LOCATION ANALYSIS MODEL FOR PALLETIZED GOODS ON THE INLAND WATERWAYS

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ABSTRACT

A large number of the truck movements in Belgium are created by the distribution of palletized goods, causing associated negative externalities on the society, environment and economy. An innovative solution to overcome these problems, is to bundle the transport over the inland waterways and organize the last mile distribution via a limited number of water-bound hubs. By doing so, one can reduce the transport distances by truck to an absolute minimum. In order to analyse the feasibility of this concept, a location analysis model was created, which identifies the most optimal locations of water-bound hubs. The introduction of a cost structure in the model enables a calculation of the financial cost of the modal shift and the potential turnover of each hub, as well as the reduction in CO_2-emissions. The analysis is performed for Belgium. Transport data on palletized building materials, collected within the 'Build over Water' project, served as the basis. Two concepts are used to calculate the optimal number of Regional Water-bound Distribution Centres and their most optimal location, resulting in 9 and 27 hubs. Through the implementation of these hubs, respectively 26% and 38% of the captured transport flows can be shifted to the inland waterways at a profitable cost today. It can be expected that these percentages will further increase in the future, as road transport will become more expensive and barge transport cheaper.

Keywords: Intermodal transport, most optimal location analysis, palletized building materials

INTRODUCTION

The demand for mobility and transport increased massively in the last decennia, and predictions indicate a further growth for the coming decennia. Most movements are using the road network (European Commission, 2011). Consequently, one notes that in many places, the demand for mobility and transport exceeds the road capacity. This results in structural congestion problems. Besides congestion, transport by truck causes also other negative externalities, like pollution and accidents. The (external) costs created by these externalities are significantly higher for road transport than for the alternative transport modes, such as barge and rail (Kreutzberger et.al., 2006).

Along the jammed roads, several Western European countries possess a wide and underutilised network of inland waterways. In former times, large numbers of merchant transport were executed via these waterways. All kinds of goods were transported by barges to the inner centre of Western European cities. But in later ages, this practice disappeared bit by bit, and canals were dumped in many cities.
However with the containerisation (starting in maritime transport in the seventies), the inland waterways were rediscovered in the 90's for container transport. More and more shippers, logistics service providers and governments are rediscovering the inland waterways. Traditionally one can see that big bulk is – as first wave - transported by barges. Recently, expanding volumes of containers found their way to the inland waterways, thereby forming the second wave (VUB & COMiSOL, 2006).
The challenge now is to find other, less evident types of loading units which could be transhipped to the waterway network. There is some interest in palletized goods, as recently a theoretical feasibility analysis (VUB & COMiSOL, 2006) and practical experiments (Verbeke et.al., 2007; VIM, 2012a) showed a clear potential for the modal shift of these goods. The time seems ready for the third wave.

Until now, practical experiments were organized as such that the intermodal transports of palletized goods set off from one (mainly) water-bound site of the supplier to another water-bound location of the customer. However, for the long term, the feasibility of the concept of a network of Regional Water-Bound Distribution Centres (RWDC's) needs to be analysed. The implantation of such RWDC's must be based on the transport flows of palletized goods. A distribution analysis of these flows enables the calculation of the most optimal RWDC locations through a location analysis. A model is set up which performs both the distribution, as the location analyses, and this on the basis of data on palletized building materials which were transported within Belgium in 2011. In this paper, the developed methodology is explained in section 3. In section 4, we focus on the project and data, whereas in section 5 we give the results. In section 2, the challenges and principles of a modal shift of palletized goods via a network of RWDC's are highlighted.

RWDC-CONCEPT

The transport of palletized goods via the inland waterways might seem like it is a new concept, but it is actually quite old. As mentioned, in former times a large portion of the transports was executed by barges. This included also palletized goods. But road transport quickly took the upper hand and their transhipment techniques optimized simultaneously. Today, it can be stated that road transport is done at a very competitive price, especially if the external costs are not included (Ricci & Black, 2005; Van Dorsser, 2004). By consequence, all transport of palletized goods by barges disappeared in Western Europe, until the early 21the century, when in the Netherlands the Distrivaart project was started. An initial study was executed by TNO in 2002-2003, which set up a concept of distribution of palletized consumer goods via the inland waterways. In the second phase a sophisticated pallet-warehouse-barge was build and launched for a pilot (Groothedde et.al., 2005; TNO Inro, 2003). This pilot – involving several beverage manufacturers – had to prove the feasibility of the concept. In the beginning of 2004 the pilot was continued by two companies. That same year, they concluded that the network could not be filled up at reasonable costs and the whole project was stopped (Poppink, 2005). However, the project awaken the Flemish interest, resulting in a theoretical feasibility analysis (VUB & COMiSOL, 2006) and several practical experiments (Verbeke et.al., 2007; VIM, 2012a), which indicate a clear potential for the modal shift of palletized goods.

The integration of a main haulage by barge, implies that suppliers and/or customers who are not located near an inland waterway, need an initial and/or final haulage via road. In those cases, one can talk about intermodal transport. Intermodal transport is defined as movements of goods in one and the same loading unit or vehicle which uses successive, various modes of transport (road, rail, water) without any handling of the goods themselves during transfers between modes (European Conference of Ministers of Transport, 1993). In this case, the various modes of transport are truck and barge, and the standard loading unit is the pallet. Note that one can distinguish different types of pallets in size and quality. The two main European categories are the 'EURO' pallets (80x120cm) and the 'INDUSTRIAL' pallets (100x120cm). A pallet of good quality can carry a load up to 2,5 ton.

The supply chain of palletized goods has very different logistical characteristics in comparison with bulk and containers. Table I illustrates these characteristics to indicate the challenges that must be dealt with when shifting palletized goods to the inland waterways.

Most of these characteristics are contrary to the typical characteristics of an inland waterway transport (IWT).

