas, a separate aptitude could not be derived for rail/road terminals. Therefore we used an average aptitude value of 57.5% for both types of terminals. In practice this value will vary, depending on the types of goods transported to/from specific regions. But the O/D data could not be correlated to the spatial distribution of the corresponding goods and/or aptitudes. Therefore ideally this aptitude value should be determined empirically. In literature, different estimates exist to estimate the transhipment volume needed to set up a new terminal (Sirikijpanichkul and Ferreira, 2005). These estimates will depend on different factors which influence the cost structure of a new terminal, such as the chosen type of network connections (e.g. hub-and-spoke versus point-to-point) (Konings et al., 2006), the type of barges that can be used, the transhipment cranes etc. The lower the estimated total cost, the lower the required transhipment volume becomes. Only the selected PTLs with minimal transhipment volumes of 10,000 TEU were included in the tables. A minimal transhipment volume of 10,000 TEU is often used as a rule of thumb to start up a new barge/road terminal in Belgium, but the actual required volume will thus depend on a more extensive list of criteria. Also for rail/road terminals, these minimum volumes will be case-specific, depending on calculations evaluating the cost structure of a new operational terminal on the basis of a set of parameters. Such cost calculations provide a more profound insight in the required minimal volumes of each PTL and should be performed prior to setting up a new terminal. Instead of using a threshold volume, the consideration of a new terminal could also be motivated solely in terms of the cost for locating an intermodal terminal and setting up connectivity (e.g. Ishfaq and Sox, 2011).

In step 6, a sub module has to be selected, to calculate the actual optimal terminal location(s). Two different sub modules were developed with two different optimization approaches. Sub module A introduces one terminal at a time, i.e. the one with the highest potential transhipment volume, while sub module B introduces several terminals at the same time, maximizing the total potential transhipments volume of the added terminals. These two discrete approaches allow separate introduction strategies in practice, which are elaborated in section 4.4. Sub module A uses a spreadsheet to calculate the optimal terminal locations, while sub module B is programmed in MATLAB software. Both sub modules are explained in the next sections. Finally, once the optimal locations are selected, they are visualized in step 7.

Sub module A

In step A1, the PTL with the highest potential transhipment volume is selected. This is the optimal location for a new terminal, in terms of transhipment volume, if only one terminal is added to the current intermodal terminal network. When this volume exceeds a threshold volume, this PTL will be selected. In step A2, this PTL is considered as an already established terminal. Therefore, the O/D couples with one location within its market area are excluded from the database. This is to avoid that if more terminals are added, they will compete with the newly added terminal. Step A3 provides an iteration loop for steps A1 and A2 until the potential transhipment volume of an added terminal is under a certain threshold value. This proposed sub module is very useful if only one terminal at a time is added to the current terminal network.

Sub Module B

In sub module B, a mathematical model is proposed to solve the optimal intermodal terminal location problem. This sub module can only provide a different outcome if more than one terminal is added to the existing network at once, as this sub module aims to maximize the total potential transhipment volume added. If one wants to add a number of terminals (*t*) to a network, the terminals selected in the previous iteration are not automatically added to the existing terminal network. The sub module is explained for *t*=2, but the same approach also solves the optimal location problem for higher *t* values. For *t*=2, the goal was to combine the potential transhipment volume of each terminal in iterative processes with the other terminals' volumes to find the highest total potential transhipment volume. This sub module consists of three algorithms, corresponding to steps B1-B3.

Step B1. *Construction of a matrix.* This algorithm calculates the sum of the volumes for every possible terminal combination for *t*=2.

Step B2. *Filter the matrix.* This algorithm is used to filter the previously conducted matrix. For *t*=2 there are two scenarios: (1) the intermodal market area with the potential volume of terminal A has no spatial overlap with the market area of the potential volume of terminal B and (2) both terminals have a certain spatial overlap of their market areas (Figure 5). In the latter case, the actual potential volumes of market areas of terminals A and B will be the sum of the potential volume of both market areas minus the potential volume of the overlapping area.

Step B3. *Search for the combinations with the highest total volume and their respective locations.* This step is built to find the optimal terminal locations. The algorithm finds the maximum volume, the optimal terminals and their real world locations. In a final step (*B4*) the optimal locations of *t+1* new terminals will be calculated.

