Beleidsondersteunende paper

PALLETS ON THE INLAND WATERWAYS

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NEDERLANDSE SAMENVATTING

De distributie van gepalletiseerde goederen gebeurt vandaag in België zo goed als uitsluitend via de weg. De vele, geassocieerde vrachtwagenbewegingen hebben daarbij niet alleen een belangrijke impact op het milieu, zij dragen ook bij tot het structureel congestieprobleem. Een innovatieve oplossing voor dit probleem is het bundelen van de transporten over de binnenvaart. Het mogelijke voor-/natransport dient dan georganiseerd te worden via een netwerk van intermodale overslagpunten. Zodoende kan men het transport met de vrachtwagen reduceren tot een absoluut minimum. Aangezien de binnenvaart significant lagere externe kosten (congestie, ongevallen, emissies en geluidsoverlast) veroorzaakt dan het wegvervoer, zou dit een welgekomen verademing kunnen bieden aan het wegennet en de maatschappij in zijn geheel.

In navolging van het Distrivaart project in Nederland, werd de haalbaarheid van het innovatieve concept ook voor Vlaanderen aangetoond door een studie in opdracht van Waterwegen en Zeekanaal NV en uitgevoerd door de VUB en COMiSOL (2006). Vooral voor fast moving consumer goods en bouwmaterialen werd er potentieel gevonden. Daaropvolgend voerde men verscheidene praktijktesten uit, waarbij verschillende transport- en overslagtechnieken werden uitgeprobeerd. Dit resulteerde in een gedetailleerde kostenstructuur. In een eerste fase bevat deze kostenstructuur enkel transport gerelateerde financiële kosten. In een tweede fase worden er verschillende scenario's – aangaande mogelijke depotkosten, administratieve kostenbesparingen en een mogelijke introductie van een kilometerheffing – aan toegevoegd. Beheerskosten, investeringen in infrastructuur en/of materieel en externe kosten worden niet in rekenschap gebracht (Verbeke, Macharis & Cornillie, 2007).

Volgens de kostenanalyse zijn de intermodale transporten die geen voor-/natransport vereisen altijd goedkoper dan hun unimodaal alternatief over de weg. Eenmaal dat er een voor- en/of natransport vereist is, moeten er extra transport- en overslagkosten gemaakt worden. Deze extra kosten zorgen ervoor dat het transport een zekere kritische afstand dient af te leggen vooraleer het intermodale alternatief goedkoper is dan zijn unimodale variant. Deze kritische afstand, of zogenaamde *break-even distance*, is afhankelijk van de lengte van het voor-/natransport. Hoe korter het voor-/natransport, des te meer het financieel haalbaar zal zijn om de goederen stroom over te slaan naar de waterweg.

Indien er een voor-/natransport vereist is door de niet watergebonden locatie van leverancier en/of afnemer, dienen er ook intermodale overslagplaatsen ingeplant te worden. De locaties van deze overslagpunten of zogeheten Regionaal Watergebonden Distributie Centra (RWDC), zijn cruciaal voor de verdere ontwikkeling van het concept. Daarom werd er binnen dit onderzoek een locatie-analyse

model (LAMBTOP: Location Analysis Model for Barge Transport Of Pallets) ontwikkeld. Het model bepaalt de meest optimale RWDC locaties op basis van de ruimtelijk distributie van de gepalletiseerde goederenstromen. Daarenboven berekent het model de meest optimale transport routes voor zowel het unimodale wegvervoer als voor het intermodale transport. Zo is men in staat om de transport gerelateerde financiële kosten en CO_2-emissies te becijferen.

Dergelijke analyse is uitgevoerd voor België, aan de hand van de 2010 data van de Algemene Directie Statistiek en Economische Informatie (ADSEI). Er werd enkel rekening gehouden met binnenlandse transporten van gepalletiseerde goederen. Deze data zijn echter beperkt naar vertrek- en aankomstgemeente. Er is met andere woorden geen informatie beschikbaar over eventuele watergebonden locaties van de leverancier of afnemer, waardoor men moet uitgaan van een voor- en natransport over de weg.

In 2010 werden volgens het ADSEI ongeveer 53 miljoen ton gepalletiseerde goederen binnen de Belgische grenzen vervoerd. Al deze transporten gebeurden over de weg, met de geassocieerde negatieve externaliteiten tot gevolg. De meeste van deze transportstromen hebben een gemeente met een groot distributie centrum of een stad als vertrekpunt of bestemming. Daar de locatie-analyse gebaseerd is op de distributieanalyse, ziet men dat de uitgekomen meest optimale RWDC locaties zich logischerwijs in of nabij deze steden en gemeenten bevinden. Hierdoor kan het innovatieve concept van het transport van gepalletiseerde goederen over de waterweg gecombineerd worden met een multimodale en duurzame stadsdistributie. De toekomstige (stedelijke) RWDC's kunnen dan fungeren als multimodale stedelijke distributie centra, van waaruit de zogenaamde '*last mile*' kan worden uitgevoerd door milieuvriendelijk transportmodi.

Uit de analyse volgt dat er een duidelijk potentieel is voor het palletvervoer via het water. De steun die door de minister is voorzien, maakt dat opstartkosten van het concept kunnen worden gecompenseerd.

Om het model dat in dit rapport wordt beschreven volop te kunnen laten functioneren, is er nood aan data met de exacte locatie van oorsprong en bestemming en een duidelijker beeld van het type goederen (bouwmaterialen, FMCG,…) en dit zowel voor binnenlandse stromen als stromen die vanuit het buitenland komen.

Cruciale factoren waar mee rekening dient gehouden te worden bij de opzet van het netwerk van RWDC's werden reeds geïdentificeerd:

- De financiële haalbaarheid hangt sterk af van het voor- en natransport en de lengte van het binnenvaartgedeelte.

- Een verdere verbetering van de competitiviteit van de binnenvaart ten opzichte van het wegtransport mag verwacht worden door enerzijds de lagere administratieve kosten in het RWDC concept, het internaliseren van de externe kosten, het aantal RWDC's die zullen ingeplant worden, het verminderen door kosten bij het verbeteren van de efficiëntie van de overslagtechnieken.

Uit de huidige analyses (gebaseerd op data die gebaseerd zijn op gemeente data) volgt dat een potentieel bestaat van 5,3 miljoen ton/jaar. De modal shift van dit tonnage zou jaarlijks ongeveer 478 000 lange vrachtwagenbewegingen reduceren tot korte voor-/natransporten. De bijhorende transport gerelateerde CO_2-emissies zouden hiermee verlaagd worden met 17 733 ton.

1   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, it can be noticed 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 materials which were transported within Belgium in 2010.

In this paper, firstly the concept of an intermodal transport of palletized goods via the inland waterways will be highlighted in section 2. In section 3, we will focus on the cost structure, whereas

the explanations about the model and the results will be given in section 4. The conclusion will be shown in the next section. This paper ends with a short focus on further research and a motivation for cooperation.

2   PALLETIZED GOODS BY BARGE

The section 'Palletized goods by barge' will start with an explanation of the intermodal hub-network. Once the properties and challenges of a modal shift of palletized goods are highlighted, we will have a look to the potential sectors (section 2.2) and the potential for a combination of the concept with a sustainable city distribution (section 2.3).

2.1   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 21[the] 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.

Figure 1 : Palletized goods transported by barge in 1964

Figure 2 : Distrivaart (source: Arie Jonkman)

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 different types of pallets can be distinguished 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): namely ships have huge volumes, speed is traditionally low and the number of drops is also usually low.

Table 1 : Supply chain characteristics of different cargo types (source: Verbeke et.al., 2012)

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

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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:

- Water-bound suppliers warehouse => inland waterway => RWDC => post-haulage via road => Non water-bound customers warehouse

- Water-bound suppliers warehouse => inland waterway => Water-bound customers warehouse

- Non water-bound suppliers warehouse => Pre-haulage via road => RWDC => inland waterway => RWDC => post-haulage via road => Non water-bound customers warehouse

- Non water-bound suppliers warehouse => Pre-haulage via road => RWDC => inland waterway => RWDC => Water-bound customers warehouse
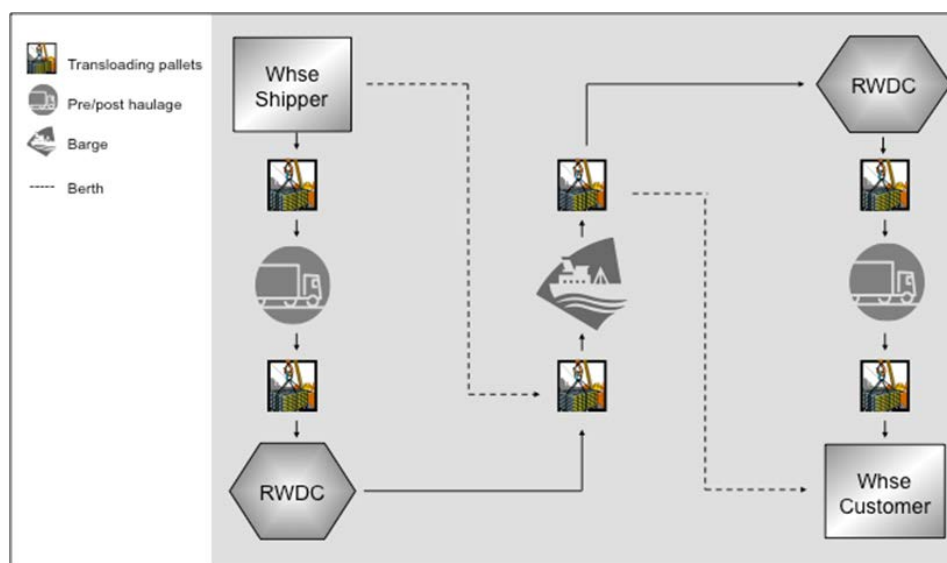
Figure 3 : Supply chain of the transport of palletized goods by barge (source: VUB & COM*i*SOL, 2006)

We will take a closer look to the different steps of the supply chain in section 3.1.2.

2.2 Inventory of the market

According to the ADSEI (Algemene Directie Statistiek en Economische Informatie) survey of 2010 approximately 68 million ton of palletized goods are transported via the Belgian roads, of which 53 million are distributed within the national borders. These inland transports are all using the road

network. Together, they are responsible for 5,64 billion tonkm, which is almost 1/3 of the overall inland tonkm performed by vehicles with a capacity of 1 ton (with the exception of agricultural, military and public vehicles). The related congestion and pollution of these transports are high, wherefore every modal shift of even a part of these flows would be welcome.

The ADSEI data do not give a any information about the content of the pallets, so no distinction can be made on that level. However, two main sectors are representing particular potential for a modal shift, namely the construction sector and the sector of the fast moving consumer goods. The transport flows of both sectors are spatially characterized by a limited number of warehouses on the supply side, and a considerable number of customers. The last ones are mostly located in or near main cities.

The construction sector is - with 7 to 8% of the Belgian BNP – an import economic motor for the country. The sector has also a large impact on mobility, as they represent 25% of the freight transport on the Belgian highways (VIM, 2012b). A lot of these freight are loaded on pallets.

In Belgium, a number of 50 producers of building materials delivers to some 250 dealers (VIM, 2012b). Many of those producers and some of the dealers are – due to historical reasons – located near an inland waterway. Consequently, pre- and /or post-haulages and the related transhipment costs can in many cases be avoided. This is in favour of a modal shift, as will be proven in section 3.

Less data are available for the palletized fast moving consumer goods (FMCG), but their flows are also limited to a small number of retailers and their warehouses. Like the construction sector, the FMCG routes are concentrated towards cities, as production and consumption are located there. Therefore, urban areas can be interesting locations for the implementation of RWDC's (VUB & COM*i*SOL, 2006).