Table I : Supply chain characteristics of different cargo types

Supply Chain Characteristic	Bulk	Containers	Pallets	Typical IWT
Number of SKU's	few	no issue	many	few
Volume per SKU	high	no issue	low	high
Speed of delivery	low	high	very high	very low
Number of drops	low	low	high	very low

The solution for matching the characteristics of the supply chains of the palletized goods with those of typical inland waterway transport is to enter well-chosen water-bound hubs in the supply chain. These hubs - or RWDC's - will work as regional distribution centres where flows of palletized goods are bundled and transhipped to a barge. The RWDC's can be supplied via road and via the inland waterway. Figure 1 illustrates the possible flows, depending on the possible water-bound facilities of the suppliers and/or customers warehouse:

1. Water-bound suppliers warehouse => inland waterway => RWDC => post-haulage via road => Non water-bound customers warehouse
2. Water-bound suppliers warehouse => inland waterway => Water-bound customers warehouse
3. Non water-bound suppliers warehouse => Pre-haulage via road => RWDC => inland waterway => RWDC => post-haulage via road => Non water-bound customers warehouse
4. Non water-bound suppliers warehouse => Pre-haulage via road => RWDC => inland waterway => RWDC => Water-bound customers warehouse

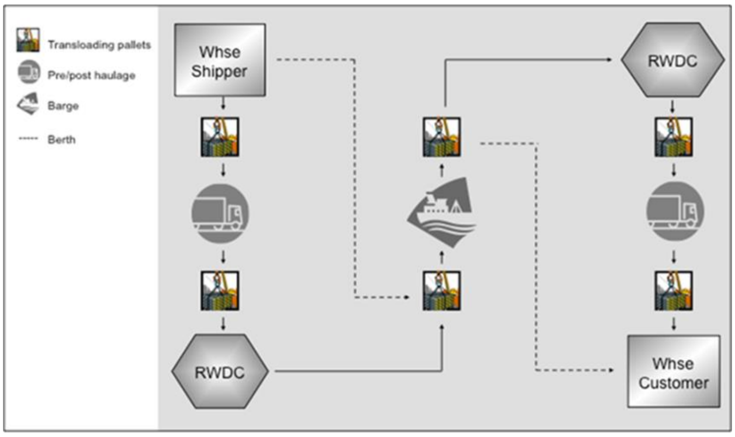

Figure 1 :Supply Chain of the Transport of Palletized Goods by Barge (VUB & COMiSOL, 2006)

MODEL

Introduction

Since in reality not every producer or customer of palletized goods has a location near an inland waterway, a network of RWDC's needs to be implanted (VUB/COMiSOL 2006). The most optimal location of these RWDC's is crucial for all stakeholders, as these locations have a large impact on the profitability of the intermodal transports. Consequently, their locations will also define the potential turnover of the RWDC (Arnold et.al., 2001; Aykin, 1995; Kayikci, 2010). The LAMBTOP (Location Analysis Model for Barge Transport Of Pallets), that will be discussed in this paper, was created to determine the most optimal RWDC locations in Belgium. Besides their locations, the model calculates the financial cost of the modal shift and the potential turnover for every one of these distribution centres. This is important information, given that the transport costs are one of the main determinants in the intermodal decision making process (Danielis et.al., 2005; LOGIQ, 2000; Vannieuwenhuyse et.al., 2003). Moreover, the transport price has proved itself as a clear bottleneck in previous studies and in the Distrivaart project (Poppink, 2005; VIM, 2012a; VUB & COMiSOL, 2006). Additionally to the financial outcome, the model also calculates the potential reduction in CO_2-emissions, to illustrate the ecological benefit of the modal shift.

In section 1, we focus on the financial cost structure, whereas in the next section we explain the used methodology for the CO2 comparison. Finally, the methodology of the LAMBTOP is given in section 3.

Cost comparison

The calculation of the financial difference between unimodal road transport and intermodal transport is performed with a cost structure which is based on the one hand on theoretical analyses (Essenciál Supply Chain Architects, 2011; Freight Best Practices, 2005) and on the other hand on practical experiments with palletized building materials (De Munck, 2010; Verbeke et.al., 2007; VIM, 2012b). The information of these experiments is obtained through contact with several transport experts that are accompanying these field tests.

In a first stage, the cost structure only considers direct transport related costs. In a later stage several scenarios were added, which include: possible depot costs, administrative savings (transport documents, payment transactions and invoices), road pricing. Managering costs, investment costs and external costs (congestion, accidents, emissions,…) are not included.

The financial costs are expressed in €/ton, whereas the distance dependent variables are expressed in €/tonkm. The time trade-offs created of the intermodal transport are not included. The interest and willingness of the construction sector for the modal shift illustrates that the gains in reliability and in cost efficiency that are booked through the modal shift, are far more important than created time trade-offs.

The following cost structure is obtained for the supply chain of the unimodal road transport:

$$C_R = C_{LT} + C_H * d_r + C_{UT} \qquad (1)$$

In comparison to the cost structure of the supply chain of the intermodal transport, which combines the costs of the different steps assuming that both the suppliers warehouse as the customers warehouse have no water-bound facilities:

$$C_I = C_{LT}+C_{PH}*d_{pr}+C_{UT}+C_{LB}+C_B*d_b+C_{UB}+C_{LT}+C_{PH}*d_{po}+C_{UT} \qquad (2)$$

