



Modal shift of palletized goods: a feasibility and location analysis for Europe

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Abstract

The modal shift of palletized goods to the inland waterways proved itself feasible for Belgium, but comes with a break-even distance. Geographical up-scaling should enhance the potential for such shift. The existing model is therefore enlarged to the European scale. Additionally, a Total Logistics Cost model was included. Results show that the potential gains are lower than expected. Mainly because previous research included only direct transport costs. The incorporation of the total logistics costs enabled us to obtain new insights in which the relation between the profitability and different commodity characteristics influence the feasibility and to which extent analyse.

Keywords: Intermodal transport of pallets, Location Analysis Model, Total Logistics Cost Model.

1. Introduction

Palletized goods are mostly transported by trucks, generating negative externalities like congestion, pollution, noise nuisance and accidents. Our daily lives are affected by those externalities, which can be expressed as social, ecological and economic costs. Intermodal transport by barge is also generating those externalities and related costs, but at lower levels than unimodal road transport (den Boer et al. 2011). The realisation of a modal shift of palletized goods to barges will, by consequence, contribute to a more sustainable transport system.

Pallets are used as loading unit for approximately 23 per cent of all freight transported (internal, import, export and transit) in Belgium (ADSEI 2010). To speak in terms of volumes; yearly over 67 million tons of palletized goods are transported on the Belgian roads (ADSEI 2010) and even over 23.523 million tons in Europe¹ (ADSEI 2011). Not all of those goods lend themselves to a modal shift towards the inland waterways.

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¹ [Reporting countries: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Estonia, Germany, Greece, Finland, France, Hungary, Latvia, Lichtenstein, Lithuania, Luxemburg, Netherlands, Norway, Poland, Portugal, Romania, Spain, Slovenia, Slovakia, Sweden, Switzerland.]

However, according to previous research (VUB and COMiSOL 2006) some goods do lend themselves to such a modal shift. Two main sectors were identified as pioneers, namely the construction sector and the sector of the Fast Moving Consumer Goods (FMCG). Although this identification was mainly based on common sense, the construction section was nonetheless chosen for feasibility analyses with the LAMBTOP (Mommens and Macharis 2014) and for several practical experiments in Belgium (Verbeke et al. 2007; Verbeke et al. 2012; VIM 2012). Different types of transhipment techniques and barges were used during these experiments to optimise the modal shift. The experiments resulted in a cost structure used in this analysis. Currently, palletized building materials are also operationally shifted to the inland waterways, namely on seven fixed (A to B) transports. In the region of Paris (France), palletized building materials are even operationally transported with a barge since 1987 (Sétra, 2008).

The second identified sector – the Fast Moving Consumer Goods – is more diverse. Based on experience in the Netherlands and France – with the ‘Distrivaart’ project (Groothedde et al. 2005; Poppink 2005), the ‘Beerboat’ in Utrecht, ‘Vracht door de Gracht’ in Amsterdam and with Franprix in Paris – we conducted in 2013 an economic feasibility analysis for a modal shift of palletized FMCG for the Brussels Region (Mommens et al. 2014). In total, 26 large generators of palletized FMCG were interviewed, and 14 amongst them shared their transport data. Cost-efficient volumes were found for palletized drinks, confirming the results of the previously mentioned studies and experiences in the Netherlands.

However, as many customers and suppliers are not located at the waterfront, pre- and post-haulages will be necessary. The mentioned projects, other studies (Cornillie and Macharis 2006; Van Dorsser 2004) and experiences (Verbeke et al. 2007; Verbeke et al. 2012; VIM 2012) have demonstrated that the length of both pre- and post-haulages has a large impact on the economic feasibility of the modal shift of palletized goods. The locations of the transhipment hubs are by consequence – as they define these lengths – a critical success factor of the concept (Arnold et al. 2001; Aykin 1995; Kayikci 2010). The need for a substantiated determination of those locations arises. Additionally, it is important, for both public as private sector, to know the economic and ecologic potential of an implantation of those transhipment hubs.

In order to answer to the above stated needs, we developed the LAMBTOP (Mommens and Macharis 2014). LAMBTOP determines the optimal hub locations and the optimal number of hubs on the bases of the transport flows. Moreover, the model gives the financial cost of the modal shift and the potential turnover (in ton) for every hub. LAMBTOP proved that intermodal barge transport of palletized goods is feasible within Belgium (Mommens and Macharis 2012; Mommens and Macharis 2014). However, this feasibility comes with a break-even distance. Break-even distance is the distance at which the costs of intermodal transport equal the costs of unimodal road transport (Rutten 1998). By up-scaling the concept to a European scale, it can be expected that the potential modal shift will enlarge, as longer transports are included. The research and results of this geographical up-scaling are presented in this paper. Moreover, a Total Logistics Cost (TLC) model is incorporated in the LAMBTOP. It enables us to have a more realistic estimation of the economic potential of the concept. By including different parameters, it allows us to analyse their impact, as well as to identify the parameters and commodity characteristics which influence the modal choice the most.

We start this paper by describing the methodology in Section 2. The section consists of two parts. First, the up-scaling and the adaptations made in the LAMBTOP methodology are explained. In the second part, a TLC-model is described which we integrated into the LAMBTOP. The obtained results based on data on palletized goods transported within Europe in 2011 are discussed in section 3. We end with the conclusions.

2. Methodology

Many suppliers and customers of palletized goods are not located at the waterfront. In order to catch the volumes which they are generating, a network of transhipment hubs needs to be created. The optimal location of those transhipment hubs is determined by the LAMBTOP model. The methodology, the changes made and the geographical enlargement to the European scale are described in Section 2.1. Besides the optimal locations, the model also calculates the financial costs of the modal shift and the potential turnover (in ton) for each of the transhipment hubs. A TLC-model is integrated in the model to do so. This TLC-model is described in Section 2.2.

