Location Analysis Model for Belgian Intermodal Terminals: Importance of the value of time in the intermodal transport chain

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A B S T R A C T

Intermodal transport, the combination and integration of several transport modes, with the use of loading units, is in most cases more environmentally friendly than unimodal road transport for the carriage of goods. The LAMBIT-model (Location Analysis Model for Belgian Intermodal Terminals) has been developed to analyse the market areas of existing and potential intermodal terminals. In the LAMBIT model, barge/road and rail/road intermodal chains can be compared to unimodal road transport within Belgium. In this paper we show how to include, next to market prices, the value of time in the model and how to integrate other factors influencing the cost structure, such as the possibility to use the terminal as an empty depot and implications of the so-called backhaul problem and the distance of the post-haulage section. Different scenarios will be evaluated and compared to the reference scenario.

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1. Introduction

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 [1]. Intermodal transport may include various types of transport modes. In this paper we concentrate on the combination rail/road and waterways/road using containers as loading units. As noted by Bontekoning et al. [2], intermodal transport gets growing recognition as well from policy makers, practitioners and academics as an important alternative transport mode that can help tackle the congestion and environmental problems caused by our transport system. Decision support systems need to be developed in order to understand the intermodal transport system better and to assess the potential success of policies to stimulate it [3].

As several transport modes are included in an intermodal transport chain, intermodal transport costs involve a variety of transport activities. Fig. 1 represents the intermodal cost function. Taking a door-to-door intermodal transport chain, the function allows calculating total intermodal transport cost between an origin and a destination.

At the port, intermodal barge transport has larger handling costs compared to unimodal road transport. This is due to the cranes that are being used for the transhipment of containers on barges. The main haulage is carried by barge or train. The advantage of intermodal transport lies in the smaller variable costs during main haulage, as a result of the scale economies that are obtained by the large capacities that can be used. Scale economies, gained by the main haulage leg of an intermodal transport chain, can further be increased by the introduction of larger vessels or longer trains. As the variable cost of barge transport is lower compared to road-only transport, the longer distance covered by the intermodal leg will make intermodal barge transport more efficient than road-only transport. At the end of the chain, this advantage is partly compensated by the extra cost that has to be paid for the terminal handling. Terminal operations necessary to tranship the goods from one mode to another imply a vertical leap in the cost curve. Reliable terminal operations, will contribute to reduce costs that take place in transhipping a container from the main haulage to the drayage. In order to achieve reliable operations and optimise the terminal processes, ICT applications will be needed. Special attention for the storage and transport of empty containers is also required. The post-haulage in the intermodal transport chain is performed by road. The final section of the cost curve of intermodal freight transport thus runs parallel to unimodal road transport.

Once the total intermodal cost is calculated, it is possible to make comparisons with road-only transport, opening the way to a series of possible scenarios that can be assessed using an appropriate set of tools. For short distances unimodal road transport performs better compared to intermodal transport. Competitiveness of intermodal transport is defined by the concept...
of break-even distance. Once a certain distance is reached, the costs of road and intermodal transport are equal. This is called the break-even point. Above the break-even point, intermodal transport costs are lower than those of unimodal road transport.

In order to have a tool to analyse the location of intermodal terminals and the effect of different policy measures, a Location Analysis Model for Belgian Intermodal Terminals (LAMBIT) has been set up (see [4,5]). This GIS-based model shows the market area of the intermodal terminals on the basis of the market price of the transport cost of each alternative. The market area is constituted of the municipalities in which the market price for intermodal transport is lower than for road-only transport. As such, it takes an All-Or-Nothing (AoN) approach for highlighting a specific municipality. The aim of this paper is to show how in the LAMBIT model the value of time and some other factors, related to empty returns, can be integrated. In Section 2 we review the literature on value of time and suggest that a depot for empty containers and empty returns can be accommodated in the LAMBIT model, and what are the potential impacts on modal choice. We also show how the AoN approach can be relaxed. The model will be further explained in Section 3. In Section 4, the new approaches are visualised and analysed.

2. Value of time and other cost factors

Next to the market price, other modal choice criteria, such as reliability, time, frequency, safety and customer satisfaction play a role in the choice of the shippers or shipping companies for using intermodal or road transport. In this paper we focus on the important criterion of time. In order to integrate this variable in a generalised cost function, the value of time is used. This enables the integration of time within the cost function as a common denominator.