The difference between the cost of the intermodal transport (C_I) and the unimodal road transport (C_R) is illustrated in Figure 2. Both transports start with an initial cost of loading the truck (C_{LT}). In the intermodal variant the truck drives, over a distance (d_{pr}), to the most optimal RWDC at a higher cost (C_{PH}) than the cost of the main haulage by truck of the unimodal transport (C_H). This is based on the assumption that one needs to take into account the probable empty return-haulage in the case of pre- and post-haulages (100% empty kilometres) (De Munck, 2010; Essenciál Supply Chain Architects, 2011), whereas the main-haulages of the unimodal transport are assumed to be done at a ratio of 26,5% of empty kilometres (Freight Best Practices, 2005).
Once the truck arrives at the RWDC, it has to be unloaded (C_{UT}), after which the palletized goods have to be loaded into a barge (C_{LB}). The loading of the barge is assumed to done by forklifts or mobile cranes. Both techniques have proved themselves feasible during the practical experiments, where different loading techniques were tested.
Once the barge is filled up to an average loading factor of 95% with palletized building materials, it navigates to an average cost (C_B) over a distance d_b. Additionally, the assumption is made that the barge transport counts 24% of empty kilometres. This percentage is validated by a market player. Once arrived at the second RWDC, the barge is unloaded (C_{UB}) with the same techniques as it was loaded. The palletized goods are then transhipped on a truck (C_{LT}), which will bring them to the final destination at the same cost as the pre-haulage (C_{PH}).

The additional transhipment costs at the RWDC (C_{UT}, C_{LB}, C_{UB} and C_{LT}) have a large impact on the overall price of the intermodal transport. For the combination of one truck (un)loading (C_{UT}) and one barge (un)loading (C_{LB}) a break-even distance of almost 60,8 km is needed. The break-even distance is the distance at which the costs of intermodal transport equal the costs of unimodal road transport (Pekin et.al., 2012; Rutten, 1998). In cases where both pre- and post-haulages are needed, one has to count a break-even distance of 121,7 km, for the transhipment costs which are made at the RWDC only. The costs of the pre- and post-haulages are not included in these break-even distances. One cannot calculate a general break-even distance, simply because it depends on the length of pre- and / or post-haulages, which varies for every origin-destination combinations.

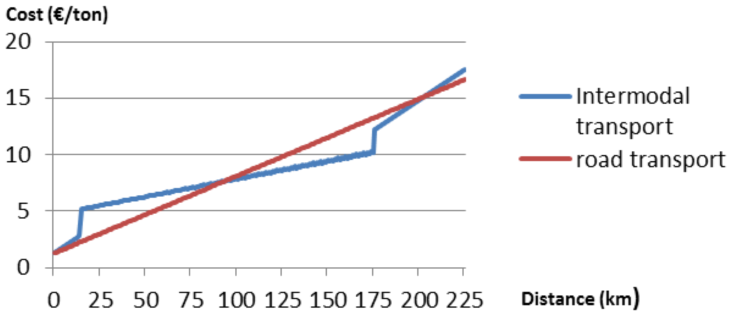

Figure 2 : Cost structure (source: own composition)

Comparing the main haulages; the financial cost of the transport by barge is more than twice as cheap as the financial cost of the main haulage by truck. The financial profit of the intermodal shift should thus be made in this section of the supply chain in order to compensate the extra handlings at the RWDC and possible pre- and/or post-haulages..

Although, as stated before, no general break-even distance can be calculated, several scenarios can be analysed for different pre- and / or post-haulages distances (see Figure 3). The initial cost contains the costs of the pre- and post-haulages and all the transhipment costs of both barge and truck.

In the case where both the suppliers and customers warehouse have water-bound facilities – and consequently no pre- and post-haulage and no additional transhipment costs of (un)loading the truck are needed – the choice for the intermodal alternative is always a profitable one.

If one pre- or post-haulage is needed, extra initial costs of these haulages and loading and unloading of the truck must be taken into account. The break-even distance of the first scenario (with 5km of pre- or post-haulage) is 68,1 km. In cases with a pre- or post-haulage of 30km, the break-even distance rises to 140,4 km.

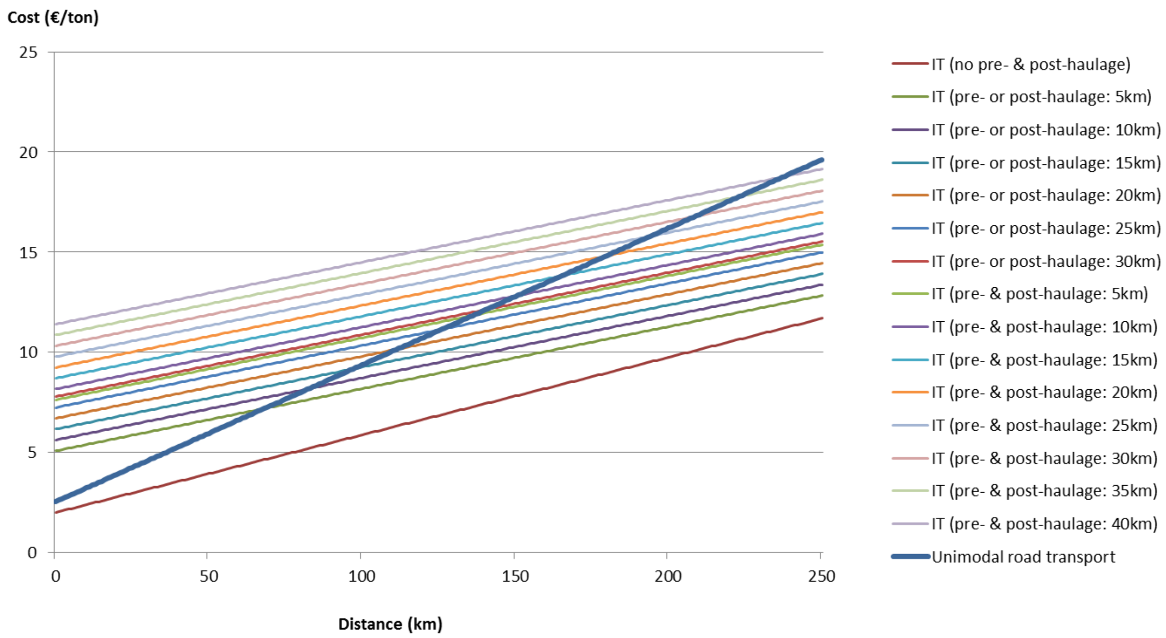

Figure 3 : Cost comparison unimodal road transport versus intermodal transport (IT) scenarios (source: own composition)