The potential difference in outcome between both sub modules can be explained by an example (Figure 5). Given are three potential terminal locations (T_A, T_C and T_E) with partly overlapping market areas (with *b* and *d* representing the overlap in market areas with T_C). For *t*=1, both sub modules will select terminal location C, as it has the highest potential transhipment volume (i.e. 15,000 TEU). Before calculating *t*=2, sub module A will exclude the market area of terminal C. Terminal E will be selected as the next additional terminal, leaving a total potential transhipment volume of 27,000 TEU. Sub module B will select locations A and E for *t*=2, offering a potential transhipment volume of 28,000 TEU.

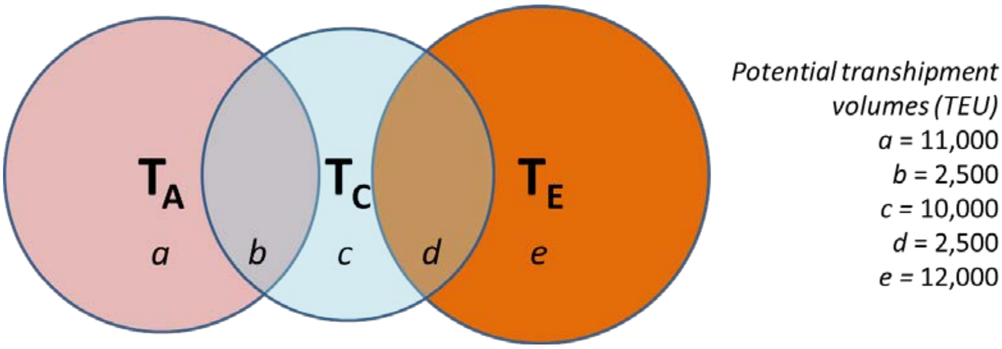

Figure 5. Overlapping market areas and the potential transhipment volumes of $T_A = a + b$, $T_C = b + c + d$ and $T_E = d + e$. (Note: the size of the market area does not correspond to the potential transhipment volume.)

4. Results and discussion

The methodology described above, is tested for Belgium. The context of this case study is described in the next paragraph. In first instance, the analysis was done using sub module A, disregarding the VOT in the total price function. This was done to calculate the optimal terminal location for low value goods with a low or negligible valuation of transport time. In second instance, the same was done using a relatively high VOT to account for goods, attaching more importance to transport time in the modal choice (e.g. perishable goods). Ishfaq and Sox (2011) argue that evaluating the network performance solely on minimizing logistics costs, may result in larger transit times, and therefore this VOT cannot be neglected. The analysis shows that different locations will be preferred depending on the importance of transport time in modal choice. Finally, the results of sub modules A and B are compared.

4.1 Case study

As an important enabler for the growth of intermodal transport in Belgium, many new intermodal terminals were set up during the last two decades, and still new terminal initiatives arise. The number of rail/road terminals has been stable for the last years, but the number of inland waterways/road terminals has increased considerably, leaving a dense terminal landscape, especially in the north-eastern part of the country (Figure 2). But due to shorter transport distances, market areas of intermodal terminals are in general smaller (in size) than their counterparts in other countries. Only the high volumes transported to and from the market areas can (partly) compensate for their limited geographic extent. However, the market areas of the current intermodal terminals do not cover the whole country, leaving 'white spots'. New terminals can eliminate white spots, but not all white spots possess enough potential volume to set up a new terminal. A denser terminal network can reduce the use of road-only transport considerably, but an oversupply of intermodal terminals could harm the sector when the capacity of terminals is underutilized. Therefore, the future inland terminal network has to be linked closely to the freight demand and supply within the region and the possible competition with existing terminals has to be accounted for.