This section presents the literature on value of time to set the context in which this component can be integrated in the LAMBIT model. In the next section, other cost related factors are integrated, such as: the possibility to use the terminal as a depot for empty containers, implications of the backhaul problem and the distance of pre- and post-haulage.

2.1. Value of time

Studies which investigate the importance of variables that are affecting modal choice show that time-related factors are ranked highest in many studies (see [6]). This section aims to provide a literature overview to position value of time (VOT) for examining intermodal freight transportation.

Especially when considering the total logistics costs, transport time clearly plays a critical role in the evaluation of transport alternatives. Woxenius [7] argues that despite a rather wide use in the modelling of transport time, the different elements of time are rarely clearly defined in the transportation literature. Speed is not enough if the service must be ordered far in advance, if the departure or arrival time does not fit, or if the service is not executed within agreed time or is irregular. Woxenius [7] defines the following major time related components in transportation in order to investigate the VOT, as shown in Fig. 2:

- **Transport time**: the transit time and duration of transport which is proportional to distance. Factors that are affecting the transport time include geographical constraints or technical limitations of the transport network. From the perspective of intermodal transport these limitations include speed limits and drive bans for road transport, interoperability obstacles for railway transport and schedules of canal lock systems for barge transport.
- **Order time**: the preparation time required before departure of transport to reserve capacity, transport rate and an itinerary.
- **Timing**: the scheduled point of time for departure and arrival for shipments. Depending on the transport mode used, timing corresponds to a degree of flexibility. Here, road transport clearly has an advantage as it can adapt its schedule compared to other transport modes. For post-haulage operations with shorter distances, timing is a critical requirement for the customers and thus it is more important than speed.
- **Punctuality**: the ability to keep to the schedule, meaning transport or transit time reliability. Average deviation from scheduled arrival time can be used to calculate punctuality.
- **Frequency**: the number of departures during a certain time. Frequency is related to timing and punctuality. The size of transport means used, will define the degree of frequency. For example rail transport will have lower frequency compared to road transport.

An accurate estimation of VOT based on the above components is required in assessing transport alternatives both for passenger and freight transport. VOT can be interpreted as a problem not only in evaluating modal choice decisions but also in assessing the impact of transport policies or infrastructure investments and the valuation of environmental and societal impact studies. Various estimation methods can be used to compute the VOT. Feo-Valero et al. [8] give a literature overview on valuing freight transport time. Currently, there is no agreement amongst researchers over the size and the nature of the VOT, so different estimates can vary strongly. Feo-Valero et al. [8] divide the methods to quantify the VOT for freight transport into a factor cost approach and the modelling of demand. The former estimates the VOT, based on the decrease in cost by the reduction in shipment transit time. The latter method can also provide information on the valuation of different attributes. A further subdivision can be made between aggregated and disaggregated models (see [9]). The data for disaggregated models is obtained by using revealed preferences, obtaining information on current levels of service, and/or by stated preferences, on the basis of hypothetical situations.

The estimation of VOT for freight transportation can be characterised as an under-researched theme [10] compared to passenger transportation. de Jong [11] examines a number of European studies by comparing their results. His literature review is not focused on methodology as most previous studies were not based on theoretical frameworks [12]. It can be concluded that only a few studies have been done in Europe to estimate VOT in freight transport, of which only very few focus on intermodal transport. A common methodology has thus not yet been reached. Additionally, Feo-Valero et al. [8] identify some critical issues influencing the estimates on the VOT, such as the decision-maker, the heterogeneity of transport flows and transport attributes. Therefore attention should be paid when comparing and extrapolating average VOT.
estimates for freight transport in European countries, especially since values of quality attributes vary greatly amongst different studies.

The study of Beuthe and Bouffioux [13] estimates the value of transport qualitative factors for shippers, based on the analysis of a stated preference experiment. In their calculations the authors partitioned the data according to types of goods such as food products, minerals, materials and chemical and pharmaceutical products. They conclude that the shippers of different commodities also show different preference profiles for modal choice variables. The time attribute is defined as door-to-door transport time, including loading and unloading. Since their paper is based on experiments with Belgian transport shippers, we have decided to use the outcomes of this study for adapting the LAMBIT cost functions. As summarised in Table 1 there is a huge difference of the VOT for different transport modes. This is mostly related to the value of the goods themselves. High value goods are usually transported by road; whereas low value goods are transported by barge or possibly by rail. This explains the huge differences in the VOT-values as shown below. If we would use in LAMBIT the values of time as indicated in this table and by transport mode, this would not give a correct image of the VOT of container transport as different types of goods can be stuffed in containers. That is why we prefer to use the highest value as an estimation for the VOT of high value goods (stuffed in containers) and the lowest for low value goods (again stuffed in containers). Note that the range between the lowest and the highest value in this table is extremely wide in relative terms (a quotient of 1500). The lowest VOT in the table (0.002 € per km per TEU) is so low that it will only slightly change the outcome of the market area of intermodal terminals.