2.3   City distribution

The allocation of a RWDC in or near to cities, makes it possible for these cities to organize their supply of palletized goods by using the available inland waterway. Instead of having a large number of deliveries entering the inner city by truck, palletized goods can be bundled in a barge. The goods are then transported via the inland waterway to the 'urban' RWDC located in or near the inner city. From there, the pallets are again bundled into smaller pieces and transported to their final destination. For ecological and societal reasons, this so-called '*last mile*' can be done by environmental friendly vehicles. The last mile is defined as being the last link between the depot and the last person who receives the goods (Gevaers et.al., 2009).
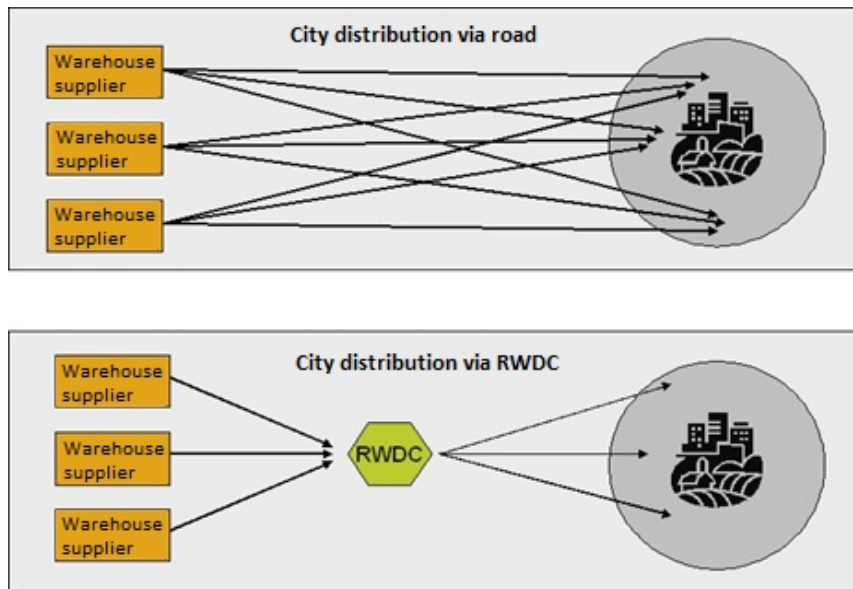
Figure 4 : City distribution (source: VUB & COM*i*SOL, 2006)

Cities are spatial concentrations of consumption of services and goods. A part of these goods are stored on pallets. An example are the many of the fast moving consumer goods that one can find in the multiple urban supermarkets. One can also think of all the palletized building materials that are needed for all small and large urban renewal and expansion projects.

On the other hand, cities are also spatial concentrations of production. In the context of urban production of palletized goods, a possibility for a (sustainable) urban pre-haulage between the urban location of production and the urban RWDC exists. In that sense the arrows of Figure 4 – which illustrates the concept of the urban RWDC – can be inversed.

It is obvious that the closer the RWDC is located to the production and consumption sites, the more the concept is economically and ecologically interesting. Consequently transports by truck – causing noise, accidents, emissions and congestion– can be limited in urban areas.

2.3.1   Some examples illustrates…

In the neighbouring countries, different public and private projects have emerged in the last years, combining the distribution of (palletized) goods and the available inland waterway. These projects will be shortly addressed to indicate the potential and feasibility of the concept.

2.3.1.1   Bierboot

Besides the already stated Distrivaart project (see section 2.1) (TNO Inro, 2003), different urban freight flows were shifted to the inland waterway in the Netherlands. One of the pioneers is the city of Utrecht. They developed the concept of the 'Bierboot', which supplies the catering industry of the

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inner city. This innovative idea fits in the overall logistics policy of the city. As they are confronted with a historical presence of dense but narrow road network, the expanding transport via these roads caused congestion, emissions, road damage and noise nuisance which rose to problematic levels. Parallel with the expanding road transport, the dense inland waterway network of the city was dumped. The city had to intervene. They introduced weight and length limitations, one-way circulations, time windows and a 'low emission zone' for the transport via road. But, the incentives entailed that it became difficult to supply the inner city, with imminent associated economic losses. The dumped inland waterway network arose as an alternative. From the early nighties on, the city started the renovate the quay and wharfs, and in 1996, they introduced the 'Bierboot'. This barge uses the inland waterways of the city to provide beer and other goods to the inner city catering industry. The 'Bierboot' has a diesel engine, and a hydraulic crane on board which executes the transhipments.

In 2010, a second 'Bierboot' was launched which is powered by an electric engine and charged at the end of every workday by green energy (Oele, 2008). In cases where there is a last mile over land, this haulage is often organized by the 'Cargohopper'. The 'Cargohopper' is an electric vehicle with different carts (Maes et.al., 2012).

Figure 5 : The Bierboot (source: nllogistiek, 2010)

The main advantages of the 'Bierboot' are that it is environmental friendly transport mode (see Table 2), independent of time windows and very reliable. The main disadvantage of the concept are the extra transhipment costs (Maes et.al., 2012).

Table 2 : Yearly PM10, CO$_2$ and NO$_x$-emissions of the Bierboot compared to vans (source: Ecofys, 2008)

Emission reduction 'Bierboot'	PM10 (kg/year)	CO$_2$ (kg/year)	NO$_x$ (kg/year)
Vans	1,88	17 400	32,64
Bierboot (diesel)	1,00	12 789	5,00
Bierboot (grey energy)	0,04	10 448	0,044
Bierboot (green energy)	0,04	971	0,044

2.3.1.2 *Vracht door de gracht*

Amsterdam is another Dutch city who has an extensive network of inland waterways within the inner city. Like in the case of Utrecht, Amsterdam took similar incentives to tackle the nuisance created by the road transport. This also entailed difficulties for the supply of the inner city. To tackle these difficulties, different projects were launched, involving the inland waterway network into the supply chain (Buck Consultants International, 2009). This paper highlights one which includes palletized goods .

Figure 6 : Vracht door de gracht – barge (source: Mokum Mariteam, 2012)

The project is called the 'Vracht door de gracht' of Mokum Mariteam. It is a partnership between three companies (Rederij 't Smidje, Rederij de Nederlanden en Canal Company), a waste management company ICOVA and a logistic service provider Koninklijke Saan. In contrast to the 'Bierboot' in Utrecht, this project is thus ran by the private sector (Platform voor elektrisch en hybride varen, 2011). The barge was launched in 2010, and is powered by electro engines. There are

also two diesel engines which are used once outside the urban area and to charge the batteries when they should ran empty (EICB, 2011). In cases where there is a last mile over land (of maximum 150m), this is organized by the 'kiki', which is an electric hand vehicle. The goods – mainly fast moving consumer goods, books and building materials – are transhipped with a hydraulic crane, which is related to the barge (Mokum Mariteam, 2010). Briefly, the 'Vracht door de gracht' project has the same main advantages and disadvantages as the 'Bierboot' project (Maes et.al., 2012).

2.3.1.3   Franprix

Two other city distribution projects which uses the inland waterway are both organized in Paris (FR). The first project is organized by the French supermarket Franprix. It is a result of a two years cooperation work between Norbert Dentressangle, Port of Paris, Voies navigables de Seine, Paris Terminal and Franprix of course. Starting in September 2012, (palletized) dry food products will be delivered on daily basis to 80 of their stores in the inner centre of Paris by a barge. In the start-up phase, 28 containers (with the equivalent of 450 pallets) will be daily transported, rising to 48 containers over time. The transports begins with a short pre-haulage by truck from the Franprix warehouse in the suburbs of Paris to the inland port of Bonneuil-sur-Marne. Here, the containers are transhipped to a barge, ready for the 20km journey along the inland waterway to the port of Bourdonnais at the foot of the Eiffel Tower. From there the last mile is organized to the individual shops. Franprix claims that they reduce their CO_2-emissions by 37%. Additionally their trucks avoid the chronic congestion in and around Paris (Groupe-Casino, 2012; Naiades, 2012b).

Figure 7 : Route of the Franprix project (source: Leparisien, 2012)

2.3.1.4   Vert chez Vous

A second project in Paris is the 'Bateau + Vélo' project of the logistic service provider Vert chez Vous. Since May 7th 2012, they use their barge, named the 'Vokoli'. This barge functions as floating distribution center on which electric bikes are centralized and loaded with parcels. The barges sails

daily 4 circles along the Seine with 5 stop where the electric bikes are transhipped to land. From these stops, the electric bikes start doing their deliveries for the different districts of Paris. In total, 3 teams of 6 electric bikes perform every day 4 rotations, or by other means, they are 4 times transhipped to and from the barge. The result is a daily maximum of 3000 parcels, 14 ton or 144 m^3 of transported volume at minimal emission levels (Naiades, 2012a; Vert chez Vous, 2012).
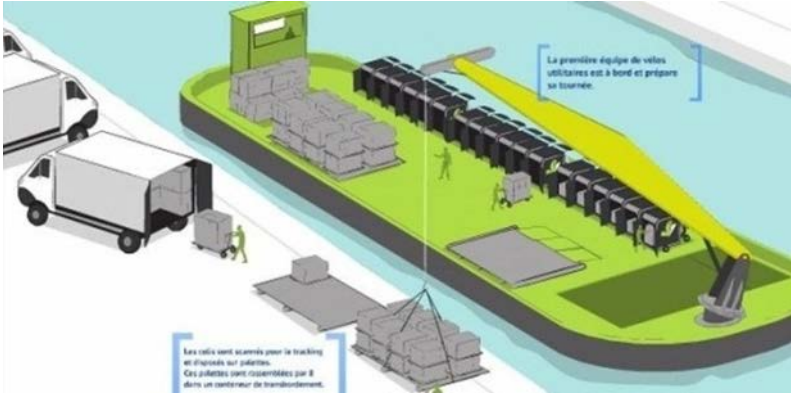
Figure 8 : Vokoli – barge (source: Vert chez Vous, 2012)

2.3.2   Conclusion

The integration of the inland waterway in the city distribution is an innovative concept, which success is tested through several projects in different West-European cities. A SWOT-analysis based on above highlighted project and the feasibility study for the transport of palletized goods via the inland waterway (VUB & COM*i*SOL, 2006) is set up below.

Table 3 : SWOT analysis city distribution via the inland waterway (source: own composition)

Strengths:	Weaknesses:
• Reduction of truck movements; especially heavy trucks entering the city • Optimalisation loading factor; including backhaul and bundling • Sustainable: reduction emissions, noise nuisance and congestion • Reliability	• Additional transhipment • Availability of (suitable) inland waterways; for example capacity (tonnage), bridges, quays • Critical mass is needed • Not all types of goods are suitable • Confidentiality and security of the goods • Limited pre and post-haulages in cases with short main-haulages by barge

Opportunities:	Threats:
- Implementation of regulations according to road transport (time windows, weight and length limitations,…) - Integration with these incentives: example independence of time windows - Integration of different types of goods (parcels, pallets, containers,…)	- Already existing city distribution centres - Conservative attitude of the logistic sector, the transport sector and even the governments

3   COST STRUCTURE

In this section we will discuss the cost structure. First of all the financial costs that are encountered when palletized goods are transported via unimodal road transport or intermodal transport. A cost comparison between both is the result. Additionally, the government aid will be highlighted. This section ends with the explanations of the structure that is used to calculate the transport related CO_2-emissions.

3.1   Financial costs

Every transport has its cost, and as this study wants to examine the possibilities of shifting the transport of palletized goods from road to the inland waterways, a financial cost comparison gives an impression on these possibilities. 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).

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. Note that the costs are based only on the modal

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shift of palletized building materials. However, due to their large variety – in terms of volume, weight, weather sensitivity and fragility – building materials can be seen as a good indicator.

In a first stage, the cost structure only considers direct transport related costs. In a later stage several scenario's 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.

3.1.1 Unimodal road transport (C_R)

For the unimodal transport via road the handling consists of loading the pallets on a truck, driving to the customer and unloading the goods. The transports are assumed to be done by a 40 ton gross weight truck, which performs 26,5% of empty kilometers (European Commission DG for Mobility and Transport, 2011; Freight Best Practices, 2005).