2.1 Location Analysis Model for Barge Transport Of Pallets.

The LAMBTOP is a GIS-model (Geographic Information System). The model was originally constructed for the Belgian territory, but it has been enlarged to a European scale for this research.

The model uses three inputs. Firstly, GIS-layers representing the different transport networks. For barge transport, the inland waterways with a CEMT class of II (~600ton) and higher are used. The road network, on the other hand, includes all European main roads. The road network is used for the calculation of both unimodal transport, as for the pre- and post-haulages in the intermodal alternatives. The last GIS-layer contains the locations of all origins and destinations. All three GIS-layers are represented in Figure 1.

The second input of the LAMBTOP is an origin-destination-matrix (OD-matrix) containing the considered palletized transport flows and volumes. A cost structure is the third and final input. These costs are based on the previously mentioned practical experience and on the TLC-model, developed by Lestiboudois and Macharis (2013). The TLC-model will be discussed in Section 2.2.

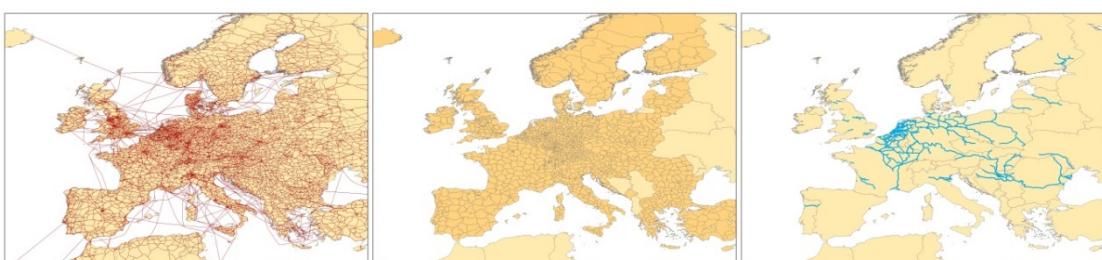


Figure 1: The input layers in ArcGIS.

Source: own composition.

The LAMBTOP uses different steps to calculate the optimal transhipment hub locations and the financial costs of both unimodal, as the intermodal transport alternative. A more detailed description of those steps can be found in Mommens and

Macharis (2014). For this research, the different steps will be explained only briefly. Some changes in the methodology were made and those will be described more profoundly.

The model starts with the distribution analysis of the volumes from the OD-matrix. On the one hand, it enables us to detect spatial concentrations or clusters. On the other hand, the distribution analysis is used to determine the optimal locations of the transhipment hubs. Those optimal locations are calculated in step 2. The location analysis is based on the p-hub median problem (Campbell 1996; ESRI 2014; O'Kelly 1987; O'Kelly et al. 1994), where the costs of pre- and post-haulages of all volumes originating from the different origins and arriving at the different destinations located within a predefined range of the inland waterways are minimized. By using this geographical limitation, the transported volumes of which the origins and/or destinations are located far away from an inland waterway –these volumes will not show any potential for a modal shift – will not influence the location analysis. The used distance is based on the limits determined by the cost structure, and is set on 75 kilometres distance for the European scale. The potential transhipment hub locations are identified as a continuous selection of points every one kilometre along the inland waterways. The optimal number of transhipment hubs is determined by the volume caught by the network of transhipment hubs and the cost-efficiency of a modal shift of this volume. For this calculation an intermodal network needs to be constructed, in which the optimal intermodal routes are calculated. The intermodal routes are based on the Dijkstra algorithm (1959), combining the minimisation of the transport time for the pre- and post-haulages and a minimisation of the distance for the transport via barges. The model takes into account the inland waterway classification, as the transport is assumed to be performed by the type of barge – being Kempenaar (50 x 6, 6 x 2,5 meter), Rhine-Herne-Canal (80 x 9,5 x 2,5 meter) and Big Rhine Barge (95 x 11,4 x 2,7 meter) – which matches the lowest class along the inland waterway route. The unimodal routes are calculated via a minimisation of the transport time using the same algorithm of Dijkstra. Previously, the LAMBTOP calculated the optimal number of hubs on the bases of all volumes accorded to the network of transhipment hubs. This has been updated as it currently also takes into account the financial potential for a modal shift of the volumes. The model uses a TLC-model to do so. The final step of LAMBTOP is a sensitivity analysis using different scenarios in the TLC-model. The TLC-model is described in Section 2.2, whereas the scenarios are described in Section 3.

2.2 Total Logistics Cost Model.

The Total Logistics Cost (TLC) model was originally developed to complement the existing LAMBTOP model with a tool that simulates the modal choice decision of companies shipping palletized goods. The modal choice model was developed from the supposition that the choice of a particular transport alternative impacts the logistics costs of organizations in ways that exceed the costs of transportation. Besides the freight rates other modal choice variables such as the lead time, reliability, depreciation of goods, value of the goods, etc. are considered. Most notably, the cost of inventory held will be impacted as a result of the choice between a unimodal and an intermodal transport alternative. Consequently, a total logistics cost approach applying the Economic Order Quantity (EOQ) principles was used to model the modal choice process for palletized goods. This approach to modelling the modal choice decision

process, called the inventory theoretic approach, was first presented by Baumol & Vinod (1970). The structure of the TLC-model presented here was inspired by the second chapter of Daganzo – Logistics Systems Analysis (2005) but was further expanded to enable the incorporation of intermodal transport alternatives.