The above VOT values are the outcome of the VOT, as calculated by Beuthe and Bouffioux [13], divided by the speed of the specific mode and converted to TEU. For road transport, an average speed of 60 km per hour is used. For inland waterways and rail, we adopted speeds of 11 and 25 km per hour respectively (ECMT [14] and Janic [15]). Multiplying the VOT values with the speed and the distance will give the time cost for a specific trajectory and this for low, medium and high value goods.

2.2. Refinements in the model

In this subsection we discuss some refinements of the model related to the importance of empty containers and the role of pre- and post-haulage in the multimodal chain. Empty containers play a large role in overall container flows. Shintania et al. [16] estimate the share of empty containers to be 21% around the world and 40% if one only considers land transport. This is related to two imbalances in container traffic. First, since some countries have a higher share of import whilst other countries are mainly exporting, a natural imbalance arises. Second, due to inefficient logistic processes and the lack of coordination between shippers, an additional imbalance exists. We discuss the implications of empty containers by means of two extreme cases. One is that container flows are essentially balanced, but due to temporal fluctuations there is not always a full container at exactly the same place for a return trip when a container arrives. In that case some effort may have to be made before a full container is found for the return trip. The other extreme case is that the flows are structurally imbalanced: for a considerable part of the full containers arriving from the port of Antwerp there are just empty containers for the return trip.

First, consider the case that the flows are structurally balanced. If the shipper can provide a full return trip, the advantage of the empty container terminal disappears. But, due to imbalances in temporal demand and inefficiency in timing, shipping companies providing road transport between port or terminal and the client, cannot always return a full container from the same or a nearby company. Often, after unloading, empty containers are returned to the port terminal, waiting to be retrieved by another shipper. These two empty runs could be limited to one empty run between the two companies. Companies might collect these containers directly at other firms, who have empty containers left, but this does not seem to happen in practice. In that case intermodal terminals may serve as a temporary depot for empty containers. The terminal can operate as a local node for the demand of empty containers in the

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Value of time in € per km per TEU for transport modes.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Road</td>
</tr>
<tr>
<td>High-value goods</td>
<td>0.576</td>
</tr>
<tr>
<td>Middle-value goods</td>
<td>0.034</td>
</tr>
<tr>
<td>Low-value goods</td>
<td>0.002</td>
</tr>
</tbody>
</table>

Source: Own setup based on [13].
region. Shipping companies are leaving the empty containers on the terminal, which saves a return trip to the sea terminal. This cost decrease should also be incorporated in the cost function. As shown in Fig. 3, this leads to the elimination of a return journey by barge or rail, which can make intermodal transport more competitive as with road transport this return trip is always necessary. The empty containers can later be refilled for the export of goods within the same area. The latter holds true when the flows between origin and destination are reasonably balanced. In case of structurally unbalanced relationships between origin and destination, the empty container has to be returned anyhow.

Second, following the introduction of the value of time in LAMBIT, it is interesting to introduce another issue: the backhaul problem, which is related to the empty returns. The backhaul problem arises when demand on the transport market is uneven between two or more connected regions. The transport in one direction exceeds the demand in the opposite direction. This situation occurs in competitive markets, on local, interregional and international level for freight and for passenger transport [17]. The backhaul problem poses difficulties to transport firms, since the capacity used in one direction is not optimally used in the opposite one. Clearly, the backhaul problem leads to low load factors and empty travel. Jonkeren et al. [17] explicitly link transport prices to the direction of transport. The backhaul problem has consequences for the prices on the transport market. In a competitive market, the transport price in the busy direction is higher than in the opposite direction. Consider for example the unbalanced trade flow between China and the USA. The freight price listed for a 1 TEU container filled with plastic bags in the busy direction (Shanghai to San Francisco) is about USD 2050, whilst the backhaul price is only about USD 1100, a reduction of almost 50%. In the extreme case the full costs of moving an empty container in the opposite direction would be covered by the price charged to the firm that pays for the transport in the busy direction. In reality it is not as extreme as this, since loading and unloading costs also have to be considered, but the price difference can indeed be as high as the 50% mentioned above. As such, the backhaul problem applies to both unimodal and multimodal transport. But it may have a differentiated impact on modal choice since it affects the balance between the transport cost and the value of transport time. As will be shown in Section 4 the presence of the backhaul problem, leading to empty containers, reinforces the competitive position of multimodal transport compared with unimodal transport by truck.