The break-even distance of the minimum scenario of pre- and post-haulage (5km) is 136,2 km. The maximum route distance via road between Belgian municipalities located within a buffer of 30km of an inland waterway is approximately 250km. Within this distance, all stated intermodal scenarios (up to a of 40 km of pre- and post-haulages) are profitable. More precisely the tipping point for a break-even distance of 250 km, is 46,8 km of pre- and post-haulage. It has to be noted that in reality the distance of the main-haulage by barge is often much longer than the main-haulage by truck, mainly due to the density of the network. In the Belgian case, the difference is on average circa 25%, which implies a decrease of the so-called tipping point to a more realistic 28,8 km. This distance corresponds to the 30 km, that is mentioned in previous studies as maximum distance of the pre- and post-haulage for which the modal shift of palletized goods can be profitable (Cornillie & Macharis, 2006; Essenciál Supply Chain Architects, 2011; Poppink, 2005).

In order to see how these cost calculations would vary in several situations, scenarios were built based on extra assumptions; such as the introduction of road pricing of 0,15€/km (Blauwens, et.al., 2011), an introduction of depot costs of 1 to 4 €/ton, administrative cost savings in case of barge transport (on purchase orders, transport documents, payment transactions) of 0,5€/ton.

CO_2 comparison

In general, intermodal transport creates less external costs (pollution, emissions, noise, congestion and accidents) than unimodal road transport (Kreutzberger et.al., 2007). In this paper only the CO_2-emissions are taken into account. The intention, in time, is to include other external costs in the analysis.

For the calculation of the CO_2-emissions, some assumptions have to be made. First of all, the haulages via road are assumed to be done by a 40 ton truck gross weight of the Euro V norm, as the obtained data lack information on the vehicle type. The CO_2-emissions are based on an average gradient of the motorways for hilly countries. The information about the average truckload allows to calculate the CO_2-emissions for all the haulages by road (unimodal variant, and pre- and post-haulage). The data of the Handbook Emission Factors for Road Transport 3.1 (INFRAS, 2010) are therefor used. The pre- and post-haulages are assumed to have an empty return-haulage, or in other words 100% empty kilometres. The main haulage in the unimodal variant is assumed to have 26,5% empty kilometres (Freight Best Practices, 2005).

The CO2-emission for barge transport are calculated on the bases of VMM (Vlaamse Milieu Maatschappij) study which uses the EMMOSS model (2012). Moreover, the assumption is made that transports are done by barges with an average load factor of 95%, and an average empty running of 24% (VMM, 2012).

Methodology

The Location Analysis Model for Barge Transport Of Pallets (LAMBTOP) is a GIS (Geographic Information System) based model, that consists of different network layers, each representing a transport mode (road and barge). The locations of departure and destination are connected to the network layers by their corresponding nodes. In many cases the municipality centres – defined as the main church of the municipality - are acting as those nodes (Fig. 4). If it is known that a departure and/or destination location is water-bound, this is included as such in the analysis.

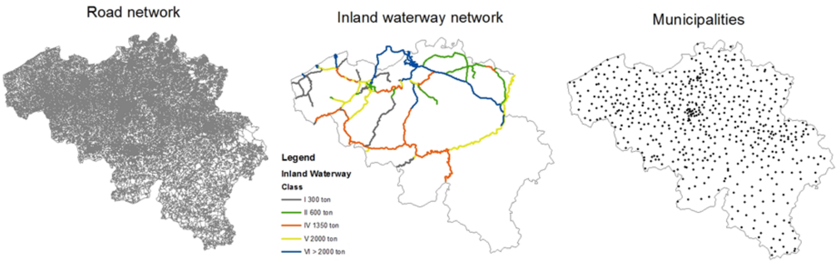

Figure 4 : The network in ArcGis (source: own composition)

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

- The inland waterways layer is extracted from the ESRI (Environmental Systems Research Institute) dataset for Europe.
- The road layer and municipality layer are obtained from the MultiNet database of Tele Atlas.

The model is set up for Belgium, but can easily be transformed for other regions and preferably even on an European scale.

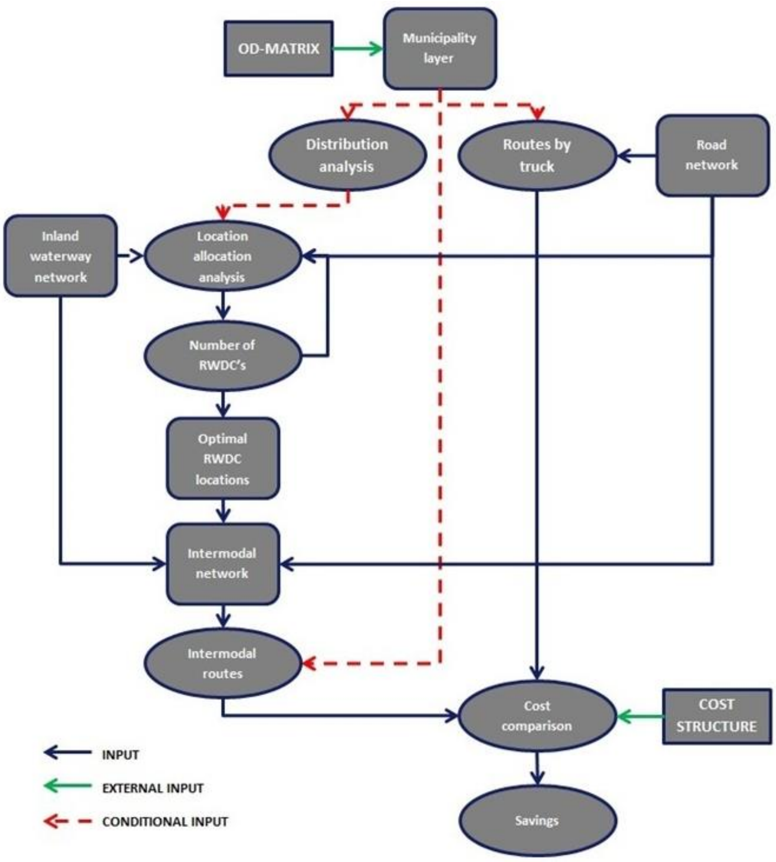

Figure 5 : The structure of the LAMBTOP (source: own composition)