In the modal choice model the total logistics cost per pallet is calculated for a unimodal road alternative and one or more intermodal alternatives – use of different types of barges – through a cost function that includes both movement costs (i.e. transport costs and handling costs) and holding costs (i.e. inventory costs and costs for the rent of warehouse facilities). Furthermore, the model is constructed on four crucial assumptions that limit the extent to which results can be generalized and these assumptions need to be taken into account when interpreting the results of the analysis presented below:

1. The total logistics costs are simultaneously minimized by shipper and receiver (i.e. the receiver determines the (fixed) shipment quantity for each transport alternative and the shipper subsequently chooses the transport alternative that minimizes the TLC)
2. One-to-one distribution is the only possible form of distribution
3. Both production and shipment of goods at the origin are driven by demand (i.e. goods are only shipped from the shipper when an order is received from the receiver)
4. The magnitude of subsequent shipments is constant

Since the shipper and receiver minimize the TLC per pallet simultaneously, the model includes the waiting costs incurred by both the shipper and the receiver as the result of holding inventory.

The abstract mathematical equation for the TLC per pallet is then given below:

$$\begin{aligned} \frac{\text{TLC}}{\text{pallet}} &= \frac{\text{Movement costs}}{\text{pallet}} + \frac{\text{Holding costs}}{\text{pallet}} \\ &= \frac{\text{Transport costs}}{\text{pallet}} + \frac{\text{Handling costs}}{\text{pallet}} + \frac{\text{Waiting costs}}{\text{pallet}} + \frac{\text{Rent costs}}{\text{pallet}} = [c_f \times \frac{1}{v} + c_v] + [c'_v] + \\ &\quad [(c_w \times T_w^{\text{shipper}}) + (c_w \times T_w^{\text{receiver}}) + (c_w \times T_t)] + [(c_r \times A_{\text{shipper}}^{\max} \times \frac{1}{2} \times \frac{1}{v}) + \\ &\quad (c_r \times A_{\text{receiver}}^{\max} \times \frac{1}{2} \times \frac{1}{v})] \end{aligned}$$

*Rent costs are multiplied by a factor $\frac{1}{2}$ because the assumption is made that pallets can be stacked in 2 layers

Where:

- v : fixed shipment quantity in pallets
- V : yearly demand of pallets ($V = v \times n$, with n = nr. of yearly shipments)
- c_f : fixed cost per shipment
- c_v : variable cost per pallet of the shipment
- c'_v : the cost of handling or moving one pallet from inventory to the vehicle
- c_w : waiting cost per pallet per unit of time
- c_r : yearly rent cost of the storage space required to store one pallet
- T_w^{shipper} : average waiting time of a pallet in inventory at the shipper's premises
- T_w^{receiver} : average waiting time of a pallet in inventory at the receiver's premises

- T_l : average lead time of the shipment
- $A_{shipper}^{max}$: maximum accumulation of inventory levels at the shipper's premises
- $A_{receiver}^{max}$: maximum accumulation of inventory levels at the receiver's premises

The terms $T_w^{shipper}$ and $T_w^{receiver}$ depend on the assumptions made with regards to the inventory strategy, but generally will increase with the shipment quantity v . The term T_l can be further subdivided into the components that make up the shipping operation, that is to say the transport itself, the loading and unloading of pallets to the trucks that perform the drayage operation and the transfer of pallets between the truck and the barge. The term T_l is then specified according to the chosen transport alternative below:

$$T_{l-t} = T_{l-load/unload} + T_{l-transport} + T_{l-transfer}$$

Transport alternative	$T_{l-load/unload}$	$T_{l-transport}$	$T_{l-transfer}$
<i>Unimodal road</i> ($i = road$)	$s_{load/unload}^{-1} \times v_{road}^* \times 2$	$\frac{d}{s_{road}}$	0
<i>Intermodal road/water way</i> ($i = ww$)	$\begin{cases} s_{load/unload}^{-1} \times v_{road}^{max} \times 2 d_{pre} > \\ s_{load/unload}^{-1} \times v_{road}^{max} \begin{cases} d_{pre} = 0 \\ d_{pre} > 0 \end{cases} = \frac{(d_{pre} + d_{post})}{s_{road}} + \frac{d_{matn}}{s_{ww}} s_{transfer}^{-1} \times v_{ww}^* \\ 0 d_{pre} + d_{post} = 0 \end{cases}$	$T_{drayage} + T_{matn}$	

Where:

- $s_{load/unload}^{-1}$: average time needed to load/unload one pallet on/from a truck
- s_l : average speed of vehicle i
- $s_{transfer}^{-1}$: average time needed to transfer one pallet from a truck to a barge (or vice versa)
- d : distance travelled to perform the shipment through unimodal road transport
- d_j : distance travelled to perform component j of the intermodal transport operation ($j: pre-haulage, main-haulage, post-haulage$)
- v_i^{max} : maximum load capacity of vehicle i in pallets
- v_i^* : optimal shipment quantity or EOQ for vehicle i in pallets

The equation presented above can now be rewritten in terms of the optimal shipment quantity and subsequently the optimal shipment quantity and minimum TLC per pallet can be found through optimization:

$$\begin{aligned} \frac{TLC^*}{pallet} &= A \times \frac{1}{v^*} + B \times v^* + C \\ \Rightarrow v^* &= \text{Min} \left\{ \sqrt{\frac{A}{B}}, v_i^{max} \right\} \end{aligned}$$

$$\Rightarrow \frac{TLC^*}{\text{pallet}} = \begin{cases} 2 \times \sqrt{A \times B} + C | v^* = \sqrt{\frac{A}{B}} \\ A \times \frac{1}{v_t^{\max}} + B \times v_t^{\max} + C | v^* = v_t^{\max} \end{cases}$$

The optimal TLC per pallet can thus be specified for the unimodal alternative and the intermodal alternative respectively. A, B and C will differ between the two alternatives since the transport cost per pallet, the average waiting time of a pallet in inventory and the rent cost per pallet differ as a result of the difference in scale of the vehicles used and the different nature of the transport operation.