The result is the following cost structure: $C_R = C_{LT} + C_H * d_r + C_{UT}$

With:

- C_R = cost of unimodal road transport

- C_{LT} = cost of loading truck

- C_H = cost of haulage by truck

- d_r = distance of haulage by truck

- C_{UT} = cost of unloading truck

3.1.2 Intermodal transport (C_I)

In the intermodal transport case, several steps are added to the supply chain. This results in a more complex cost structure, which will be illustrated in the next paragraphs.

3.1.2.1 Pre- and / or post-haulage

Where neither the supplier as the customer warehouses are located near an inland waterway, pre- and post-haulages are needed. These haulages are assumed to be done – due to the weight and volume of palletized goods – by motorized vehicles. Depending of the size of these vehicles – going from a regular van to a truck with trailer – 8 to 34 EURO pallets can be transported. This number varies when EURO and INDUSTRIAL pallets are mixed, or when only INDUSTRIAL pallets are transported.

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For the analysis, the assumption is made that the possible pre- and / or post-haulage are executed by a 40 ton gross weight truck, as it is the case for the unimodal road transport. Due to the lack of a backhaul, an assumption of 100% empty kilometers is made. The handling costs of (un)loading the truck are also included, which results in the following equation:

$$C_{LT} + C_{PH} * d_{ph} + C_{UT}$$

With:

- C_{LT}= cost of loading truck

- C_{PH}= cost of pre-or post-haulage by truck

- d_{ph}= distance of pre-or post-haulage by truck

- C_{UT}= cost of unloading truck

3.1.2.2 *Transhipment cost of (un)loading the barge (C_{LB})*

Whereas the loading and unloading of palletized goods into a truck are very optimized, the transhipment techniques of these goods to a barge are not yet. Within the framework of various practical experiments, different transhipment techniques for loading and unloading the barges were tested. The used techniques influenced the final transhipment cost. These costs also vary with the used type of barge, the type of goods (fragility and volume), the weather sensitivity of the goods, the quality of the pallets and the tidal characteristics of the inland waterway. Through this, the costs are spread in a range going from € 0,5 to € 6 per ton (De Munck, 2010; VIM,2012b).

Table 4 gives a brief overview of the practical experiments. Both forklifts and mobile cranes appear to be good handling techniques when optimized technically. The transhipment volumes vary between 120 to 180 pallets per hour. At this tempo, it takes approximately one day to fill a barge of Rhine Herne Canal type (1350 ton).

Mobile cranes are in an initial phase more expensive than forklifts (VIM, 2012b). Therefore the cost structure assumes the use of forklifts. Additionally, it assumes a same average loading rhythm as stated and it includes the waiting time of the barge (Verbeke, Cornillie & Macharis, 2007).

Table 4 : Results of practical experiments (PE) (source: Verbeke et.al., 2012)

Experiment description	PE 1	PE 2	PE 3	PE 4	PE 5	PE 6	PE 7	PE 8	PE 9
Transhipment technique	Crane + pallet hook 1	Auto crane	Forklift	Crane + pallet hook 2	Crane + pallet hook 3	Crane + pallet hook 3	Crane + pallet hook 3	Forklift in hold & on quay	Forklift in hold & on quay
Average ton/h	45	90	150	120	150	180	120	160	120
Average €/ton	6	3,5	0,66	2,75	1,2	1	1	0,5-0,8	1

The cost can be diminished by reducing the transhipment time. On the one hand, this can be done by increasing the transhipment volumes, but as can be seen in Table 4, the transhipment techniques seem to have reached their volume limits. On the other hand, smaller barges can be used to reduce the transhipment volumes and consequently the (un)loading time. For the last, a part of the benefits of economies of scale are lost in the main-haulage of the supply chain.

A last innovative technique is to couple the crane to the barge, as it is the case with the 'Bierboot' and the 'Vracht door de gracht' barge. The main advantage of this innovation is that the handler has a better overview of both the quay as the cargo space of the barge, whereas the handler of a mobile crane located on the quay lacks the overview of the whole cargo space of barge. An extra staff member is needed to assist the handler in such cases. Also in cases where forklifts are used, minimal 2 staff members are needed to do the handling (one on the quay and one in the barge). Thanks to the innovation of barges equipped with cranes, investment cost in mobile cranes or in forklifts and the additional hiring of an extra staff member can be saved. The investment in the construction of the barges equipped with a crane is on the other hand a lot higher than the investment costs in normal barges. The reduced range and flexibility of such barge-cranes are other disadvantages of this innovation. Nevertheless plans for such new Belgian barges equipped with cranes are actually on the drawing board.

Figure 9 : Illustrations of loading and sailing of the barge (source: Verbeke et.al., 2007; VIM, 2012)

3.1.2.3 Possible extra costs and added value at RWDC

The regional water-bound distribution centres function in the first place as hub where the palletized goods are transhipped from and to the barge. However, in many cases some storage of goods will be inevitable. Therefore, storage place should be included in the RWDC site. Depending on the value and weather sensitivity of the goods, some investments will be necessary to ensure the safety of these palletized goods.

Additionally, the pallets flows need to be managed to, so therefore extra staff should be hired.

As investments and extra costs on staff are necessary, the RWDC should be used as a step in the supply chain where some added value is created (VIM, 2012).

Firstly, the storage in itself can be such a created added value. It adds costs to the intermodal supply chain, but it can be a cost gaining activity when customers or producers pay for it as it saves space and costs at their warehouses. Sudden peaks in demand can also easily be absorbed, as the palletized goods are closer to the location of delivery.

Secondly, thanks to the use of a RWDC, one other distribution centre can be economized through direct deliveries to the RWDC.

Thirdly, pallets of different stakeholders can be bundled into one barge or pre- or post-haulage. This will save transport related financial and external costs.

Finally, another possibility to create added value is for example flexible opening hours of the RWDC (VIM, 2012).

The initial theoretical feasibility study assumed that a minimal RWDC turnover of 100 000 pallets per year, or circa 100 000 to 120 000 ton per year – assuming an average load of 1 to 1,2 ton per pallet – would be needed (VUB & COM*i*SOL, 2006). According to the more recent results of a practical experiment of the 'Build Over Water' project, the minimal needed turnover of a RDWC is however estimated at 200 000 to 250 000 ton per year. When the RWDC can combine the shift of palletized goods with other logistic activities, than the minimal turnover reduces to 75 000 to 100 000 ton/year (VIM, 2012b).

3.1.2.4 Main-haulage by barge (C_B)

The main-haulage via the inland waterway might be done by different types of barges. Different tests have been performed in the past years, using a 'Kempenaar' (practical experiment 1 in 2006), a pontoon (practical experiment 3 in 2007) and a 'Rhine Herne Canal'. Depending on the barge type, respectively 500, 420 to 1125 pallets can be transported, when the palletized goods are stackable.

The sailing costs of the pontoon turned out to be too high (approximately the double of the sailing costs of the other types). The 'Rhine Herne Canal' type is - thanks to economies of scale – cheaper than a 'Kempenaar'. The 'Rhine Herne Canal' type seems thus to be the most optimal barge type of the three (Van Dorsser, 2004; Verbeke et.al., 2007; VIM, 2012b), but it does not suits the inland waterways of class II. For transports routes which use these smaller waterways, a 'Kempenaar' is the most optimal barge choice.

The most efficient cargo space is a box shape. It can be expected– as more and more palletized goods will be transported via the inland waterways – that the barge types will become more adjusted to this kind of transport, or they will even be built specially for it. Plans for such new barges are actually on the drawing board. By the beginning of 2012, several small barges (300 ton) specially made for the transport of palletized goods will commute on the inland waterways.
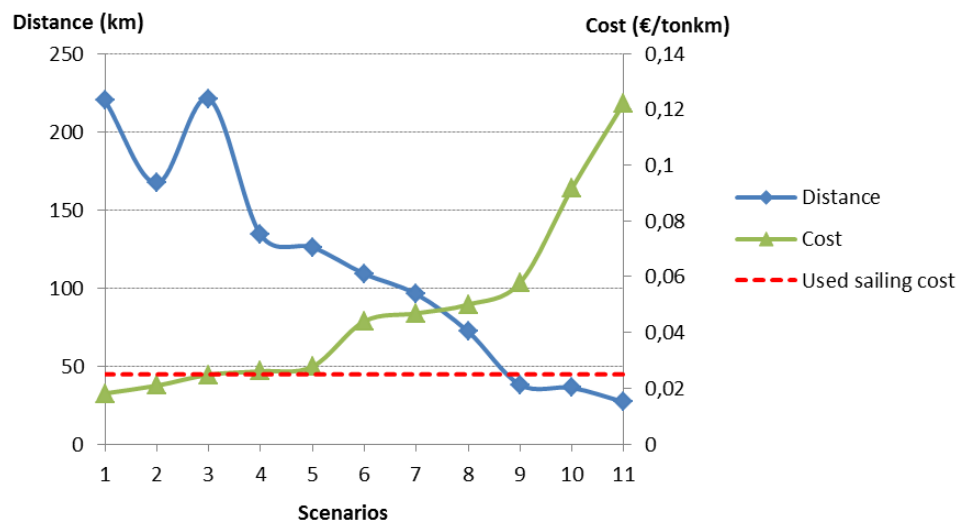
Figure 10 : Sailing cost barge versus distance main-haulage (source: Essenciál Supply Chain Architects, 2011)

The scenario's in Figure 10 are existing flows of palletized goods that are potentially available for a modal shift to the inland waterway. The used data are real commercial cost data offered by road and inland waterway transport companies (Essenciál Supply Chain Architects, 2011). Furthermore, it can be seen in Figure 10 that the sailing cost varies with the length of the main-haulage via the inland waterway. The financial cost depends heavily on the availability of barges close to the loading quay.

The used sailing cost is also indicated in Figure 10. A fixed average sailing cost is used. It is expressed in €/tonkm because – just like the unimodal and the pre-and post-haulages cost values – it depends on the route distance $(C_B * d_b)$.

with:

- C_B= cost of main-haulage by barge
- d_b= distance of main-haulage by barge

The value of the used sailing cost corresponds with a transport distance which can vary between approximately 120 to 220km. In the next paragraphs one will see that this interval includes almost all Belgian inland transports of palletized goods for which the modal shift is potentially profitable alternative.

Additionally, it is assumed that the transports are done by barges with an average load factor of 95% (Essenciál Supply Chain Architects, 2011; Groothedde et.al., 2005), and an average empty running of 24% (VMM, 2012). This last percentage is also confirmed by a market player.

3.1.3 Cost comparison

The following cost structure is obtained when combining the costs of the stated steps of the intermodal transport: $C_I = C_{LT} + C_{PH} * d_{pr} + C_{UT} + C_{LB} + C_B * d_b + C_{UB} + C_{LT} + C_{PH} * d_{po} + C_{UT}$

With:

- C_I= cost of intermodal transport
- C_{LT}= cost of loading truck
- C_{PH}= cost of pre-or post-haulage by truck
- d_{pr}= distance of pre-haulage by truck
- C_{UT}= cost of unloading truck
- C_{LB}= cost of loading barge
- C_B= cost of main-haulage by barge
- d_b= distance of main-haulage by barge
- C_{UB}= cost of unloading barge
- d_{po}= distance of post-haulage by truck

The difference between the cost of the intermodal transport (C_I) and the unimodal road transport (C_R) is illustrated in Figure 11. 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 a probable empty return-haulage has to be taken into account 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 (European Commission DG for Mobility and Transport, 2011 ; Freight Best Practices, 2005).
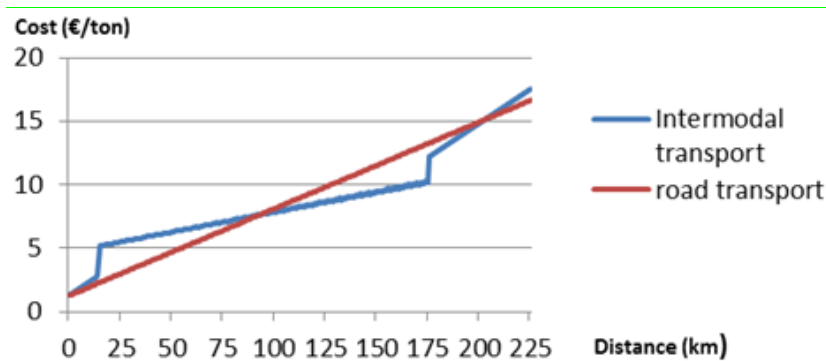
Figure 11 : Cost structure (source: own composition)

The additional transhipment costs at the RWDC (C_{UT}, C_{LB}, C_{UB} and C_{LT}) have a large impact on the overall cost 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, other break-even distance is 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.