As a first step, the obtained geographical information about the flows of the palletized goods is uploaded to the model in the form of an origin-destination matrix (OD-matrix) (Fig. 5). This OD-matrix is linked to their corresponding node in the origin-destination-point layer. This enables us to identify and map the transport flows of palletized goods.

The model identifies the OD-combinations and computes the unimodal routes travelled via the road network. These routes are calculated by a shortest time path algorithm. For every path algorithm in the entire analysis (unimodal routes, buffer, location analysis, intermodal routes), the algorithm of Dijkstra is used (Dijkstra, 1959).

Step 2 is the distribution analysis of transport of palletized goods. This distribution will determine the future locations of the RWDC's. The distribution locations (the nodes of the departure and arrival locations) are weighted with the sum of the tonnage of all the routes that start and arrive in these receptive nodes. Next, a precondition is formulated, namely the distribution locations used as 'market area' for the location analysis of the RWDC's are limited to the nodes which are located within a predefined buffer of an inland waterway (illustrated in Figure 6). Within this analysis the buffer is fixed once at 15km and once at 30km using the road network by a shortest time path algorithm. Although the critical maximum distance of the pre- and post-haulage necessary for the overall intermodal transport to be profitable depends on the overall transport distance and the used cost structure, it can be assumed that for the Belgian case 30 kilometres of pre- and post-haulage is the ultimate maximum (Cornillie & Macharis, 2006; Essenciál Supply Chain Architects, 2011; Poppink, 2005). By using this delimitation, intermodal routes with too long and consequently too expensive pre- and post-haulages will be excluded.

On the other hand, we use a buffer of 15km – where only locations close to the inland waterways are taken into account – for an analysis which optimizes the relationship between the minimisation of pre-and post-haulage distances and the minimisation of the number of RWDC's.

The potential locations of the RWDC's are defined as locations on an inland waterway with a capacity of minimal 600 ton, and lying within a predefined distance (50m) of a trafficable road. Thanks to this precondition, the future RWDC's will not be located in a pedestrian city centre or in a protected nature reserve. Furthermore, the RWDC's will already have a direct connection to the existing road network, thereby avoiding heavy investments in road infrastructure.

The determination of the optimal locations (step 3) is based on the 'Location-Allocation' procedure of the 'ArcGIS Network Analyst' tool. The procedure starts with the calculation of the shortest path between every distribution location and every potential RWDC location, using the road network and the algorithm of Dijkstra. Then an edited version of the obtained cost matrix is constructed (Hillsman editing, 1984) which enables the heuristic to solve a variety of different problem types. Next, the location-allocation process generates a set of semi-randomized solutions and applies the vertex substitution heuristic of Teitz and Bart (1968) to create a group of good solutions (Church et.al., 1994). A metaheuristic then combines this group to create better solutions, until no additional improvement is found. Finally the metaheuristic delivers the best solution found (ESRI, 2010).

The most optimal locations of the RWDC's vary with the number of chosen RWDC's. This number is chosen on the basis of the 'market share' and the spatial distribution of the RWDC's. In the concept which uses a buffer of 30 km, the idea is that it is better to enlarge one water-bound distribution centre rather than to open two of them in the same 'market area'. So the number of RWDC's will be limited. In the concept with a buffer of 15 km, the RWDC's are seen as small transhipment platforms which may or may not be combined with other logistic activities. This permits a higher number of RWDC's, which is interesting as it lowers the distances of pre- and post-haulages.

Once the number and the optimal location of the future RWDC's is set, a GIS network is created specific for intermodal transport. It combines the road layer (for the pre- and post-haulage), the RWDC locations (as transhipment nodes) and the inland waterway network layer. Within this created intermodal network a shortest time path algorithm for the pre- and post-haulages and a shortest route algorithm for the main-haulage by barge are performed for every OD-combination.

The respective distances of the unimodal routes by road and the intermodal routes – with pre- and post-haulage by road and main-haulage by barge – are calculated for all these OD-combinations and the distances are linked to the cost structure. A cost analysis is performed for every individual OD-route. The combination of all routes gives a global overview, whereby the routes for which the modal shift is profitable will describe a realistic potential for modal shift and a realistic potential turnover (in ton) of the future RWDC's. Assuming that these profitable transports will be shifted towards the inland waterways, it is possible to calculate the saved truck movements and consequently an estimation of the potential CO_2 reduction. Different cost scenarios, like road pricing, an introduction of depot costs, administrative cost saving provide a further analysis.

BUILD-OVER-WATER PROJECT

The construction sector is - with 7 to 8% of the Belgian BNP – an import economic motor for the country. The sector has a large impact on mobility too, as they represent 25% of the freight transport on the Belgian highways (VIM, 2012b). A lot of these freight are loaded on pallets. In total almost 53 million ton of freight is yearly transported within the Belgian borders (ADSEI). It is not possible to pick out the palletized building materials from these data, but a feasibility analysis (VUB & COMiSOL, 2006) demonstrated that 6 to 7 million ton of palletized building materials showed potential for a modal shift to the inland waterways.

The ‘Build over Water’ project (coordinated by VIM, 2012) consists of two parts. First, a feasibility analysis was performed on the basis of different practical experiments. The second stage of the project consisted of a distribution- and location analysis, which uses the LAMBTOP model. Through these analyses, the most optimal RWDC locations are identified, and the potential gains they will bring to the cost and ecologic efficiency.