Furthermore, the transport distance, arguably the most important aspect of a transport operation, will differ between the distinct components of the operation. Both the movement costs and the holding costs are a function of the distance since the transport costs and the waiting cost incurred during the lead time increase with distance. Indirectly, also the waiting cost per pallet incurred due to the time spent in inventory as well as the rent cost per pallet increase with distance since the optimal shipment quantity is an increasing function of the distance travelled. Accordingly, the mathematical expression for the optimal shipment quantity and the optimal TLC per pallet, taking into account the capacity restraints, can be specified for both transport alternatives:

Unimodal road alternative

$$v_{\text{road}}^* = \text{Min}\{v_{\text{road}}^{\text{opt}}; v_{\text{road}}^{\max}\}$$

$$\frac{TLC_{\text{road}}^*}{\text{pallet}} = \begin{cases} 2 \times \sqrt{A \times B} + C = 2 \times \sqrt{a' + d \times b'} + a + d \times b | v_{\text{road}}^{\text{opt}} \leq v_{\text{road}}^{\max} \\ A \times \frac{1}{v_{\text{road}}^{\max}} + B \times v_{\text{road}}^{\max} + C = D + d \times E | v_{\text{road}}^{\text{opt}} > v_{\text{road}}^{\max} \end{cases}$$

Intermodal road/waterway alternative

$$v_{\text{ww}}^* = \text{Min}\{v_{\text{ww}}^{\text{opt}}; v_{\text{ww}}^{\max}\}$$

$$\frac{TLC_{\text{ww}}^*}{\text{pallet}} = \begin{cases} 2 \times \sqrt{a' + d_{\text{matn}} \times b'} + (a + d_{\text{matn}} \times b + d_{\text{drayage}} \times c) | v_{\text{ww}}^{\text{opt}} \leq v_{\text{ww}}^{\max} \\ D + d_{\text{matn}} \times E + d_{\text{drayage}} \times F | v_{\text{ww}}^{\text{opt}} > v_{\text{ww}}^{\max} \end{cases}$$

Where:

- $v_{\text{road}}^{\text{opt}}$: optimal shipment quantity for the unimodal alternative without capacity restrictions
- $v_{\text{ww}}^{\text{opt}}$: optimal shipment quantity for the intermodal alternative without capacity restrictions

Break-even analysis can then be applied by equating the mathematical expressions for the TLC per pallet of the unimodal and the intermodal alternative:

$$\frac{TLC_{road}^*}{\text{pallet}} = \frac{TLC_{ww}^*}{\text{pallet}}$$

Given the form of the mathematical expressions for both the unimodal and the intermodal transport alternatives one can see that in theory four situations can occur. The situation that applies thus depends on whether the optimal shipment quantity has reached the maximum load capacity of the main vehicle of transportation. Since the optimal shipment quantity is an increasing function of the distance travelled, the four above described situations can also be identified in terms of these distances.

Situation 1: $v_{road}^{opt} \leq v_{road}^{max}$ and $v_{ww}^{opt} \leq v_{ww}^{max}$ and where $d \leq d_{road}^{max}$
and $d_{matn} \leq d_{ww}^{max}$

$$S_1: \begin{cases} \frac{TLC_{road}^*}{\text{pallet}} = 2\sqrt{a' + d \times b'} + a + d \times b \\ \frac{TLC_{ww}^*}{\text{pallet}} = 2 \times \sqrt{a' + d_{matn} \times b'} + (a + d_{matn} \times b + d_{drayage} \times c) \end{cases}$$

Situation 2: $v_{road}^{opt} > v_{road}^{max}$ and $v_{ww}^{opt} \leq v_{ww}^{max}$ and where $d > d_{road}^{max}$
and $d_{matn} \leq d_{ww}^{max}$

$$S_2: \begin{cases} \frac{TLC_{road}^*}{\text{pallet}} = D + d \times E \\ \frac{TLC_{ww}^*}{\text{pallet}} = 2 \times \sqrt{a' + d_{matn} \times b'} + (a + d_{matn} \times b + d_{drayage} \times c) \end{cases}$$

Situation 3: $v_{road}^{opt} \leq v_{road}^{max}$ and $v_{ww}^{opt} > v_{ww}^{max}$ and where $d \leq d_{road}^{max}$
and $d_{matn} > d_{ww}^{max}$

$$S_3: \begin{cases} \frac{TLC_{road}^*}{\text{pallet}} = 2\sqrt{a' + d \times b'} + a + d \times b \\ \frac{TLC_{ww}^*}{\text{pallet}} = D + d_{matn} \times E + d_{drayage} \times F \end{cases}$$

Situation 4: $v_{road}^{opt} \leq v_{road}^{max}$ and $v_{ww}^{opt} > v_{ww}^{max}$ and where $d \leq d_{road}^{max}$ and $d_{matn} > d_{ww}^{max}$

$$S_4: \begin{cases} \frac{TLC_{road}^*}{\text{pallet}} = D + d \times E \\ \frac{TLC_{ww}^*}{\text{pallet}} = D + d_{matn} \times E + d_{drayage} \times F \end{cases}$$

In reality, the third situation will not occur due to the difference in the capacities of the vehicles used. Which of the above situations applies can then be determined by depicting the TLC-curves for both transport alternatives as a function of the main-haulage distance travelled on a graph (See figure 1). In order to allow for solving the applicable equation, it is assumed that the main haulage distance for intermodal transport equals the distance travelled in performing the unimodal transport operation and that the pre- and post-haulage distances are given. The break-even distance can subsequently be calculated by solving the equation. In the analysis based on the European transport data, the length of the different haulages will be calculated individually per origin-destination-combination.