Third, the distance of the pre- and post-haulage by road has an important impact on the total cost. The costs of pre- and end haulage determine an important share of the total costs [18]. The break-even distance is largely affected by this pre- and post-haulage (PPH). When the distance decreases, PPH becomes more crucial [19]. In the present version of LAMBIT we use an All-Or-Nothing approach: a municipality is either cheaper reachable by road or by a specific intermodal terminal. In order to show more advanced visualisations of the market area, a price ratio analysis has been performed. For each municipality, the ratio of intermodal transport market price and unimodal road transport market price is calculated. A ratio analysis can be used to visualise the market area of each terminal with gradual shades and by doing so, the cost of pre- and end haulage is also visualised.

3. LAMBIT: Location Analysis Model for Belgian Intermodal Terminals

Our GIS-based location analysis model is built upon two pillars: setting up the network and including the cost function [4]. The network consists of four different layers: the road network, the inland waterways network, the rail network and the (post)final-haulage network (see Fig. 4). The total length of the road network in 2005 was 118,414.6 km of which 1747.4 km were motorway. In 2010 the rail network measured 3582 km in total [20], whilst the commercially navigable inland waterway network is 1532 km long [21]. LAMBIT encompasses 9 barge/road and 4 rail/road terminals. The geographic locations of the intermodal terminals and the municipality centres are defined and connected to the network layers by their corresponding nodes.

As a second step, the transport prices are calculated based on the real market price structures for each transport mode. The variable costs are depending on the distance travelled and the fixed costs are related to the nodes in the network.

The total cost of intermodal transport is composed of the transhipment cost in the port of Antwerp to a barge or a wagon, the cost of the intermodal main haul (by barge or by rail), the transhipment cost in the inland terminal to a truck and the cost of post-haulage by truck. The total intermodal transport cost is obtained by adding all of these mentioned fixed and variable costs.

Access to reliable data is essential in order to achieve accurate results from the location analysis model. In this respect, the network for Belgium was obtained from the maps of ESRI and TELE ATLAS. The transport prices for inland waterways and unimodal road transport are calculated as averages from the market prices, which were obtained from transport companies, inland barge terminals and rail operators.

Only the freight flows of the port of Antwerp to the different municipalities are considered in the model, as this port is connected to all the terminals with daily shuttles. A shortest path algorithm allows calculating the paths that should be considered for further comparisons amongst modes. The costs for unimodal road, inland waterways/road and rail/road transport are compared in each municipality and the cheapest option is selected. The market area of each inland terminal is then highlighted in the model. As a further step, the potential of the inland terminals can be derived by aggregating the number of containers that are currently transported to/from the municipalities by road (based on data of the National Institute of Statistics).

The model enables to assess different policy options. First of all, the current terminal landscape is obtained, which can be used as a reference point in the policy analysis. As a second step, new terminals can be added into the network to study their effects on the market area of the existing terminals. Furthermore, different policy options can be simulated such as: subsidy schemes, oil price
increases, and internalisation of external costs scenarios (see [22]).
The LAMBIT approach can easily be applied to other countries as
we did already for Turkey (see [23]).

4. Implementation in LAMBIT and results

As mentioned in the previous section, LAMBIT can be used as a
tool to evaluate intermodal transport policies. In Fig. 5 the
reference output of the LAMBIT model is depicted. These results are
based on the model version where only the direct costs of transport
are considered, whereas the value of time is ignored. Municipalities
are highlighted, when intermodal transport provides a more
attractive transport price compared to unimodal road transport
based on the current market prices. The green market areas belong
to barge terminals, the yellow-red ones are those of a rail/road
terminal. The terminals which are located far from the port of
Antwerp, benefit more from the lower variable costs of intermodal
transport compared to unimodal road transport and they have
larger market areas. This is explained by the intermodal cost
structure (see Section 1). The longer the distance travelled, the
greater the extent to which the lower variable costs of intermodal
transport can compensate for the extra transhipment costs at the
terminals. This figure will serve as a reference case in order to
compare it to the output of the refinements in the LAMBIT model.
The new version differs from the reference version in two respects:
first the value of time is integrated in LAMBIT, including the two
model refinements, second, a ratio-analysis is performed to
visualise the market area.