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 scenario's can be analysed for different pre- and / or post-haulages distances (see Figure 12). The initial cost

contains the costs of the pre- and post-haulages and all the transhipment costs of both barge and truck.
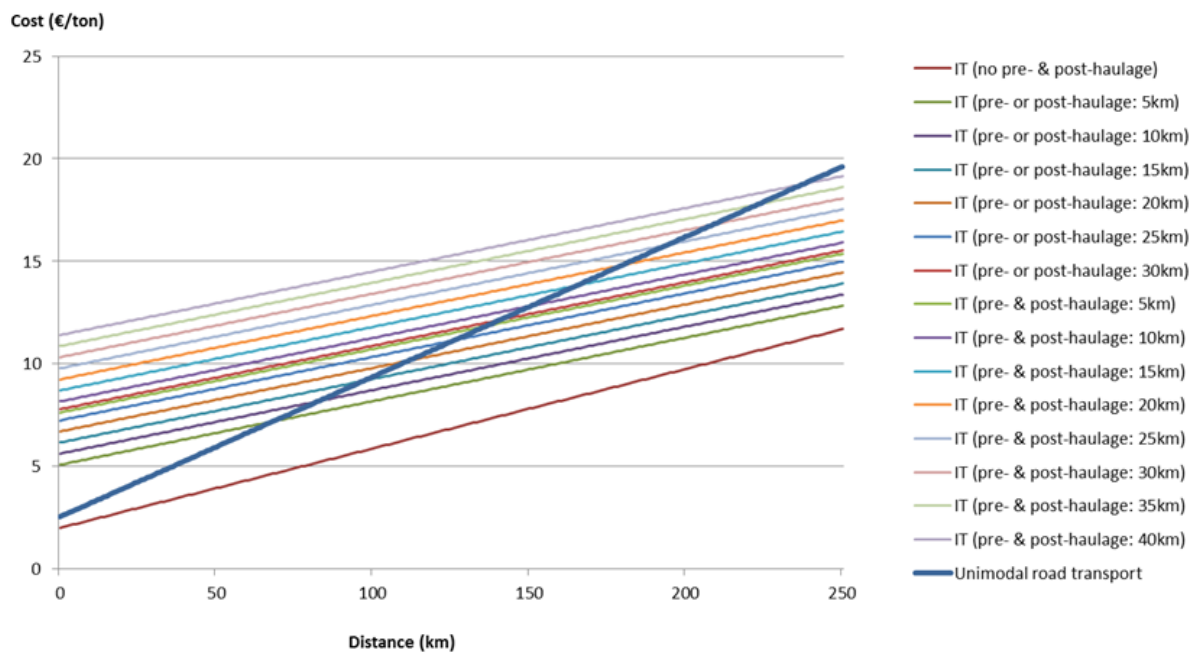
Figure 12 : Cost comparison unimodal road transport for pallets versus intermodal transport (IT) scenario's (source: own composition)

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.

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 scenario's (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 20%, which implies a decrease of the so-called tipping point to a more realistic 29,97 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, scenario's 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 (Cosemans, 2010).

3.1.4 Government aid

To improve transhipment and transport techniques and to set up good example, the Flemish government has set aside 1,525 million euro for the support of the modal shift of palletized goods to the inland waterway. The measure started in 2012 and will last three years (European Commission, 2011c; Waterwegen en Zeekanaal NV & NV De Scheepvaart, 2011).

The 1,525 million euro are divided into two investment incentives. The first one is the investment support incentive. Here, a maximum € 200 000 is spend per case over a period of maximum 3 years. It is allocated in a 80/20 partition, where the applicant pays 20% of the costs and the government pays the remaining 80%. The intention of this incentive is to stimulate innovations regarding transhipment and transport techniques, like for example to purchase or build new cranes or barges. The other incentive is designed to cover initial financial deficits in the transport part of the supply chain. If the applicant can prove that he or she runs a deficit (expressed in €/pallet), the government spends a sum which varies in time; from 80% of the deficit in the first year, to respectively 60% and 40% of the deficit for year two and three. The aid is only granted on the condition that both origin and destination are located in Flanders and that the financial surplus is not higher than 30% of the total transport cost. The evaluation criteria are taken into account the efficiency (availability of back-haulages), the volume, the viability of the project, the percentage of the volume of the applicant which will be shifted, the societal value and the employability (European Commission, 2011c; Waterwegen en Zeekanaal NV & NV De Scheepvaart, 2011).

3.2 CO_2-emissions

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.
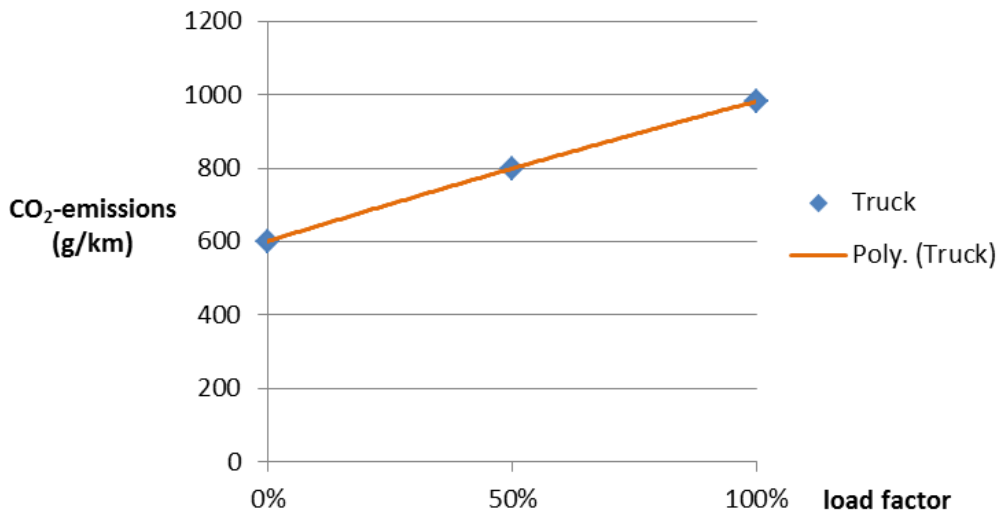
Figure 13 : CO$_2$-emissions for trucks 40ton gross weight, Euro V on average motorway in a hilly country (source: INFRAS, 2010)

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).

4   LAMBTOP

The above mentioned financial cost comparison indicates a financial potential for intermodal transport scenario's. Especially in cases where pre- and/or post-haulage distances are limited. The more, the decision of the Flemish Regional Government to support the modal shift of palletized goods to the inland waterways for the next three years, will boost the innovative concept.

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.

4.1   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. 14). If it is known that a departure and/or destination location is water-bound, this is included as such in the analysis.

Figure 14 : 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.
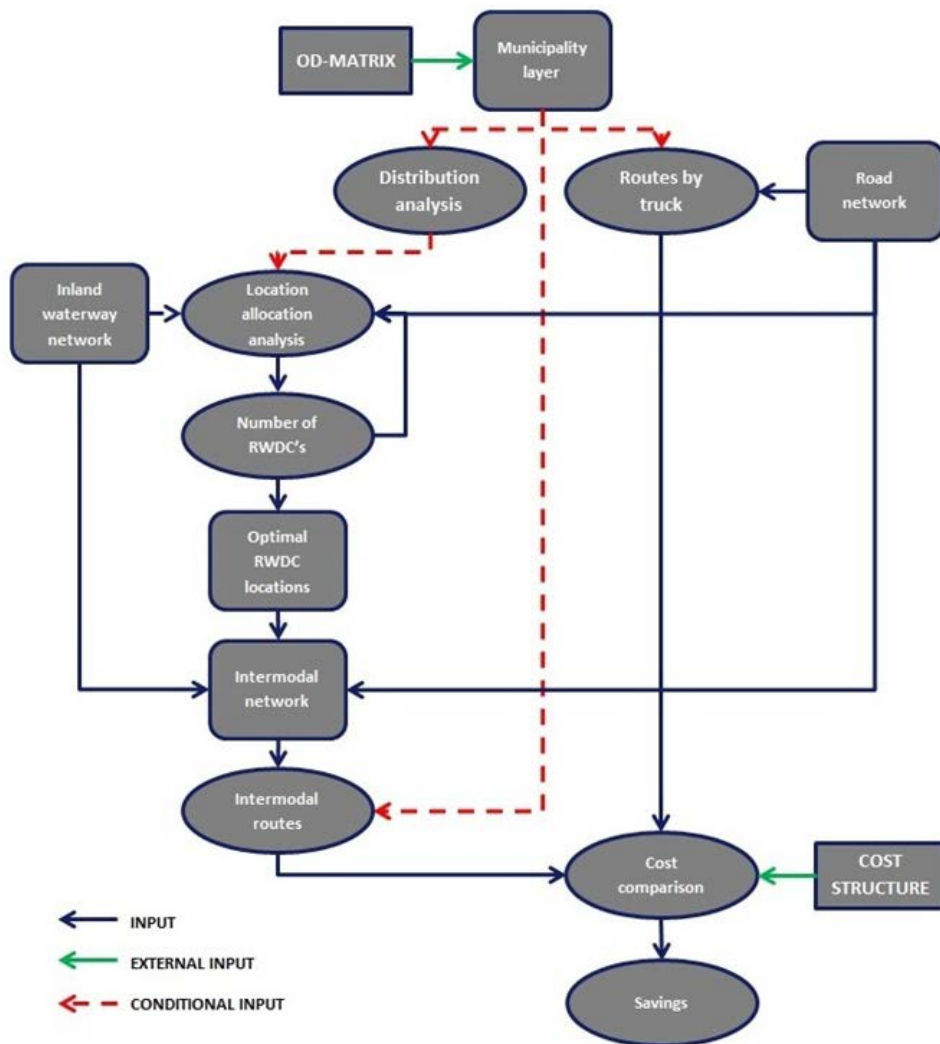
Figure 15 : LAMBTOP structure (source: own composition)

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. 15). 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).

In the calculations, transports shorter than 50km (straight) are excluded. This precondition is justified, given that no information is known about the use of water-bound sites by the supplier and by the customer. Moreover the origins and destinations are given at municipality level, so by consequence pre- and post-haulages are inevitable. This affects the cost of the intermodal transport

to such an extent (see section 3.1.3), that transports under 50km are not profitable in theory. If data are available on water-bound locations, and by this way on the avoidance of pre- and/or post-haulage, the precondition of 50 km can easily be removed from the model without further consequences.

The model also identifies the OD-combinations which meet the first precondition of 50km, and computes the routes travelled by road. 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 combinations that meet the above stated precondition and that start and arrive in these respective nodes. Next, a second 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 16). Within this analysis the buffer is fixed 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.

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 (150m) 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 most 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).

Predefined or existing RWDC locations can be integrated in the location analysis. They are seen as 'required' locations. The model will calculate additional most optimal RWDC locations assuming the existence of 'required' ones.

The most optimal locations of the RWDC's vary with the number of chosen RWDC's. This optimal number is determined on the basis of an analysis which optimizes the relationship between the minimisation of pre-and post-haulage distances and the minimisation of the number of RWDC's. 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 most 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 scenario's, like road pricing, an introduction of depot costs, administrative cost saving provide a further analysis.