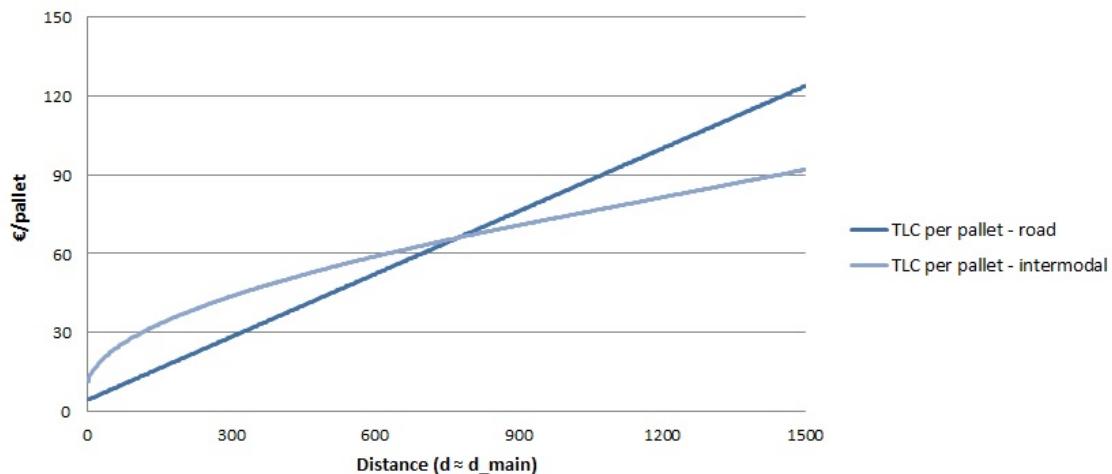


Figure 2: Cost functions of the TLC per pallet for the unimodal road and intermodal road/waterway alternatives.

Source: own composition.

Finally, the impact of changes in the values of important attributes of the transport operation and of the transported good such as the freight rates, the value of the good and the shelf-life of the good on the TLC per pallet and on the break-even distance can be analyzed. Furthermore, the effect of the internalisation of external costs on the break-even distance and thus on the modal choice decision can be examined.

The TLC-model incorporated in the LAMBTOP model defines the terms of the abstract mathematical equation for the TLC per pallet given above, namely c_f , c_v , c'_v , c_w , T_w^{shpper} , $T_w^{reciever}$, c_r , as follows:

$$\begin{aligned}
 c_f &= c_s + c_d \times d_{main} + c_t \times T_{main} \\
 c_v &= c'_d + c'_t \\
 c'_v &= c_{handling} \times T_{handling} \\
 c_w &= \pi \times (i + j) \\
 T_w^{shpper} &= (v_1 + v_2 + v) \times \frac{1}{2} \times \frac{1}{D'_{mean}} \\
 T_w^{reciever} &= \left(v \times \frac{1}{2} + SS \right) \times \frac{1}{D'_{mean}} \\
 c_r &= (c_{opp} \times S_v)
 \end{aligned}$$

Where:

- c_s : fixed shipment cost, independent of distance, travel time and shipment quantity (e.g. port dues)
- c_d : marginal shipment cost per kilometer travelled, independent of the shipment quantity
- c_t : marginal shipment cost per unit of travel time, independent of the shipment quantity

- c'_d : marginal cost of transporting one pallet over one kilometer
- c'_t : marginal cost of transporting one pallet for one unit of time
- $c_{handling}$: cost per unit of time of operating a forklift truck
- $T_{handling}$: average time required to move one pallet from the inventory to the transportation vehicle
- n : value of one pallet of the transported good
- i : discount rate as a percentage per unit of time
- j : loss in value of the good due to depreciation as a percentage per unit of time
- $v1$: Inventory trigger point shipper
- $v2$: Inventory trigger point shipper – waiting costs
- D'_{mean} : average demand rate (items per unit of time)
- SS : safety inventory level

The TLC-model is included in the LAMTOP, and is used to calculate the optimal number of hubs and the financial potential of a modal shift for each origin-destination-combination in the next section.3.

3. Results and discussion.

The analysis proposed in this paper is based on the ADSEI 2011 transport data of palletized goods within Europe. This dataset contains the data which were collected in the reporting countries, which are mentioned in the footnote on page 1 of this paper. The dataset covers a total volume of over 2.352 billion tons. It contains for each origin-destination (OD) -combination the transported tonnage, the ton-km, the vehicle-km, the reporting country and the origin and destination, which are given on NUTS3 level. The data are checked on double counting.

The transport volume for each origin-destination-combination is in this research assumed to represent the yearly demand between both regions, and is as such included in the model. This transported volume is also assumed to be distributed equally in time, resulting in a constant daily demand for each OD-combination.

The origin and destinations are filtered using the location criterion of 75 kilometres, selecting only those combinations with both origin and destination located in this predefined range. Figure 3 illustrates the distribution of the volume of those selected combinations. Large volumes are situated in the Netherlands, Flanders, western part of Germany and the Region of Paris. No data were available for the NUTS3 regions in grey, which are concentrated in the eastern part of Germany. Only the volumes represented in Figure 3 – total of 1.054 billion tons – are taken into account during the location analysis of the transhipment hubs.