The first step is to develop a new cost function for the LAMBIT
model, which currently uses market prices. The following formula
contains the calculation of total costs for intermodal transport:

$$TC = P_M + P_T$$  \hspace{1cm} (1)

$$P_M = T_i + p_m(d)d_m + T_m + P_p(d_i - d)$$  \hspace{1cm} (2)

$$P_T = (d)d_iV_T$$  \hspace{1cm} (3)

where $P_M$ is the price of intermodal transport; $P_T$ the value of time.
This is in function (per kilometre) of a distance $d$; $T_i$ the price of
container transhipment in the seaport; $p_m(d)$ the price of main
hauling by barge or rail transport. This is in function (per kilometre)
of a distance $d$; $T_m$ the price of container transhipment in the
inland terminal; $P_p$ the fixed costs of post-haulage by road
transport; $P_p$ the price per kilometre for post-haulage by road
transport; $d_i$ the distance between the seaport and an inland
terminal; $d_m$ the distance by main haulage; $d_i - d$ the distance of post-haulage by road
transport; $V_T$ the average speed for each transport mode; and $V_T$
is the value of time for containers.
As discussed above we use the data of Beuth and Bouffioux [13] for the VOT. For an estimation on speed, an ECMT report is consulted for the average speed of rail and inland navigation. For road transport, data from Janic [15] is used. Average speed makes a distinction for short distance road transport (post-haulage) which is slower compared to longer distance main haulage (see Table 2).

If one considers the normal cost function and adds the information on VOT together with average speed, one can see how the time factor impacts the market area of the terminals. With a scenario on low value of time only a very slight decrease of the market area of intermodal terminals is observed. Compared to Fig. 5, market area shrinks only by 5 municipalities, which can be expected as the speed of road transport is higher than the ones of inland navigation and rail. Because of the low impact of the VOT for low value goods, the image does not change drastically. With a high value of time, intermodal transport cannot compete with unimodal road transport thus no market area for the inland terminals can be shown. Also a medium value of time as shown in Fig. 6 results in only a small market area for the inland terminals (80 municipalities).

In order to investigate the middle- and high value of time market segments further, we developed two additional scenarios related to the phenomenon of empty returns.

In the first scenario, the introduction of the backhaul problem, the cost function of LAMBIT is adapted. LAMBIT can calculate transport costs for round trips by splitting these costs into two separate ones: the one-way and the return trip costs. If one considers the intermodal transport of a container from a port to its hinterland, the total cost can be calculated using Eq. (1). For the transport in the opposite direction, the same total cost can be achieved. The total cost of the round-trip transport adds two times the transport price one way and two times the value of time one way:

\[
TC = (2P_{M \text{ ow}}) + (2P_{T \text{ ow}})
\]  

(4)

where \(P_{M \text{ ow}}\) is the price of intermodal transport for one way; and \(P_{T \text{ ow}}\) is the value of time for one way.

But the latter only holds true if the return trip is not empty. If the return trip is empty, the generalised cost of the return trip does no longer include the value of time. The generalised costs for the round trip would be equal to:

\[
TC = (2P_{M \text{ ow}}) + (1P_{T \text{ ow}})
\]

(5)

But, since we consider a competitive market, the costs of the round-trip will be passed to the outbound trip. This results in the fact that the transport cost in the dominant direction is much higher than the transport cost of the return trip. Jonkeren et al. [17] researched this and empirical data proof that the difference in prices between outbound and inbound transport are smaller than the difference in the value of time for a one way trip. The cost of the return trip is not fully transferred to the outbound trip, but it is only partially. If one considers this amount to be 50% of this cost, this results in Eq. (6). This would be the total cost shippers have to pay for the transport of their goods from Antwerp to a municipality in the Belgian hinterland.

\[
TC = (1.5P_{M \text{ ow}}) + (P_{T \text{ ow}})
\]

(6)