The distribution- and location analysis are based on historic, Belgian transport flows of palletized building materials for the year 2011. They are obtained via an oriented survey; in which 9 out of the 50 reported producers participated. Together, they represent 1,163 million ton of transported palletized goods. The overall potential of palletized building materials is estimated to be 6 to 7 million tons. The survey covers in other words approximately 1/6 of the total potential.
The data contain information about the producer, the tonnage and the origin and destination on municipality level. For the water-bound sites, the address location is used as geographic node. In cases where a municipality contains both water- and no water-bound destinations, the assigned tonnage is proportionally divided over these locations. For all non-water-bound locations or cases for which no address information is given, the tonnages were assigned to the municipality centre, which is defined as the main church of the municipality.

The 1,163 million ton of palletized building materials creates an origin-destination-matrix (OD-matrix) of 1 462 combinations. This matrix is uploaded in the model, which gives the following results.

RESULTS

As said, the model identifies the origin-destination combinations, and distributes their respective weight (tonnage) as the sum of the tonnages of all the routes which start and arrive in that location. This distribution-analysis is illustrated in Figure 6. The production locations are – as origins - mainly concentrated in the west and north of the country. The tonnage of the destinations is more equally distributed, but one can still distinct some general larger concentrations in the Flemish part of the country, the ABC-axis (Antwerp-Brussels-Charleroi) and around the city of Liège.

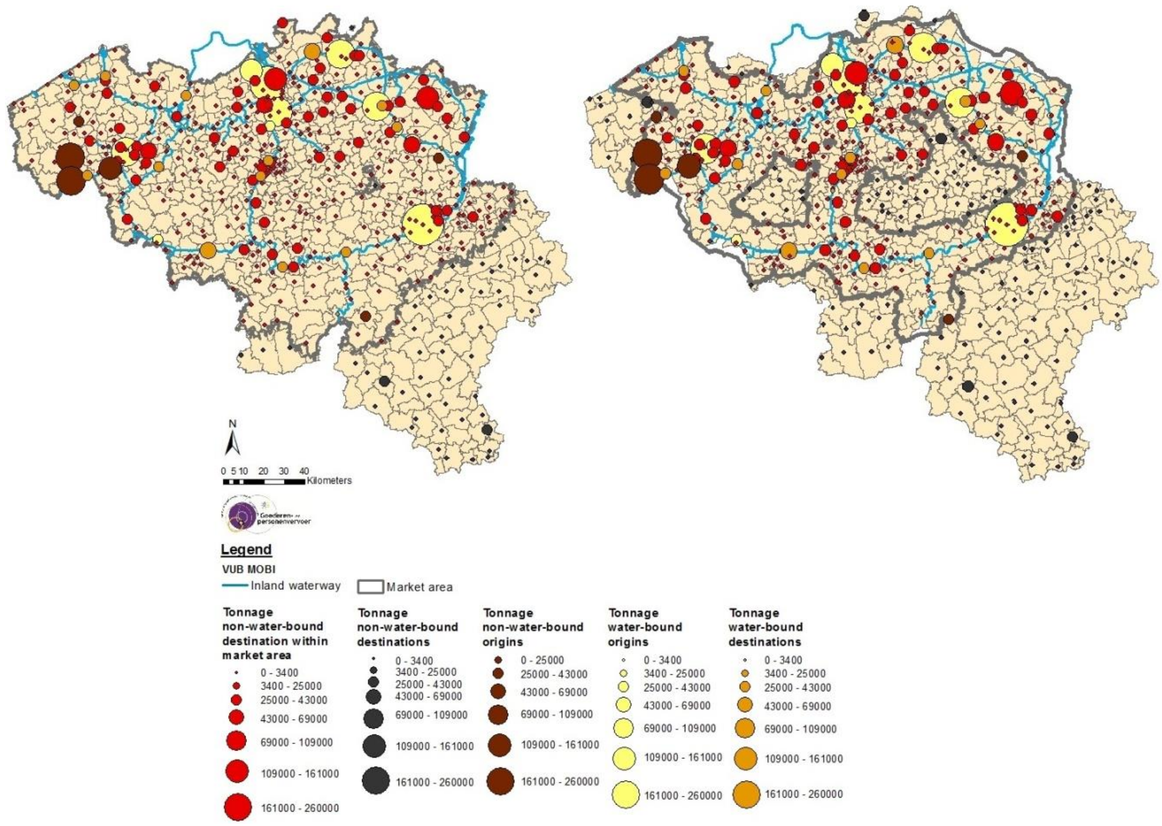

Figure 6 : Distribution analysis (tonnage per municipality) + potential market area (source: own composition)

In order to limit the distances of pre- and/or post-haulage in prospect of the profitability of the modal shift, only the distribution locations which are lying within the predefined buffer of 30 km (in the left map) and 15 km (in the right map) of an inland waterway are selected as the 'market area' for the future most optimal RWDC.

The distribution of all non-water-bound locations which are located within the respective buffers will determine the future locations of the RWDC's. For the concept with a buffer of 30 km, the location analysis works out an optimal number of nine RWDC's. If one takes a buffer of 30 km around these nine most optimal RWDC locations, they cover together 96,5% of the 1,184 million tons which are defined as the 'market area'. A number lower than nine RWDC's lacks to serve some considerable market areas within a reasonable pre- and post-haulage distance. Once more than nine RWDC's are chosen, the added value of the new RWDC's is negligible.

In the case of a market area of 15 km, the model returns 27 most optimal RWDC locations. Together they cover 99,2% of the 1,122 million non-water-bound tons which are distributed within the market area. Four of the 27 most optimal locations are closely located to an water-bound origin location. So one can expect that these neighbouring locations will merge in time to one transhipment location.