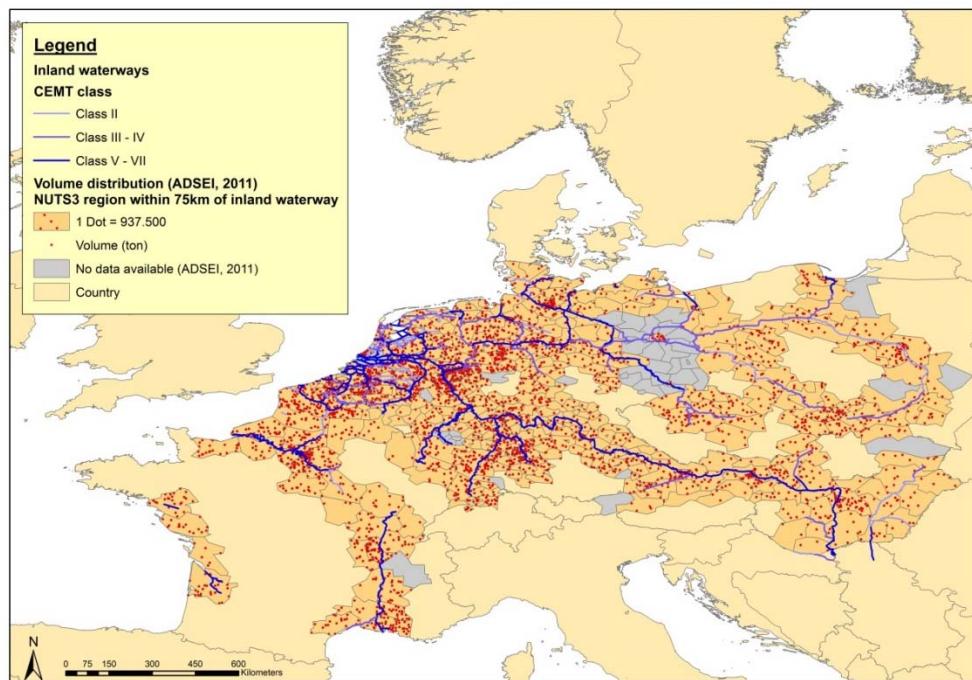


Figure 3: Distribution analysis.

Source: own composition.

The optimal locations of the transhipment hubs are calculated on the basis of this volume and the described LAMBTOP methodology. The actual location analysis is performed multiple times in a loop, each time calculating the instant optimal network for an increasing number of transhipment hubs. A network of 31 transhipment hubs catches most potential volumes in relation to the number of hubs in the network. The transhipment hubs are situated closely to the volume concentrations – namely the main industrial areas (production) and large city regions (consumption). Figure 4 illustrates the optimal locations and also the already existing intermodal terminals (2010) located near an inland waterway. Transhipment hubs for palletized goods do not need as much infrastructure as for example container terminals.

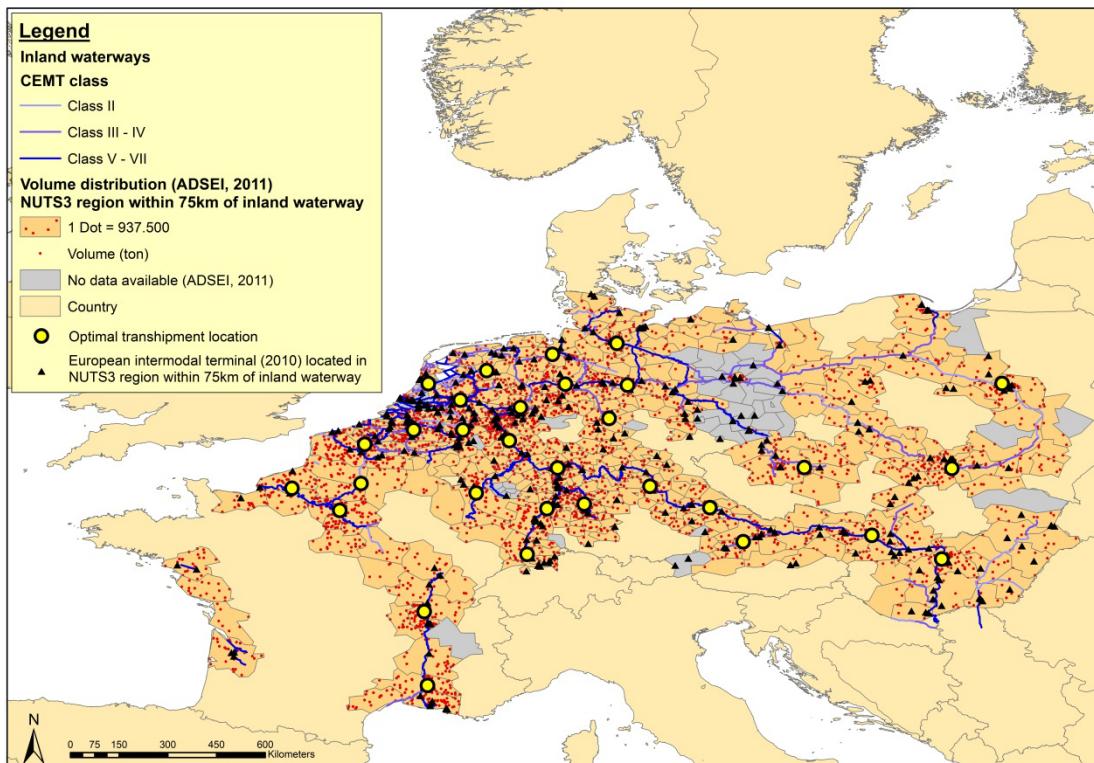


Figure 4: Location analysis.