4.2 Results

To identify the transport routes of palletized goods in Belgium, we used transport data for 2010 collected by ADSEI (Algemene Directie Statistiek en Economische Informatie). These data contain information about type of goods (container, pallets,…), the tonnage, tonkm, distance and the origin and destination (level of municipality) of the inland transports. No distinction can be made on the

goods itself. International transportations are also available, but not at the municipality level. They are therefore excluded from this analysis.

The data are obtained by a weekly at random sample of 1000 truck or trailers. All vehicles with a capacity of 1 ton or more are included, with the exception of agricultural, military and public vehicles. Every truck or trailer can be counted only once a year. The trailers are exhaustive questioned once a year, the trucks are on average questioned once every 2 years. The ADSEI data are thereby a clear indicator of the transport movements in Belgium and their tonnage.

In 2010, almost 53 million tons of palletized goods were transported via road within the Belgian borders, creating a OD-matrix of 11 244 combinations. This matrix is uploaded in LAMBTOP. No distinction can be made on the goods itself, so it cannot be known if the goods are palletized building materials or drinks which lend themselves for a potential modal shift, or if it are fresh products on pallets for which a modal shift is not applicable. The stated tonnages are in other words an overestimation of the real potential tonnages. Despite this data gap, the ADSEI data are still used as input, as they are a good indicator of the transport flows in Belgium and their volumes. Moreover, data on transport flows of 1,163 million palletized building materials within Belgium, show similar spatial concentrations (VIM, 2012b).

Due to the limited geographical information on origin and arrival location, these locations have to be spatially joined to the municipality centres. Consequently, pre- and post-haulage by truck and additional transhipments become inevitable. This affects the financial costs of the intermodal routes to such an extent that there is no prospect of developing intermodal transport of palletized goods over distances shorter than 50km. Under the current cost structure, one transhipment from truck to barge equals a break-even distance of 60,8 km (see Figure 12). The more logical option of taking 60 km or even 121,7 km – break-even distance equal to the cost of two transhipments – is disregarded, as we will in a later stadium of this research, study different scenario's in regard of the cost structure and possible water-bound locations of both producer and customer.

15,620 million ton of palletized goods survived this presumption of 50km, reducing the OD-matrix to 5 194 combinations.

The model identifies the origin destination combinations which meet the precondition of 50 km (straight), and the distribution locations are weighted with the sum of the tonnage of all these routes that start and arrive in that municipality. As one wants to limit the distances of pre- and / or post-haulage in prospect of the profitability of the modal shift, only the distribution locations within a buffer of 30km (via road) of an inland waterway are selected as the market area for the future RWDC's (red colour in Figure 16). Available literature (Cornillie & Macharis, 2006; Essenciál Supply

Chain Architects, 2011; Poppink, 2005) and own theoretical cost analysis (section 3) indicate that 30 kilometres of pre- and post-haulage is the ultimate maximum for the modal shift of palletized goods within Belgium.
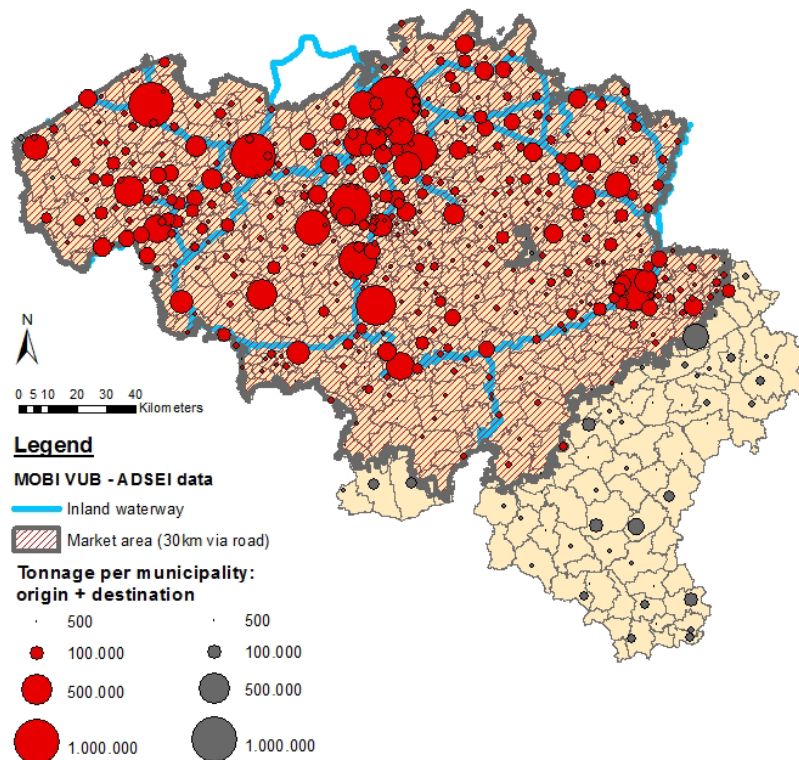
Figure 16 : Distribution analysis (tonnage per municipality) + potential market area

In general, the main Belgian cities (Antwerp, Bruges, Gent, Liège, Charleroi, Kortrijk, Mechelen, Mons, Hasselt, Brussels,…) and municipalities which locate major distribution centres (Halle and Ath for Colruyt; Nivelles, Sint-Katelijne-Waver and Kontich for Carrefour; Ninove and Asse for Delhaize and Bornem for Lidl,…) are representing the largest tonnages (Table 5). More general 4 main geographic concentrations can be distinguished, as can be seen in Figure 16. Firstly, there is a clear concentration in the south of the province of West-Flandres. Second main concentration is the so called ABC-axis (Antwerp, Brussels, Charleroi), going from north to south in the centre of the country. A third concentration can be found in the Kempen, in the north-east of the country. Note also the higher values there for the municipalities along the Albertkanaal (inland waterway). The last concentration is situated around the city of Liège. All 4 spatial concentrations are taken into account in market area for the location analysis of the RWDC's (red colour).

Table 5 : Distribution locations with the largest tonnages (source: own composition)

Municipality	Tonnage (departure + arrival of transports longer than 50km)	Municipality	Tonnage (departure + arrival of transports longer than 50km)
Antwerp	1 472 856	Beveren	380 602
Bruges	1 043 153	Bornem	375 399
Gent	1 007 885	Kontich	371 102
Liège	912 891	Mechelen	369 021
Asse	868 811	Genk	345 469
Nivelles	844 970	Spa	338 667
Halle	733 563	Veurne	311 989
Sint-Katelijne-Waver	696 183	Herstal	300 568
Ninove	644 621	Mons	293 219
Ath	463 666	Hasselt	287 050
Roeselare	443 613	Brussels	283 538
Charleroi	404 585	Tournai	279 594
Kortrijk	383 372	Leuven	246 526

As the represented tonnages of the distribution locations are equal to the sum of the tonnage of all these routes that start and arrive in that municipality, a total of 31,2 million ton is counted. More than 29,7 million ton or 95,2% of this 31,2 million ton is located within the 30 km buffer from an inland waterway. The spatial distribution of these 29,7 million tons will determine the most optimal RWDC locations.

Before calculating them, the Flemish inland waterway administrators (Waterwegen en Zeekanaal nv & nv De Scheepvaart) have delivered us 15 locations which they identified as potential RWDC locations. Additionally, they are looking for other potential RWDC locations in the area around Menen and the area around Roeselare. The 15 already selected lots are located in the following municipalities:

- Aalst
- Aalter
- Antwerp

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- Bree
- Dilsen-Stockem
- Geel
- Genk

- Hasselt
- Lummen
- Maasmechelen
- Meerhout

- Mol
- Ravels
- Tessenderlo
- Zwijnaarde

Initially, all those locations are entered in the location-allocation procedure as 'required' RWDC locations. The model calculates in such case the most optimal locations of additional RWDC's. A network of 25 RWDC's – combining the 15 pre-fixed and 10 calculated locations - is computed as being most optimal. They are listed in Table 6, with the tonnage they capture within the 'market area' (of 30 km).

Table 6 : Initial RWDC locations with their captured tonnage (source: own composition)

RWDC location	Captured tonnage	RWDC location	Captured tonnage
Antwerp*	4 367 566	Geel*	679 085
Aalst*	3 227 517	Ravels*	624 824
Liège	2 733 872	Genk*	530 140
Menen	2 242 234	Huy	431 473
Ittre	2 116 831	Lummen*	391 355
Leuven	1 981 221	Dinant	305 843
Aalter*	1 868 508	Bree*	286 836
Zwijnaarde*	1 524 992	Meerhout*	280 147
Mont-de-l'Enclus	1 223 115	Mol*	235 981
Charleroi	1 204 157	Dilsen-Stockem*	120 892
Mons	1 185 876	Tessenderlo*	119 831
Ostend	872 860	Maasmechelen*	115 725
Hasselt*	863 307	*delivered location	

While several locations capture more than one million tons, the least performing RWDC's are capturing only a tenth of this tonnage. Most of those last are pre-fixed locations. They are also located close to each other, sometimes even in neighbouring municipalities. As such, they act in the same spatial market segment, and their added value decline.

The most optimal intermodal network has less than 25 RWDC's. Namely, in this case 21 locations are selected. The (pre-fixed) RWDC locations of Genk, Meerhout, Tessenderlo and Maasmechelen are deducted. The remaining locations are retained. The only difference is an increase of the captured tonnage of several RWDC's (Table 7). Together they cover 99,3% of the 29,77 million ton. Each one of them operates more or less within its own market area.

Table 7 : Final RWDC locations with their captured tonnage (source: own composition)

RWDC location	Captured tonnage	RWDC location	Captured tonnage
Antwerp*	4 367 566	Mons	1 185 876
Aalst*	3 227 517	Geel*	959 231
Liège	2 738 817	Ostend	872 860
Menen	2 242 234	Ravels*	624 824
Ittre	2 116 831	Lummen*	498 002
Leuven	1 981 221	Huy	431 473
Aalter*	1 868 508	Bree*	340 321
Zwijnaarde*	1 524 992	Dinant	305 843
Hasselt	1 327 645	Mol*	249 431
Mont-de-l'Enclus	1 223 115	Dilsen-Stockem*	243 724
Charleroi	1 204 157	*delivered location	

The RWDC of Antwerp represents the largest potential. The RWDC of Menen and Liège are covering respectively the concentrations around Kortrijk and Liège, while the RWDC of Aalst and Ittre are capturing the tonnages of the several large distribution centres in the middle of the country. The other RWDC locations have a potential turnover that varies between 0,4 and 2 million tons. Bree,

Dinant, Mol and Dilsen-Stockem are representing the smallest potential tonnages. Still they meet the suggested the minimum turnover of 250 000 tons which would be needed for a profitable RWDC, assuming an upperlimit scenario (VIM, 2012).
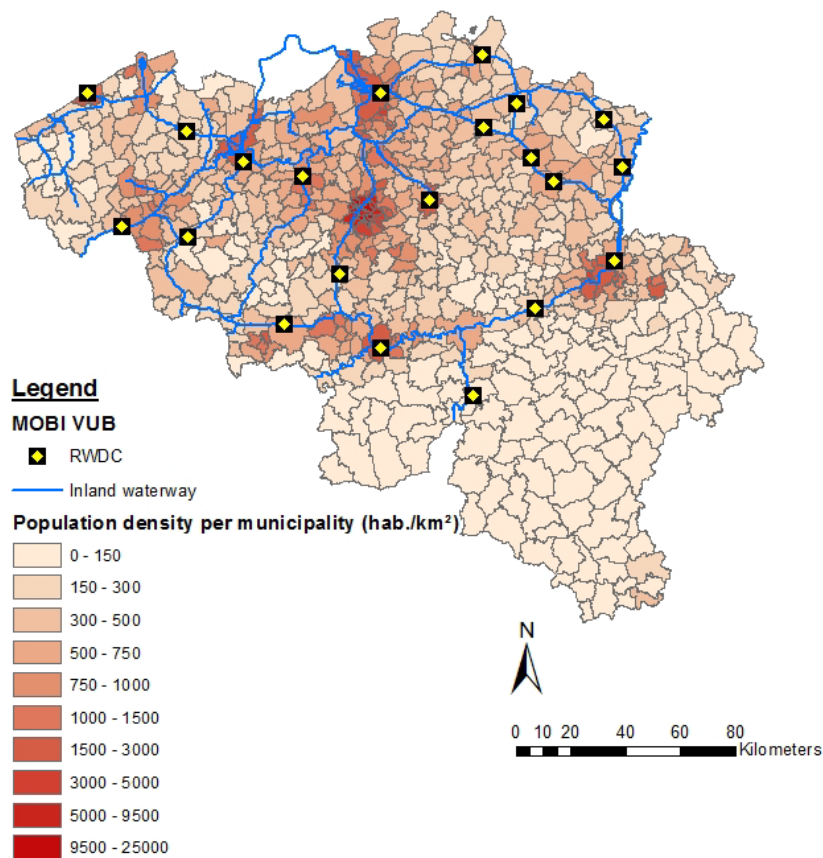
Figure 17 : RWDC locations and their market area relative to the population density

Figure 17 illustrates the most optimal RWDC's locations in respect of the population density on the municipality level. Most of the RWDC's are located in or close to a main Belgian city, as for example Antwerp, Aalst, Liège, Leuven, Hasselt and Charleroi. Consequently the future RWDC's can be integrated in visions for sustainable city distribution. They can function as multimodal city distribution centres, saving many trucks entering the city and reducing convergent caused external costs (congestion, emissions, accidents and noise). The last urban mile can then be bundled and organized by environmental friendly vehicles, such as electric ones.