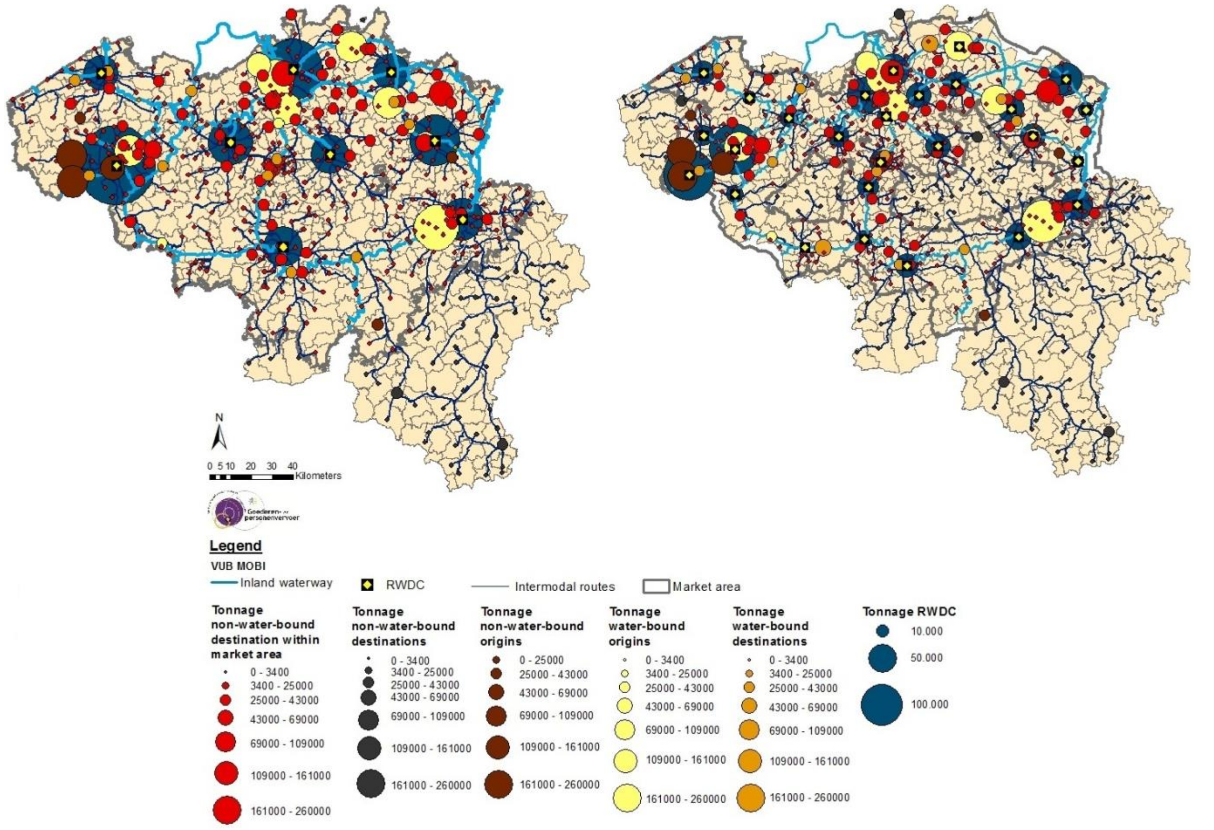

Figure 7 : Overall potential turnover of RWDC and the intermodal routes (source: own composition)

Figure 7 illustrates the spatial distribution of the most optimal RDWC locations for both concepts. Additionally the intermodal routes and the overall potential turnover (in tons) of the RWDC's are shown. The overall potential turnover of a RWDC is the tonnage which would be transhipped there, if all given OD-combinations would be shifted to the inland waterway. Of course this is not a realistic assumption, because according to the cost structure, the flows have to cope with a minimal break-even distance of 68 km (section 'Cost comparison).

To have a realistic view on the potential of both concepts, the intermodal and unimodal routes were linked with the cost structure, which resulted in a profitability analysis for every individual route. Additionally several scenarios were analysed to illustrate their respective impact and also to test the robustness of the results.
Figure 8 illustrates the overall results which show that today over 300 000 tons of palletized building materials can be transhipped via the 9 most optimal RWDC locations to the inland

waterways at a profitable cost. In the case of 27 RWDC's (or 'concept 15 km'), the profitable amount rises to almost 450 000 tons. These data are for the survey which covered approximately 1/6 of the total potential transport flows of palletized building materials. So one can suppose that the real profitable modal shift of palletized building materials will be a lot larger than those stated tonnages.

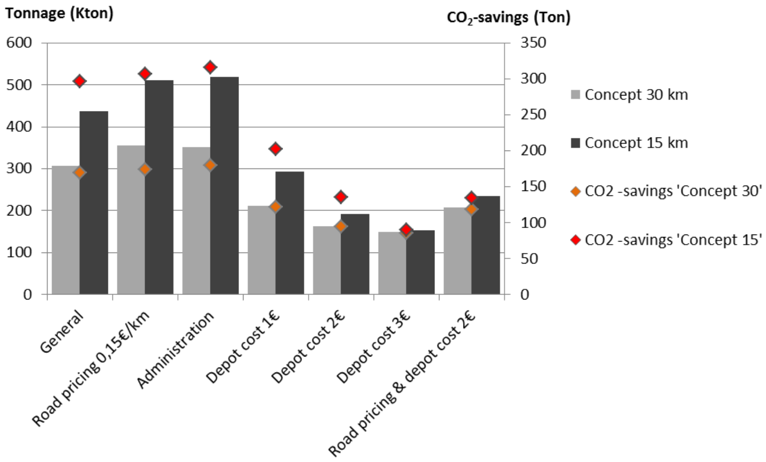

Figure 8 : Tonnage and CO_2-emission savings for the profitable intermodal routes of each scenario (source: own composition)

The potential savings in transport related CO_2-emissions are also shown in Figure 8. The total CO_2-emission savings for the profitable intermodal routes with respect to their unimodal alternatives varies between 85 and 316 ton, depending on the used concept and the used scenario. The proportional ecologic gains are clearly rising with the use of 'concept 15 km'. This is also the case for the scenario of road pricing, where one assumes an implementation of a road pricing system conform the rate of the LWK-Maut in Germany (Blauwens, et.al., 2011). For this scenario, the profitable modal shift grows with approximately 15%, to over 350 000 for 'concept 30 km', and almost 520 000 for 'concept 15 km'. The introduction of administrative costs savings to the general cost structure has more or less the same impact as road pricing.
When costs for depot activities are added to the general cost structure, it reduces the profitability of the concept. Adding value to this activity through flexible opening hours or by bundling of post-haulages is at the moment necessary.