4.2 Results for sub module A

If the methodology of sub module A is applied, while not accounting for the VOT, nine new terminals are selected within Belgium that can potentially attract transhipment volumes over 10,000 TEU. Except for two, all the terminals are barge/road terminals, as for intermodal barge transport it is easier to be competitive on shorter distances than for intermodal rail/road transport. Table 1 displays the market shares needed to achieve transhipment threshold values of 10,000 TEU per year. It is clear that only limited potential exists for medium-sized terminals within Flanders. In the case of Wielsbeke/Zulte, 22.2% of the total goods in the market area of this terminal should shift to intermodal barge/road transport to yearly tranship 10,000 TEU, this corresponds to 38.6% of the goods with an aptitude to shift to intermodal. Bearing in mind this pre-set aptitude of 57.5%, for the case of Turnhout, almost all goods with an aptitude to shift, need to shift to intermodal barge transport to obtain a total yearly transhipment volume of 10,000 TEU. Lower aptitude percentages would even decrease the number of suitable locations.

Table 1. Additional terminals and their estimated market potential (excl. VOT).

Number of added terminals	Location	Transhipment	Total potential volume in market area (ton)	Market share needed to tranship 10,000 TEU (%)	Market share needed to tranship 10,000 TEU (%)*
1	Wielsbeke/Zulte	Barge/Road	540,360	22.2	38.6
2	Heist-op-den-Berg	Rail/Road	439,154	27.3	47.5
3	Gent	Barge/Road	375,068	32.0	55.6
4	Mont-Saint-Guibert	Rail/Road	259,015	46.3	80.6
5	Brugge	Barge/Road	256,561	46.8	81.3
6	Grobbendonk	Barge/Road	242,492	49.5	86.1
7	Roeselare	Barge/Road	239,799	50.0	87.0
8	Tubize	Barge/Road	224,046	53.6	93.1
9	Turnhout	Barge/Road	218,380	55.0	95.6

* Given a 57.5% aptitude to switch to intermodal transport, meaning that on average only 57.5% of the total goods can be shifted to intermodal transport.

These potential locations and their respective market areas can also be visualised (Figure 6). The location with the highest potential volume is located on the border of the municipalities Wielsbeke and Zulte. It is clear that not all white spots can be covered by the introduction of nine new intermodal terminals in Belgium. For the resulting white spots, intermodal transport cannot be organized, catching a sufficient potential volume. This can be due to a weak competitive position compared to unimodal road transport and/or the lack of sufficient volumes in a region. It should be noted that for intermodal rail transport, subsidy schemes exist. However, their future is uncertain, so the elimination or the reduction of support for intermodal rail transport can impact the market area of rail terminals, this is also clear from a sensitivity analysis that was performed. This analysis also shows that small changes in transport prices can have a severe impact on the potential for intermodal transport. This indicates that slight changes in transport prices might have a great impact on the competitiveness of the different modes. Currently, rail services can only be profitable if they are integrated as terminals in a larger network, where the terminal is only a single stop in a longer trajectory. Also, some PTLs, located close to existing terminals were selected (e.g. Grobbendonk, Gent). In practice, these locations are less favourable, as small fluctuations in price levels can enlarge the market areas of the existing terminals, making new initiatives unnecessary, resulting in competition between both terminals. Therefore potential terminal locations 3 and 6 do not have real future prospects due to the all-or-nothing approach used.

A next observation is that no PTLs close to the border have been selected, except for Turnhout. This can be explained by the fact that transport volumes to/from neighbouring countries are not included in the analysis. The possibility of competition for market area in Belgium with foreign terminals was ascertained, but no conflicting market areas were found. Nevertheless, the market areas of the selected PTLs in the northwest of Belgium border on the ones of northern France.