In Table 6, the 'calculated' most optimal locations (on municipality level) are given according to the chosen number of RWDC's.

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**Table 8 : Most Optimal RWDC locations according the chosen number of RWDC's (source: own composition)**

Chosen number of RWDC's									
16	17	18	19	20	21	22	23	24	25
Kortrijk	Kortrijk	Menen	Menen	Menen	Menen	Menen	Menen	Menen	Menen
Ecaussinnes	Châtelet	Ecaussinnes	Ittre	Ittre	Ittre	Ittre	Ittre	Ittre	Halle
Liège	Liège	Liège	Liège	Liège	Liège	Liège	Liège	Liège	Liège
Leuven	Brussels	Leuven	Leuven	Leuven	Leuven	Leuven	Leuven	Leuven	Leuven
Ostend	Ostend	Ostend	Ostend	Ostend	Ostend	Ostend	Ostend	Ostend	Ostend
	Mons	Namur	Huy	Huy	Huy	Huy	Avelgem	Avelgem	Avelgem
		Péruwelz	Péruwelz	Mont-de-l'Enclus	Mont-de-l'Enclus	Mont-de-l'Enclus	Bernissart	Bernissart	Pont-à-Celles
			Sambreville	Sambreville	Charleroi	Charleroi	Charleroi	Charleroi	Charleroi
				Mons	Mons	Mons	Namur	Namur	Andenne
					Dinant	Dinant	Dinant	Dinant	Dinant
						Bruges	Bruges	Bruges	Bruges
							Seraing	Seraing	Liège²
								Visé	Visé
									Bernissart

The most optimal RWDC locations are integrated in a new created intermodal network. Once this network is built, the model calculates the optimal routes. Therefore, it uses a shortest time path algorithm for the pre- and post-haulages via road, and a shortest distance path algorithm for the main-haulage by barge. The routes are calculated for all 5 194 OD-combinations which meet the initial pre-condition of 50 km route distance (straight). The average route distance of the intermodal transport of these 5 194 OD-combinations is 182 km, of which on average 141 km is performed by barge. The remainder 41 km are the sum of pre- and post-haulages, and they are done by truck. The average uni-modal transport via road has a length of 116 km. The difference in average lengths is logical as the intermodal transport is mostly confronted with a detour to the RWDC's. Additionally, the road network is much more dense than the inland waterway network. The last one is characterized by roughly two east-west-axes and four north-south-axes (see Figure 17), whereby many intermodal routes face longer distances through detours caused by this spatial structure. The high ratio between the transport distances of the intermodal transport and the unimodal road transport affects the cost ratio between them, as the cost structure is based on the transport distances.
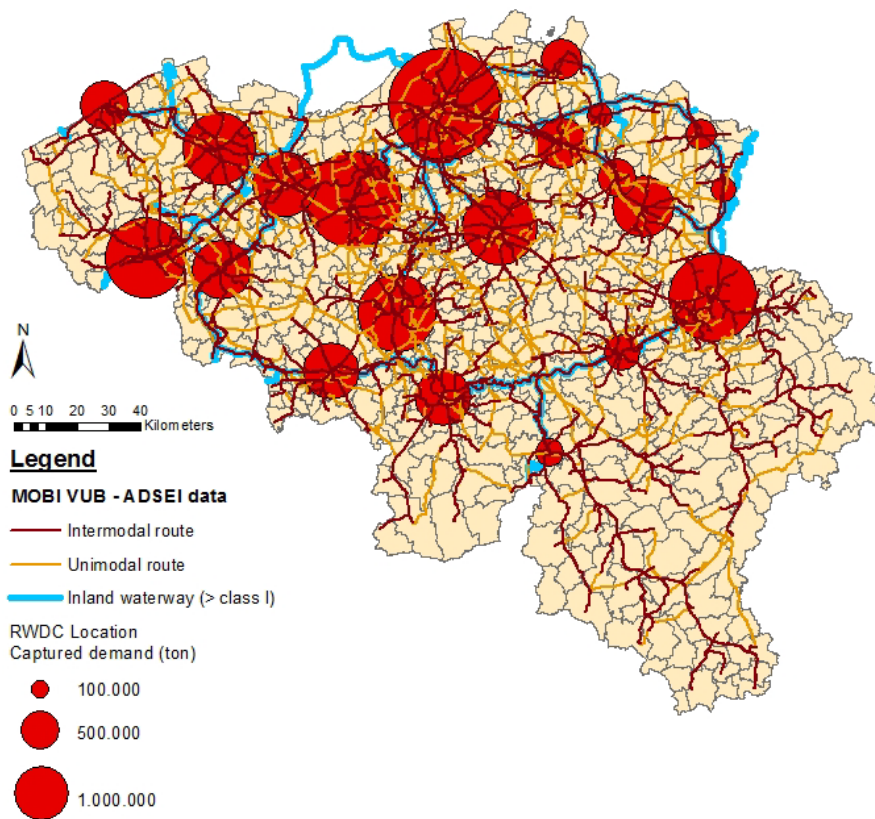
Figure 18 : Overall potential turnover of RWDC and the unimodal and intermodal routes

By taking a closer look at the cost structure, different scenario's can be made based on the same analysis as Figure 12 in section 3.1.3. The difference with this Figure 12, is that the scenario's are more realistic by assuming that the distance of the main-haulage by barge is 20% longer than the distance of the unimodal transport by truck, as the comparison of the reality of the 5 194 OD-combinations illustrates.
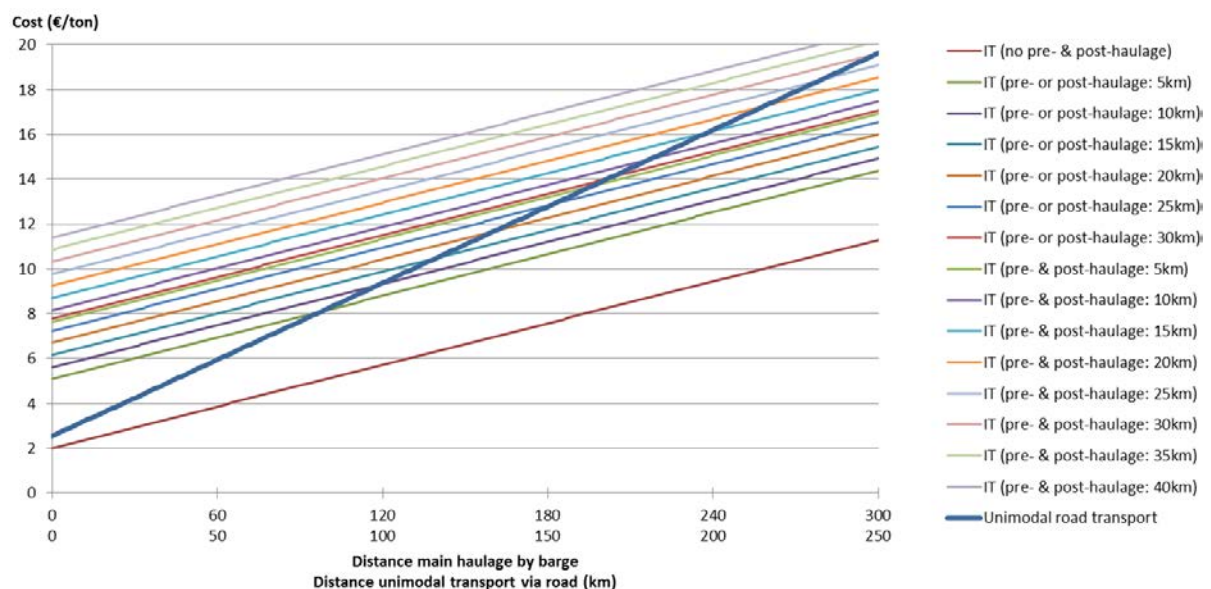
Figure 19 : Cost structure with different scenario's of pre- and post-haulages (source: own composition)

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Figure 19 shows this new comparison of the cost of the intermodal route versus the cost of the unimodal transport. When both producer and customer are located near the inland waterway – 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 stays 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. With the mentioned 20% distance ratio, the break-even distance is 82 km.

When looking to the scenario's, it can be seen that once the distances via road are long (minimum longer than 82 km) intermodal transports with a short pre- OR post-haulage are profitable. For transports where both pre- and post-haulages are needed, a minimal break-even distance of 164 km is needed.

To have a realistic view on the potential of the concept, the intermodal and unimodal routes were linked with the cost structure, which resulted in a profitability analysis for every individual route. Additionally several scenario's were analysed to illustrate their respective impact and also to test the robustness of the results. Due to data limitations, the analysis is initially performed assuming both pre- and pot-haulage for every OD-combination.

The overall results show that today almost 56 000 tons of palletized goods can be transhipped via the 21 most optimal RWDC locations to the inland waterways at a profitable cost. This number represents over 2000 fully loaded trucks, that would do short pre-and/or post-haulages instead of long main-haulages. It also demonstrates that the current concept of a modal shift of palletized goods – without subsidies and improvements - has a potential position in the market. The introduction of administrative costs savings almost doubles the profitable tonnage (96 353) and consequently also the number saved main-haulages. By replacing the truck – as main transport mode – by a barge, the transport related negative impacts on society, economy and environment will also decline. The potential savings in transport related CO_2-emissions are calculated within this analysis. The modal shift of the profitable routes – using the general cost structure – will save 221 tons of CO_2. In a scenario where administrative cost savings are assumed, the potential CO_2 savings increase to a total of 512 tons.

Table 9 proves the importance of the transport lengths of the different transport modes are playing in the profitability of the modal shift. The transport lengths of the 14 profitable OD-combinations are on average much longer and the ratio is smaller.