Source: own composition.

The optimal routes in both the road network as in the by the model constructed intermodal network are calculated, and linked to the TLC-model. Contrary to what is expected, not one OD-combination can cost-efficiently be shifted towards the inland waterways. This result is also in contrast to previous research done in Belgium, where viable volumes were identified (Mommens and Macharis 2014). The main reason is the introduction of the TLC-model, as the inclusion of costs for reliability, lead time, depreciation of goods, value of the goods, etc. – instead of only the direct transport costs used in previous research – is not favourable for the intermodal alternative. Although the outcome is more realistic, it does actually not mean that the modal shift of palletized goods is impossible. Because, by looking closer to the reasons for this absence of potential, it becomes clear that the absence stresses the limitations of the concept. Moreover, the concept only applies to a limited range of commodity types with well-defined distribution and geographical patterns. This statement is underpinned by the following arguments.

Firstly, the European transport data illustrate that the average transport distance for the majority of the analysed volume is rather short. More precisely almost 70 per cent of the analysed volume has a transport distance shorter than 150 kilometres. This does not play in favour of a modal shift, as intermodal transport has to concur with a break-even distance. However, previous studies (Mommens and Macharis 2014; Verbeke et al. 2012) and mentioned practical experiences prove that a modal shift of palletized goods is realizable on relatively short distances. The main reason for that is that those transports are characterised by short pre- and post-haulage distances. More often the origin or destination is located at the waterfront, avoiding as such the costs for loading and unloading the truck as well as for the truck driving itself. In this analysis, the used

transport data are aggregated on NUTS3 level. They lack information about the real location of the origin and destination, and no information is given on the water-bound location of the origin and/or destination. As a consequence, all transport flows are assumed to have the geographical centre of their respectively NUTS3 region as origin, and they are assumed to arrive in the geographical centre of the corresponding NUTS3 region of the destination. As such, all the researched transport-flows have to cope with relatively long pre- and post-haulages. This implicates a significant increase in the costs of the intermodal alternative, and condemns the modal shift to be unrealizable.

Besides the large impact of the geographical generalization of the transport data, it has, to be noted that no information is given on the commodities and its characteristics as well. The initial analysis is by consequence based on a generalization of the commodity characteristics. For sure, not all commodities lend themselves for a modal shift towards the inland waterways. Some commodities have physical constraints, like for example sensitivity for humidity or certain temperatures. Such constraints can be tackled by additional infrastructure in the transhipment hubs and barges. Other goods are for example fragile, and the extra handling in the intermodal alternative comes with extra damage and costs. Some goods are not stackable, reducing the number of layers in the barge to only one and increasing the transport costs. Also, other commodity characteristics – like the depreciation, the shelf-life and the value of the goods – influence the total logistics costs and so the feasibility of the modal shift. Those last characteristics are included in the model and in the analysis. We used a standard scenario based on values obtained through literature (Blauwens et al. 2012; Essencial Supply Chain Architects 2011) and contact with transport experts². Some additional realistic variations were introduced to those characteristics or variables, in order to test the sensitivity of the performed analysis, as well as to identify the characteristics with a large impact on the feasibility of the modal shift. Table 1 illustrates the used characteristics, their value and the additional variations included in the analysis. In the interest of not only including economic costs, we incorporated an extra variation, taking into account the external costs for the entire supply chain (Maibach et al. 2008).

Table 1: Characteristics and their values.

	<i>Standard</i>	<i>Variation 1</i>	<i>Variation 2</i>	<i>Variation 3</i>	<i>Variation 4</i>
Value of good (€/pallet)	250	100	500	750	1000
Depreciation (per cent)	2,5	1	5	20	50
Shelf-Life (years)	2	5	10	25	100
Yearly demand (ton)	OD-matrix				
Transport distances (km)	OD-matrix				
Reliability road transport – speed (60km/h) (per cent)	0 (=60km/h)	-50 (=90km/h)	25 (=45km/h)	50 (=30km/h)	

² [The transport experts assist Flemish companies in their search for possibilities to shift (portions of) their transport flows to the inland waterways. The advice and services provided to the transport companies by these transport experts are free of charge, as the experts are appointed by a cooperation of waterway administrators and enterprise unions.]

Reliability barge transport – speed depends barge type (per cent)	0	10	25
Internalisation external costs (€/pallet)	No	Internalisation	
Working hours hub (h)	8	24	
Working hours barge transport (h)	8	24	

Changes in the variables will cause changes in the total logistics costs, in the break-even distance and by consequence in the feasibility of the concept. Theoretical analyses with the TLC-model indicate that the higher the shelf-life, the more feasible the modal shift will be. This is illustrated in Figure 5 for the comparison between unimodal road transport and intermodal transport performed with a Kempenaar or with a Big Rhine barge. A similar relation can be seen for the yearly demand. For the value of the good, we see that the higher the value, the less feasible the modal shift will be.