Fig. 7 shows the market area for all intermodal terminals, using Eq. (6), for the backhaul problem. The figure shows that some terminals profit from this new approach, resulting in 141 out of 589 municipalities which can be served favourably by intermodal transport. If all containers would be loaded in both directions, the component of the value of time is equal to the component of the direct price (Eqs. (1) and (4)). In this case road transport gets more interesting, since it is faster. But if containers are empty, the value of time decreases in importance in the total cost (Eq. (6)). In this case slower transport becomes more attractive. More empty containers give more chances for intermodal transport. The backhaul problem can clearly influence the modal choice. The weight of the transport price increases in comparison to the value of time for empty trips. The more empty returns to the port, the higher will be the share of the direct price in the total cost, giving opportunities for slower modes.

Fig. 8 shows the market areas of the terminals, when these would be used as a depot of empty containers. The figure indicates

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*The figure of 50% is based on the maximum difference observed in Jonkeren et al. (2011). It is consistent with the anecdotal evidence reported in Section 2.*

### Table 2

<table>
<thead>
<tr>
<th>Transport mode</th>
<th>Average speed (km/h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unimodal road</td>
<td>60</td>
</tr>
<tr>
<td>Post haulage</td>
<td>35</td>
</tr>
<tr>
<td>Rail</td>
<td>25</td>
</tr>
<tr>
<td>Inland navigation</td>
<td>11</td>
</tr>
</tbody>
</table>

Source: Own calculations based on Janic [15] and ECMT [14].
Fig. 8. LAMBIT market areas of intermodal terminals taking into account the VOT (high value of goods) and a decrease in cost due to the empty depot function of the terminal.

that intermodal terminals lose market area to road transport, in comparison to the reference output, even if we take this cost reduction into account. The main reason is that this simulation is made for high-value goods, making transport by road more interesting compared to intermodal transport. The market areas shown in Fig. 8 are the result of the empty container function, since the output for the high-value goods solely, showed no market area for the terminals. It is striking that market areas of all rail terminals grow strongly, whilst market areas of barge terminals are small or non-existent. In total 175 municipalities would be in a favourable condition to let intermodal transport be used by the companies located in that municipality.

Finally, one can calculate price ratios for each municipality in order to visualise the degree to which intermodal transport is more favourable than road transport. The ratio divides the intermodal transport market price by the unimodal road transport market price. Working with ratios can make it possible to visualise the market area of each terminal with gradual shades. Fig. 9 depicts the market area for each terminal based on the cost ratio. Here, an illustrative scenario is taken as an example to perform the ratio analysis. The ratio analysis can easily be applied to other scenarios that are performed in this paper. A ratio lower than 1 means that intermodal transport is more attractive. Instead of the All-Or-Nothing approach, we give here an indication in how far intermodal transport is more attractive. Closer to the location of each terminal, intermodal transport becomes relatively cheaper with a lower ratio compared to unimodal road transport. In other words, the further away from the terminals, the more the cost ratio increases.

The ratio analysis introduces a more realistic market area for the intermodal transport. This analysis demonstrates the impact of post-haulage within the intermodal transport chain.

5. Conclusions

In this paper, the location analysis model for intermodal terminals (LAMBIT) has been improved by integrating next to the market price, the value of time. Taking this value of time into account shows that the types of goods in the containers have an important impact. If these values are high, intermodal transport has no market area. If however we have lower values of time for lower value goods or we take into account the possibility of the empty depot function of the intermodal terminals or the empty returns, we get a clear view of the current situation of intermodal transport in Belgium. Also a further improvement was realised on the visualisation of the market area for intermodal terminals. A refinement of the competitiveness of each municipality can now be better visualised. These adaptations enable to make LAMBIT a more realistic model on which further policy measures are possible to be evaluated. The analysis of the cost function as discussed in this paper, also allows gaining more insight in the importance of each cost element in the total cost of intermodal transport.

Further research will be dedicated to integrating other quality indicators affecting modal choice, such as frequency, reliability, flexibility, and loss of goods. Another variable which will be integrated is congestion. As no monetary values exist for most of the modal choice variables a multi-criteria or multi-objective function approach will be followed. Such an approach would allow to weight the different modal choice variables and to come to a general assessment of a proposed trajectory on the different modal choice variables. As this weighting cannot be done anymore on the basis of a monetary weighting as introduced in this paper, the weights will have to be derived from a discrete choice experiment or another type of stated preference elicitation.

References


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