Table 9 : Comparison of averages distances (source: own composition)

Average distance \ OD-combinations	14 OD-combinations	5 194 OD-combinations (no scenario)
Intermodal transport distance (km)	231,8	181,9
Pre- and post-haulage distance (km)	16,5	40,6
Main-haulage by barge (km)	215,3	141,3
Unimodal road transport	194,9	116,1
Ratio (main-haulage by barge/unimodal road transport)	1,10	1,22

The spatial distribution of these profitable transports (Figure 20) is marked by proportionally diminished turnover of the RWDC's of the centre of the country.
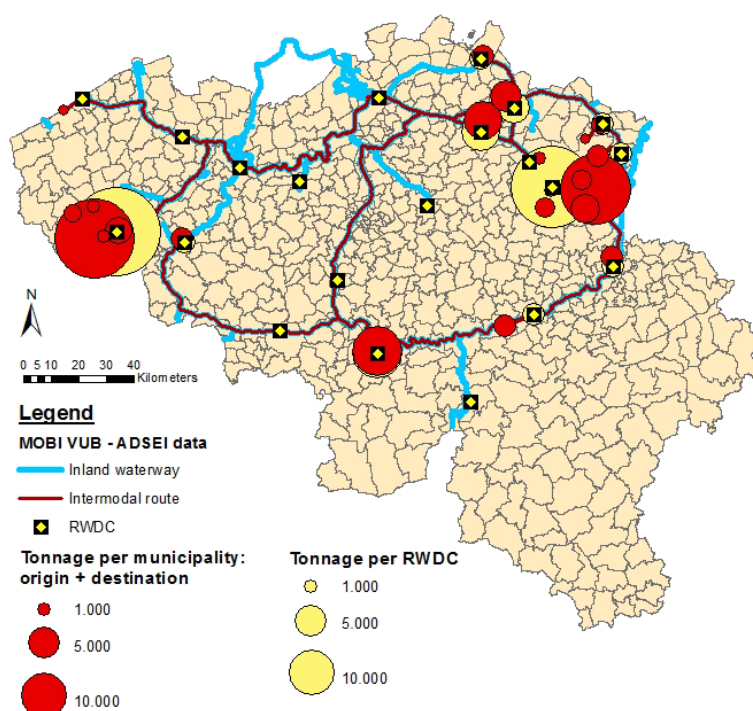
Figure 20 : Potential turnover of RWDC for the 14 profitable OD-combinations (source: own composition)

This once again illustrates the importance of the transport lengths. The transports which start or arrive in this central region cannot be that long, as the analysis is limited to the Belgian borders.

Additionally, the spatial structure of the Belgian inland waterways consists of roughly two east-west-axes and four connecting north-south-axes. Hence, the intermodal transports from or to the RWDC's of the central region have to travel firstly in the north-south direction and then tilt to the east or west. The ratio between the transport distance of the intermodal transport and the transport distance of the unimodal road transport is therefore high. As the cost structure is based on transport distances, the intermodal transports from or to the central region are structurally less cost attractive. An example of such transport is one from Brussels to Liège. The distance by road is approximately 100km, while the distance via the inland waterways is more than 180km long. The cost benefit of the barge transport per km is through this almost neutralized.

An introduction of a road pricing scenario, where a general implementation of a road pricing system conform the rate of the LWK-Maut in Germany (Blauwens, et.al., 2011) is assumed, will have an significant impact. The profitable modal shift will rise to more than 450 000 tons. The potential reduction in CO_2-emissions will increase even more spectacularly to 10 680 tons. This massive gain can be explained by the fact that the average loading factor plays an important role in the impact on which the road pricing affects the transportation cost. For example when a truck transports 25 pallets of 1 ton each, the effect of an introduction of a road pricing of 0,15 €/km will add 0,006 €/tonkm to the general cost structure. Meanwhile, when a truck is loaded with only one pallet of 1 ton, the introduction of road pricing will add 0,15 €/tonkm. The new profitable OD-combinations are by consequence mostly limited in weight. Moreover, the average loading factor also influences the CO_2 calculation. Additionally, scale effects have even larger impact on this calculation, which explains the more spectacular increase in CO_2 reduction.

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 combination of depot costs and the road pricing scenario gives a profitable outcome of 130 000, 95 000 and 80 000 tons, when respectively € 2, € 3 and € 4 are counted for the depot activities.

463 OD-combinations meet to the subsidy preconditions which state that the deficit cannot be larger than 30% of the total transport cost and that both origin and destination are located in Flanders. The aid can go potentially to 1,165 million ton of palletized goods, but it would cost the Flemish government just for the first year already 4,057 million euros.

Figure 21 illustrates the cost comparison between the (different steps of the supply chain of) the unimodal and intermodal alternative for 1 656 OD-combinations. These 1 656 are all the combinations which have a pre- and post-haulage distance of maximum 30 km. They are selected

from the original matrix of 5 194 OD-combinations. The boxplots include the necessary transhipment costs for each of the alternatives. It can be seen that the impact of the costs for pre-and post-haulage is large. The small range of the pre/post haulage boxplot is due to the limited variation in the pre- and post-haulage distance (maximum 30km). The figure, once again, illustrates the competitiveness of the barge transport in comparison with the unimodal road transport. Moreover, it has to be noticed that the boxplot of the intermodal transport has a strong overlap with the boxplot of the unimodal road transport, which demonstrates that the cost difference between both alternatives is limited.
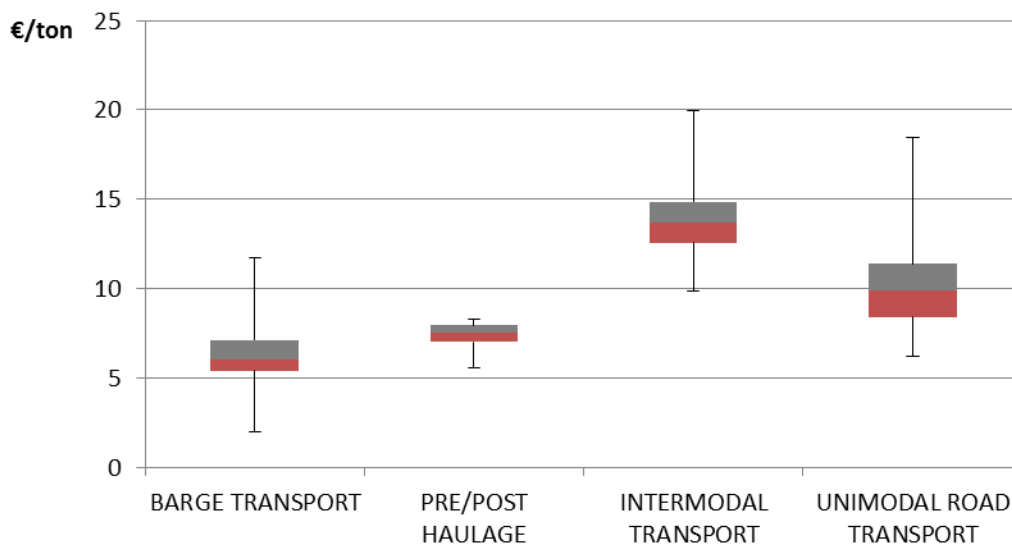
Figure 21 : Cost comparison of 1 656 OD-combinations (source: own composition)

The competiveness of intermodal transport is expected to increase in the future. First of all the contemporary transhipment techniques are mostly still in a test phase. It can be assumed that the transhipment costs will further decline in time as they become more efficient through better techniques, trained staff and commercial use. Secondly, the financial costs of road transport are expected to rise due to congestion, road pricing, rising fuel prizes and limitations on drive and rest periods (European Commission, 2011b). A third argument posits that the barge types will become more adjusted to the transport of pallets or even specially build for it. Plans for such new barges are actually on the drawing board. It is expected that for the beginning of 2013 several of such small barges (300 ton) specially made for the transport of palletized goods will commute on the inland waterways of the Benelux. Fourthly, the pre- and post-haulage can be optimized by using for example milk routes or direct deliveries to the RWDC instead of to an intermediate distribution centre. An sensitivity analysis has been performed to investigate the possible impacts the four stated arguments (see Table 10). Changes in the overall cost ratio (C_R/C_M) of the 5 194 OD-combinations are calculated for a shift of 5, 10, 15 or 20% in the cost of the four different parts of the transport (pre-

and post-haulage, (un)loading the barge, main-haulage by barge, main-haulage by truck) (Kim & Van Wee, 2011). Changes in the cost of loading and unloading the truck are not taken into account, because these actions are already very optimized (Essenciál Supply Chain Architects, 2011; Van Dorrser, 2004).

It can be seen that the largest impact is created when the financial cost of the road transport changes. The changes in pre- and post-haulage costs and in sailing costs have a similar impacts, which are almost three times smaller than the impact of ditto changes in the unimodal road costs. The impact varies with the ratio between the transport distances via road, waterway and pre- and post-haulages. The higher the distance of one of them, the larger his impact. The higher the overall distances of these three, the smaller the impact of the transhipment costs. As we selected only the OD-combinations which distances are longer than 50km (straight), the impact of cost changes of the transhipment to a barge is rather small.

Table 10: Sensitivity analysis (source: own composition)

Cost	Causes	± 5%	± 10%	± 15%	± 20%
Pre- & post-haulage	Groupage, milkroute, RWDC deliveries	± 2,14%	± 4,29%	± 6,43%	± 8,58%
Inland waterway	Capacity, type barge	± 2,08%	± 4,16%	± 6,24%	± 8,32%
Road	Congestion, road pricing, loading rate	± 5,96%	± 12,40%	± 19,37%	± 26,95%
Transhipment	tides, techniques	± 1,01%	± 2,02%	± 3,04%	± 4,05%

Finally as consequence of the data limitations concerning the departure and arrival locations, the assumption had to be made that pre- and post-haulage are inevitable. The tonnages are assigned to the municipality centres, which are by Tele Atlas defined as the main church of the corresponding municipality. Historically, churches are not located at the inland waterway to preserve them from floods. When the inland waterway is a navigable river, the distance between the river and the church can although be limited as the city centre is built at the river. If the inland waterway is a canal constructed by man, the distance to the municipality churches is often much higher. The higher the distance between church and RWDC, the higher the cost of the pre- and post-haulage part of the supply chain. In reality some of the suppliers and / or customers have of course a water-bound

location, through which a pre- and / or post-haulage can be avoided. The impact of water-bound facilities is tested in the next two scenario's.

4.2.1 Scenario 1

The first scenario argues that pre- or post-haulage can be avoided. This is done by only taking into account the OD-combinations of which the departure OR arrival municipality is intersected by an inland waterway. Then, the assumption is made that the supplier or customer who is located in such municipality has an water-bound site with quay facilities. Through this his or her pre- or post-haulage can be avoided.

On the other side of the supply chain there is still one pre- or post-haulage that has to be organized, so one still needs to implant RWDC's. Due to the speculative aspect of this first scenario, no new RWDC location-allocation analysis will be performed. Instead, the flows of the none water-bound part of the supply chain will be assigned to the 21 optimal location that are stated above.

Looking to the cost structure, the scenario seems potentially more feasible. The average cost deficit, of all OD-combinations which meet the preconditions of the scenario and have one pre- or post-haulage of maximum 30 km, is reduced to only 0,82 €/ton.
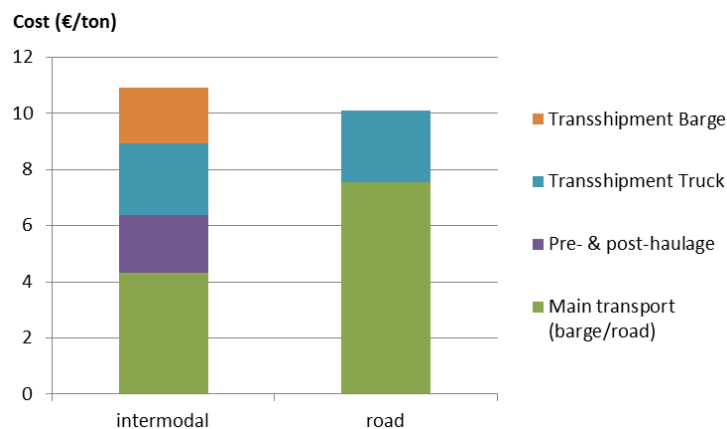
Figure 22 : Cost structure scenario 1 (source: own composition)