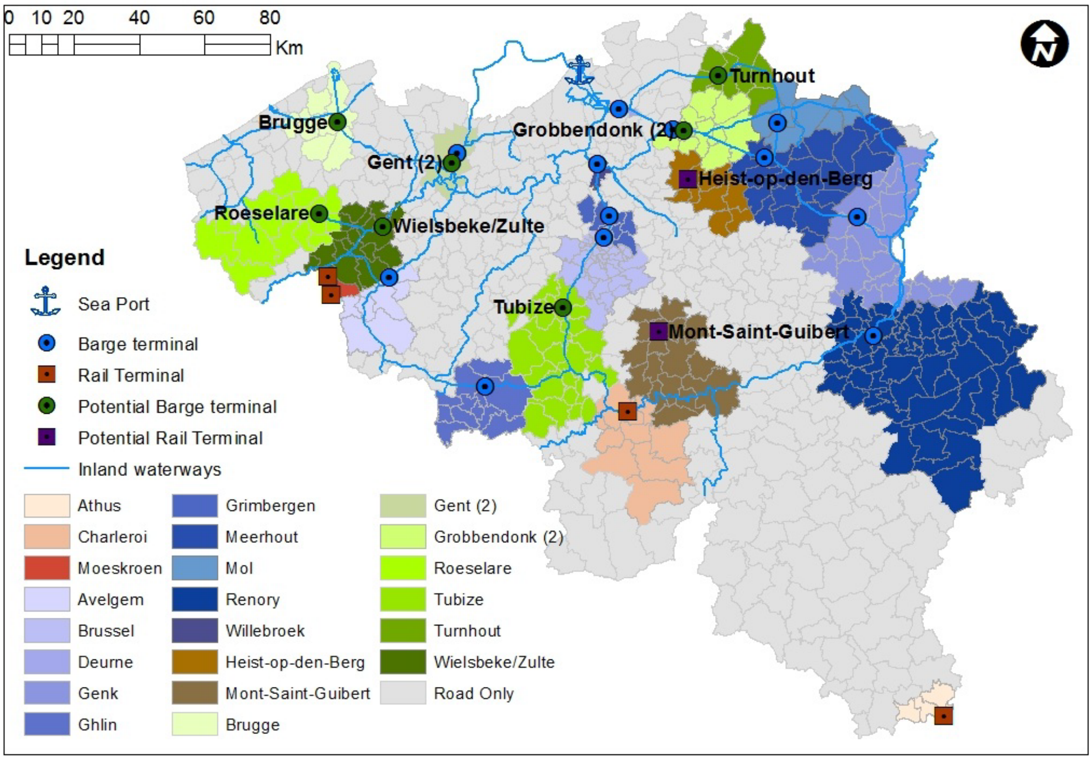

Figure 6. Nine potential terminal locations in Belgium with the highest potential transhipment volumes and their respective market areas, added to the existing terminal network.

4.3 Accounting for the value of time

A parallel analysis was performed using the methodology of sub module A, including the Value Of Time besides transport price in the route calculations and price comparisons (Table 2). It is clear that different PTLs have been selected in comparison to the previous analysis, when VOT was not accounted for, except for the terminal in Heist-op-den-Berg. Different explanations contribute to this new PTL selection. As transport time disadvantages slower modes, and mainly barge, only one barge/road terminal is selected. As road transport is the fastest mode, all PTLs' market areas will retain their size or shrink in comparison to the previous analysis. The number of rail/road terminals suited could also diminish when the support for intermodal rail transport declines. Only four terminals are able to catch sufficient transhipment volumes, considering the same 57.5% aptitude.

Table 2. Additional terminals and their estimated market potential (incl. VOT).

Number of added terminals	Location	Transhipment	Total potential volume in market area (ton)	Market share needed to tranship 10,000 TEU (%)	Market share needed to tranship 10,000 TEU (%)*
1	Heist-op-den-Berg	Rail/Road	352,692	34.0	59.2
2	Herentals	Barge/Road	326,840	36.7	63.9
3	Willebroek	Rail/Road	283,270	42.4	73.7
4	Gembloux	Rail/Road	232,716	51.6	89.7

* Given a 57.5% aptitude to switch to intermodal transport, meaning that on average only 57.5% of the total goods can be shifted to intermodal transport.

Again, the best suited terminal locations and their potential market areas are depicted (Figure 7). It is clear that these four terminals cannot fill the pre-identified white spots. The three identified most northern terminal locations are located close to the Port of Antwerp, filling white spots in the province of Antwerp. This seems counterintuitive, as intermodal transport gets more competitive as distances increase. But due to the importance attached to transport time in this case, longer trajectories lose interest. Some PTLs from the previous analysis seem to be replaced by PTLs close by. For instance the PTL in Herentals better retains its potential transhipment volume compared to the PTL in Grobbendonk. This is explained by the fact that Herentals is able to retain the part of its market area with a high transhipment potential, while Grobbendonk loses a part of its market area with a high potential transhipment volume. This explains why Grobbendonk scores better in the first analysis and Herentals in the second. It is therefore of importance if the biggest potential transhipment volumes are close to the PTL. Other locations which were selected in the previous analysis disappear as in these cases longer transport times make intermodal transport less competitive. The same ‘problem’ as in the previous analysis occurs, as PTLs are selected close to existing terminals.