The last scenario combines the concept of road pricing (0,15 €/km) with a depot cost of 2 €. Under these circumstances 17,8% and 20,2% (respective for 'concept 30' and 'concept 15km') of the initial 1,163 million tons can be shifted at a profitable cost. When one maps (Figure 9) the intermodal routes of these profitable combinations, one can see that they are mostly allocated to RWDC's in the west and the east of the country. Transport distances are therefore high, so the break-even distance is reached (Figure 3). This fact hints the argument for a construction of an international RWDC network, where average transport distances will be higher. Consequently the financial and ecological benefits of the concept becomes bigger.

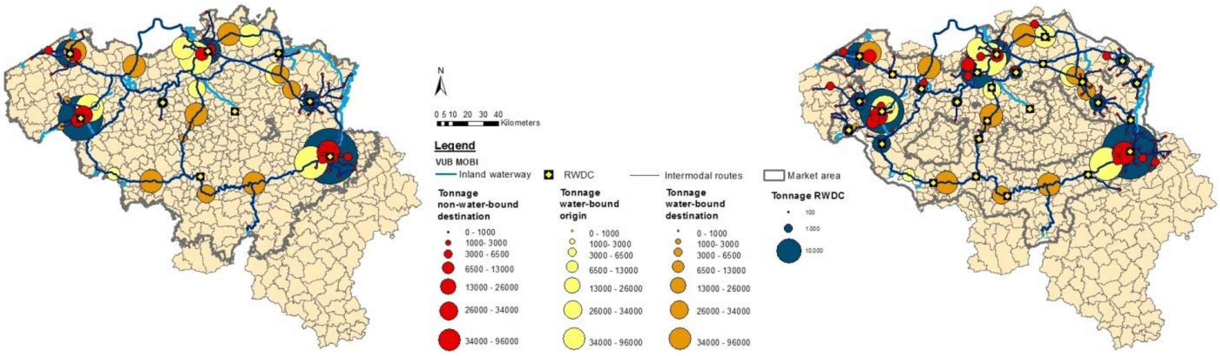

Figure 9 : profitable intermodal routes for scenario with road pricing and depot cost (source: own composition)

CONCLUSIONS

The transport of palletized goods via the Belgian inland waterways has gone a long way since the Distrivaart project in the Netherlands (re)introduced the concept. In a first phase, a theoretical feasibility analysis (VUB & COMiSOL, 2006) illustrated a clear potential for palletized building materials and fast moving consumer goods. In a next phase the theory was tested in practice. Through multiple experiments with different types of barges and transhipment techniques, the most efficient ones could be picked out and a cost structure was developed.

This cost structure is based on transport related financial costs. Different scenarios were built, such as a introduction of road pricing, administrative savings and depot costs. The cost structure shows an absolute economical potential for the modal shift of transports of palletized goods when both producer and customer are located near the inland waterway. In cases where the suppliers and/or customers warehouse is not located at an inland waterway, an implantation of a RWDC and pre- and / or post-haulages become inevitable. It is obvious that the shorter these haulages are, the more (financially) feasible it will be to shift the palletized goods. So the location choice of the RWDC, and consequently the minimization of pre- and/or post-haulages, is crucial for the whole success of the concept.

In this paper, the LAMBTOP is described, which allows to analyse the most optimal RWDC locations. Moreover, the model is able to calculate the financial cost of the modal shift and the potential turnover of every RWDC, as well as the reduction in CO_2-emissions. The model was used for the analysis of Belgian transport data for 2011 on palletized building materials. They were collected within the framework of the 'Build-over-Water' project.

The results of this analysis emphasises a clear potential for a modal shift of these palletized building materials to the inland waterways, which substantiate the previous results of the feasibility analysis (VUB & COMiSOL, 2006). The most optimal location and the potential for modal shift will also depend on the chosen number of RWDC's. Therefore, two concepts are used, namely: 'concept 30 km', where the aim is to minimize the number of RDWC's to a maximum, and 'concept 15 km' optimizes the relationship between the minimisation of pre- and post-haulage distances and the minimisation of the number of RWDC's.
For this analysis the optimal number of RWDC's is - respective to 'concept 30' and 'concept 15' – 9 and 27. Crucial factors are the amount of kilometres for pre- and post-haulage.
The modal shift of palletized goods has besides cost efficiency, also environmental and societal benefits. For the moment only the CO2-emissions are included in the external cost analysis, but their results illustrate already the ecological importance of the modal shift.
One has to notice that the used data also captures just a small part of the overall potential of transported palletized goods. The potential in the building sector is estimated at 6 to 7 million tons. Additional several fast moving consumer goods have showed potential too. Another limitation is the lack at detailed and international data. Coherent data collection is often limited to national/regional borders, whereas the transport networks and transport flows are not. Especially in the case of intermodal transport – for which the break-even distance is an important concept – the international flows represent a big potential which is not yet included in the analysis.
Further research will focus on the broadening of the geographical scale of the model. Parallel the model will be updated to the newest market, costs evolutions including the value of time and the regularity and reliability of barge transport.

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