According to the used cost structure, 631 of these 2 432 OD-combinations are profitable. For them, there is an average cost benefit of 1,02 €/ton per OD-combination. If all 631 OD-combinations would be shifted towards the waterway 123 687 main-haulages by truck would be saved, and the 1,7 million ton of palletized goods would do their main-haulage by barge. This would save 1,6 million euros of direct transport costs. If these transports are shifted to the inland waterways, also save 4 273 ton of CO_2-emissions can be saved.
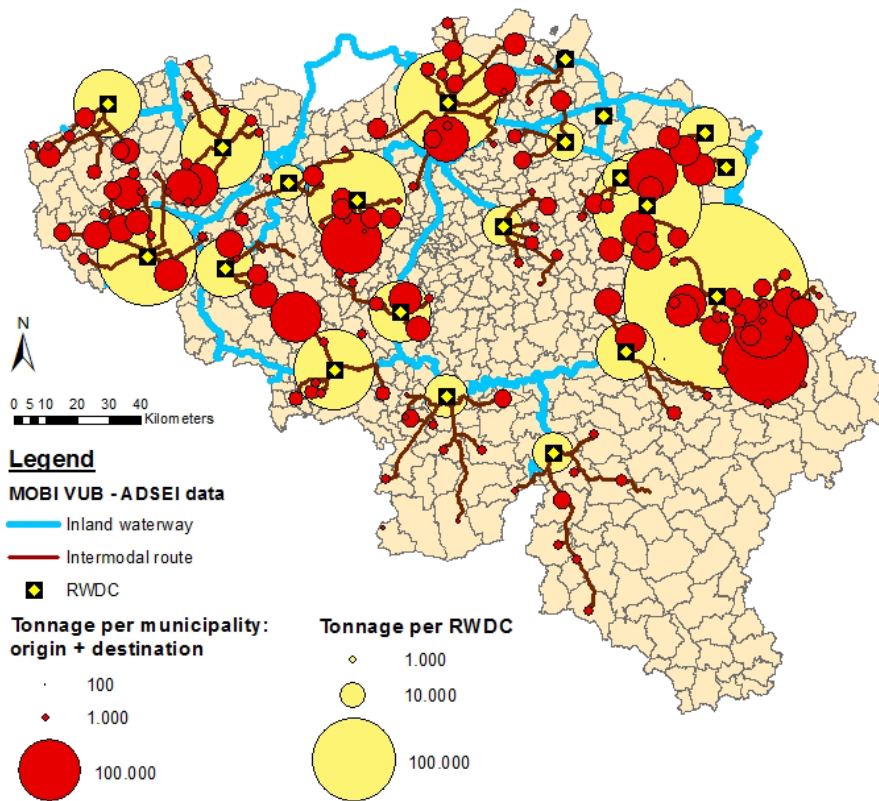
Figure 23 : Potential turnover of RWDC for the 632 profitable OD-combinations in scenario 1 (source: own composition)

The spatial distribution of the profitable transports (Figure 23) is marked by proportionally larger turnover of the RWDC's the west and the east of the country. This can once again be explained by the transport distance. The reason why the turnover of the RWDC of Zwijnaarde, Geel, Ravels and Mol is almost negligible, is because they are surrounded by several inland waterways. Therefore, the neighbouring municipalities are often also intersected by an inland waterway, and consequently the transports starting or arriving in these municipalities are assumed to be transhipped directly to that inland waterway, instead of transported to the closest RWDC.

4.2.2 Scenario 2

The second scenario is similar to the first one, with that respect that now pre- and post-haulages can be avoided. Therefore, only the OD-combinations of which the departure and arrival municipality are intersected by an inland waterway are selected. Following the assumption that the supplier as well as the customer are located along that inland waterway with quay facilities. The cost structure of scenario 2 is the most beneficial one, as the cost of loading and unloading the truck as well as the costs of pre- and post-haulages are avoided. Moreover the main-haulage by barge and the transhipments costs of the intermodal transport are both cheaper than their unimodal variant. In this scenario no RWDC's are needed, all the transports go directly from the supplier to the customer.
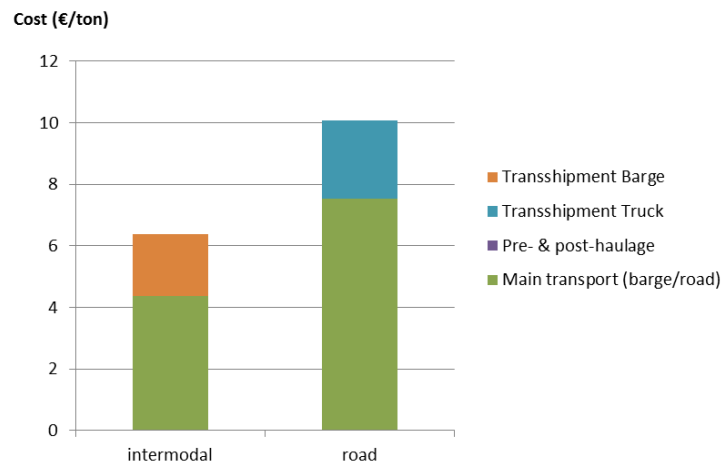
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Figure 24 : Cost structure of scenario 2 (source: own composition)

In total, 1 781 OD-combinations meet the preconditions of scenario 2. For all of them, the modal shift towards the inland waterways is an profitable choice. As the almost 5,850 million ton are nowadays transported by truck – including almost 545 thousand truck movements – their transhipment to barge would save almost 21,3 million euro of direct transport costs.

5   CONCLUSION

The innovative concept of transporting palletized goods via the Belgian inland waterways has gone a long way since the Distrivaart project in the Netherlands introduced the concept. In a first phase, a theoretical feasibility analysis (2006) illustrated a clear potential for palletized building materials and fast moving consumer goods. In the past years the theory was tested in practice. Through multiple experiments with different transport and transhipment techniques, the most optimal techniques and barge type could be picked out and a cost structure was developed.

This cost structure is based on transport related financial costs. Different cost scenario's – which include possible depot costs, administrative savings and an introduction of road pricing – are added in a later stage. Managing costs, investment costs and external costs (congestion, accidents, emissions,…) are not included. The cost structure shows a very clear economical potential for the modal shift of transports of palletized goods when both producer and customer are located near the inland waterway. When only one or none of them has water-bound facilities – and consequently pre- and / or post-haulage are inevitable – a critical distance is needed before the intermodal alternative becomes cheaper than its unimodal road transport. This critical distance, or so called *break-even distance*, depends of the length of the pre- and / or post-haulages. It is obvious that the shorter these haulages are, the more (financially) feasible it will be to shift the palletized goods.

The used data are limited to the start and arrival municipality, no information is given on the possible water-bound location of the producer and customer of palletized goods. In other words a pre- and post-haulage have to be assumed.

If pre- and / or post-haulages are needed, one needs to implement transhipment hubs or so called regional water-bound distribution centres (RWDC). The locations of these RWDC's are crucial for the further development of the concept. Therefor we created a location analysis model (LAMBTOP). The model calculates the most optimal RWDC locations on the basis of the spatial distribution of the transport flows. Additionally it calculates the optimal transport routes for unimodal road transport, as for the intermodal alternative. This enables to compute the transport distances and therefore the transport related financial costs and CO_2-emissions.

In 2010, almost 53 million ton of palletized goods were transported within the Belgian borders by truck. All these truck movements contribute to expanding negative externalities (as congestion, pollution, noise nuisance and accidents) of road transport. As intermodal transport creates significantly less negative externalities, it can be said that every modal shift of even a part of the transport flows of palletized goods would be welcome. Moreover, the distribution analysis shows us that most of these flows are starting or arriving in cities or in municipalities which locate large distribution centres. Since the location analysis of the most optimal RWDC locations is based on this distribution analysis, the most optimal RWDC locations are logically situated near to the main Belgian cities and large distribution centres. By consequence, the innovative concept of pallets on the inland waterways could be combined with a multimodal and sustainable city distribution. The future (urban) RWDC's could then function as multimodal city distribution centres from which the last mile can be bundled and transported by sustainable transport modes.

Waterwegen & Zeekanaal nv and nv De Scheepvaart have already 15 locations in mind as being future RWDC's. These locations were included in the location-analysis. The LAMBTOP model kept 11 of the 15 locations as most optimal ones. Additionally it calculated that 10 more most optimal RWDC's are needed. In other words, the model advises 21 RWDC's. The overall potential tonnage which could be shifted to the inland waterways is 5,3 million tons, inasmuch we define the overall potential tonnage as the tonnage of transports which cover distances longer than 50km (straight) and for which the sum of the pre- and post-haulage is limited to maximum 30km (via road). If the overall potential would be shifted entirely to the inland waterways, 1 656 OD-combinations or approximately 478 000 main truck haulages would be reduced to short pre- and post-haulages. This would reduce the transport related CO_2-emissions by 17 733 tons.

Once the cost structure is applied, several of the intermodal routes are profitable in comparison with their unimodal road alternative. Data limitations have a large impact on the profitability. That is why we worked with two scenario's which assume possible avoidance of pre- and / or post-haulages. As a result, the profitable modal shift is much higher in these scenario's. Several producers of building materials are located at an inland waterway, so there is clearly a potential there.

Besides, the initial modal shift can be doubled by including the obtained costs reduction in the administration. One can obtain even larger profitable tonnages by introducing a general road pricing system of 0,15€/km. The modal shift grows in such cases with a factor 9.

It can furthermore be assumed that the costs of intermodal transport of palletized goods will decline in time, as the transport and transhipment become more efficient through better techniques, bundling, trained staff and commercial use. The subsidy of the Flemish government will also enhance the financial feasibility for a modal shift. Moreover, the cost of road transport is predicted to rise. Both evolutions are in favour of the intermodal transport alternative.

As conclusion, the financial feasibility is the largest threshold which the concept encounters. The subsidy of the Flemish government and transport cost evolutions will help to overcome this threshold. Still the pre- and post-haulages have to limited as much as possible. An enlargement of concept to the neighbouring countries will therefore dramatically increase the potential.

6 FUTURE RESEARCH

The current analysis limits itself to the inland transports of palletized goods in Belgium. As stated in the conclusion, the enlargement with transport flows from and to neighbouring countries would improve the economic feasibility, in terms of turnover volume as profitability of OD-combinations.

A second research goal is to search and find more detailed data. Firstly, concerning the OD-combinations, where we would like to obtain data regarding the water-bound locations of producer and / or consumers. Secondly, we want to obtain further specifications on the content of the goods themselves. Are we talking about fast moving consumer goods, building materials, or other volumes? What are the specifications concerning security, stackability and weather resistance of the goods? This will enable us to have a clearer view on flows which could be shifted and which not. Finally we want to update the actual cost structure with more data. Now it uses cost data which are obtained from different Flemish transport experts which accompany the several practical experiments. As more players enter the intermodal transport pallet market, it would be useful to obtain their commercial prices.

Another potential research track is to enlarge the external cost analysis. Firstly, with other main transport related emissions (like NH_3, SO_2, CO, NO_X, N_2O, TSP and CH_4) and noise nuisance. Secondly the transport time can be included in the analysis. This will make it possible to include congestion as an external cost.

Finally, we could make the link between this innovative transport concept and the concept of sustainable city distribution. The introduction of the available urban inland waterway in the supply chain offers a clear economic, societal and ecologic potential, as different mentioned projects illustrate.

7 MOTIVATION FOR COOPERATION

In order to verify the obtained results, we presented them to several public as private stakeholders. Their input (for example cost structures) and remarks, helped us to make the analysis the most realistic as possible. In the next paragraphs, we will give a short overview of the role of the different stakeholders.

7.1 Transport experts

We had contact with two transport experts. One of them is Ir. Filip Verbeke. He is transport counselor for nv De Scheepvaart/VOKA. He accompanies companies in terms of inland waterway transport, and this for the provinces of Antwerp and Limburg. Filip Verbeke has a lot of experience regarding the intermodal transport of palletized goods, as he accompanied most of the practical experiments. He gave us by consequence a lot of insight in the concept; its opportunities, thresholds and costs.

The other transport expert is Ir. Carl Verhamme. He works as expert and counselor for the Port of Brussels. In the past, he was involved in the transport of pallets via the inland waterways. This transport was performed by pontoons, which did not appeared to be possible at reasonable price. Now he accompanies the monthly intermodal transport of palletized building materials between Willebroek and Brussels. This transport saves 45 truck movements a month.

The Port of Brussels and Waterwegen en Zeekanaal got acquainted with the LAMBTOP and its results.

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