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. The results are dramatic for most terminals, except (off course) for Heist-op-den-Berg and Grobbendonk. The rail terminals - as rail is a faster mode - are better able to retain a part of their original market areas. It is clear that optimal locations change thoroughly, depending on the importance attached to transport time in modal choice.

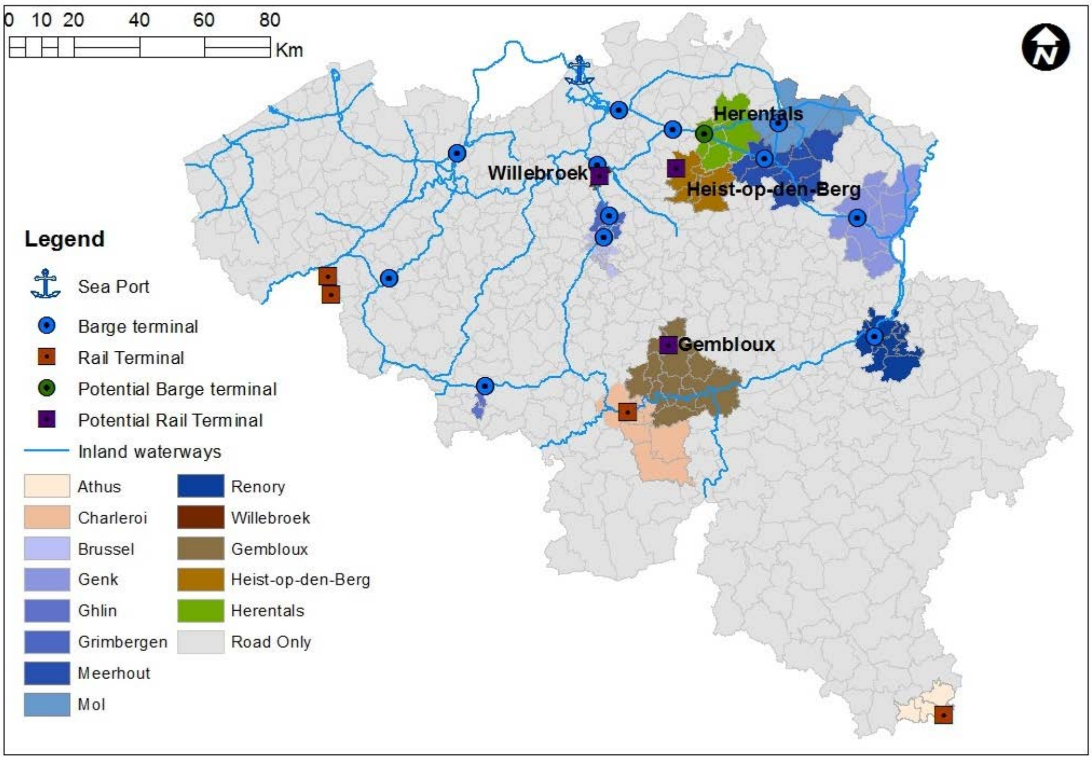

Figure 7. The four potential terminal locations in Belgium with the highest potential transhipment volumes when VOT is considered as a modal choice variable.

In addition we can also calculate the impact of these potential new terminals on the total transportation price of the whole system. This can be calculated by multiplying the price savings with the potential volume in a municipality, for all municipalities in the market area of a terminal. Here the results vary strongly between terminals. The location which scores best is in Jemeppe-sur-Sambre, close to the suggested location in Gembloux. The location derived from the previous analyses which scores best, is in Wielsbeke/Zulte, followed by the one in Gembloux. The other locations can only realize price savings lower than half of the savings that are possible from the set-up of a new terminal in Jemeppe-sur-Sambre.

4.4 Comparing sub modules A and B

When the analysis is performed, using sub module B, the same results occur, but due to computing constraints the optimal configuration was only calculated up to t=3 new terminal locations. For t=1 both sub modules logically have the same outcome as only one terminal is added to the existing network. For t=2, the total potential market area volume of all terminal combinations of two terminals was calculated. As for the previous sub module, the selected terminals were Wielsbeke/Zulte and Heist-op-den-Berg when VOT was ignored in modal choice. The first sub module is preferred when one terminal at a time is introduced, while the second is preferred when a number of terminals (t) are added to the network at the same time, although both sub modules provide the same results as only a small number of terminals are added to the current Belgian terminal network. The main reason for this is that the Belgian terminal landscape is already dense and that volumes are spread across the territory.

The results of both sub modules could also be applied in practice, depending on the implementation strategy. The first sub module serves a gradual introduction of new terminals, where a new terminal is implemented and evaluated before a second terminal is constructed. Therefore, this strategy is less risky as it provides high transhipment volumes for every terminal in the short run. The network coverage is less optimal in the long run and it will take a long time before a sufficient number of terminals are constructed. The second strategy aims to optimize the terminal landscape at once by adding a certain number of terminals at the same time. But, the risk is higher as several terminals are constructed at the same time, so a new terminal is not evaluated before a next one is built. The implementation time for this strategy is shorter and the intermodal coverage is higher in the short term. The second strategy can also be altered to implement one terminal at a time (less risky, optimal coverage only if all t terminals are added, and less optimal on the short run, but optimal in the long run). Therefore, sub module A is better suited if the terminal landscape is already dense while the second sub module is more appropriate if the landscape is not dense yet and many new terminals are desirable.

5. Conclusions

The increased use of intermodal container transport is a key objective towards a sustainable freight transport system. Although, the use of more sustainable transport chains largely depends on the location of the intermodal terminals. This study investigated the need for, and the optimal location of, new intermodal freight terminals in Belgium. The existing LAMBIT methodology was used as a framework for the analysis and a dedicated module was added. The aim was to find optimal terminal locations, maximizing the potential transhipment volumes, without competing with the already established terminals. Based on this meta-analysis, the locations in Belgium with the highest transhipment potential have been identified and the optimal location for one additional terminal is in Wielsbeke/Zulte. Nevertheless, this methodology can also be applied to other case studies to find the potential locations with the highest possible transhipment volumes, when the necessary data are available. The methodology was tested, using two different optimization sub modules. Both sub modules can be related to a specific implementation strategy, i.e. a faster or a more gradual addition of new terminals. The GIS-based approach used to calculate the optimal terminal location allows a comprehensive analysis and representation of the results.

It's clear from the analyses above that the variables used in the selection of the optimal terminal locations, will severely impact the location choice. When a higher importance is attached to transport time in modal choice, different locations prove more interesting and also faster transport modes are clearly preferred. Therefore this analysis not only shows the importance of the variables considered in decision making, but also the importance of the perspective that is central in decision making, influencing the methodology chosen. Different goods with different preferences will therefore necessitate different transhipment locations. Therefore, it's important to identify the real potential for modal shift within the container segment, as different products transported will have different preferences in modal choice. Also the spatial spread of goods with different aptitudes among space and the relation to modal choice preferences should be accounted for. Including more modal choice variables would increase the reliability of this analysis, but accurate estimations and the weighting and monetizing of these variables is needed. But cost estimations involve the risk of introducing a plurality of assumptions. To really comprise the behaviour of all actors, a multi-actor multi-criteria analysis (Macharis, 2004) could prove useful. In addition, also a multi-commodity approach, multi-allocation and the inclusion of capacitated terminals, where terminals have a maximum transhipment capacity, seem promising extensions for future research. Additionally, transport demand is not fixed in time and space, like most modal choice variables considered. Optimal locations therefore are not constant over time and the relation with the construction time and commissioning of a terminal are crucial. Finally, different locations can be selected in a meta-analysis, but local conditions such as land availability and stakeholder approval should be investigated prior to setting up new terminal initiatives.

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