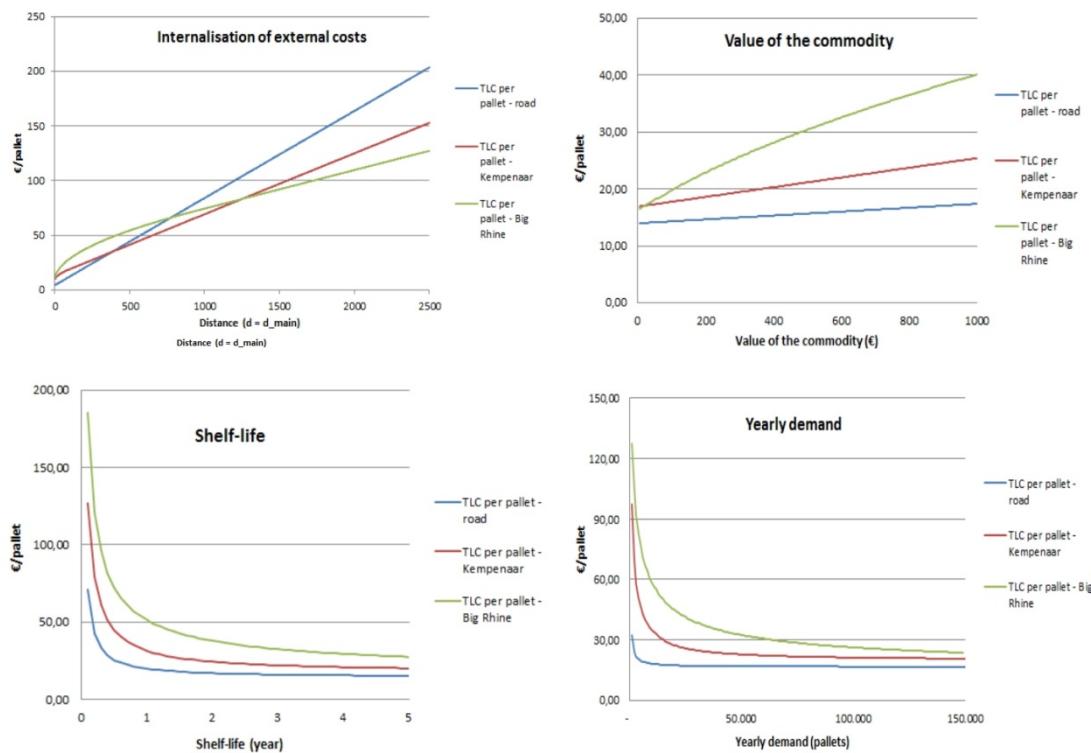


Figure 5: Relations between TLC and characteristics.
Source: own composition.

The relations presented in Figure 5 are expected, but were to our extent non-explored in the relation to the modal shift of palletized goods. The extent in which these variables influence the feasibility of the modal shift will depend on the characteristics of the

supply chain. That is why we first describe the favourable supply chain composition, before figuring the impact of the different variables, based on the analysed OD-matrix.

The characteristics of the supply chain do also influence the feasibility of the concept. From our research of the economic feasibility of a modal shift of palletized Fast Moving Consumer Goods, we know that the focus needs to be oriented towards the mass distribution, especially in the initial stage of the concept (Mommens et al. 2014). Preferably uniform, large flows which are often situated between the production site and distribution centres of large suppliers. The consolidation of such large flows in transhipment hubs is necessary to catch enough volume in order to justify the implantation of such hubs. From the study of VIM (2012), a yearly volume of 20.000 pallets would be necessary to do so. However, supply chains can have very different compositions (Tavasszy and Ruijgrok 2013). The model used in this research assumes only one-to-one distribution chains. Currently, we are developing a transport model which will include also other chain compositions. It is our aim to link this transport model and the LAMBTOP within future research.

When summarizing the previous arguments, the concept should focus on commodities which meet the favourable characteristics presented in Table 2. The relative importance of the impact of those characteristics on the feasibility of the modal shift is also presented. This importance is given quantitatively by the relative change in the ratio TLC intermodal / TLC unimodal for the overall analysed volume. For the other characteristics, we described their importance qualitatively.

Table 2: Characteristics favourable for a modal shift.

<i>Characteristic</i>	<i>Favourable</i>	<i>Importance</i>			
Weather resistance	Resistant	Important: require lot of investments in hub and barge			
Stackability	Stackable	Very important: benefit of economies of scales			
Flow volume	Large	Very important: reduce costs in the whole supply chain			
Uniformity pallets	Uniform	Important: reduce the handling and consequently the costs			
Location near inland waterway	Near or at	Very important: reduce costs or avoid extra handling and transport			
<i>TLC-model variables</i>		<i>Favourable</i>	<i>Variation 1</i>	<i>Variation 2</i>	<i>Variation 3</i>
Value of the goods	Low	53,9 per cent	-63,4 per cent	-116,1 per cent	-161,5 per cent
Depreciation	Low	2,0 per cent	-3,4 per cent	-22,6 per cent	-57,9 per cent
Shelf-life	Long	43,7 per cent	60,3 per cent	71,9 per cent	77,0 per cent
Reliability of road transport	Low	-18,4 per cent	13,6 per cent	31,8 per cent	
Reliability of barge transport	High	-0,6 per cent	-1,8 per cent		
Internalisation external cost	Internalisation	25,6 per cent			
24h daily working hours hub and barge	24h	1,7 per cent			

The values in Table 2 prove that the modal shift of palletized goods will not be generally applicable. Only large, uniform volumes of low value goods characterized by

low depreciation rates and long shelf-life show profitable potential to be shifted to the inland waterways. These goods represent just a fraction of all the palletized goods transported on the European road nowadays. A variety of palletized goods does not meet those characteristics. This however does not mean that the concept is unrealisable. Still, large volumes can be found which do meet them. In specific sectors, like the construction sector for instance, where such volumes are representing a large portion of the overall transport volume. One can also not neglect the impact of those flows in and on our daily traffic, as VIM (2012) states that the construction sector is taking into account 25 per cent of all freight transport on Belgian highways. VIM also mentions that a large portion of these building materials is loaded on pallets. Moreover, many of the sectors suppliers and customers are for historic reasons located at or near an inland waterway. That is also true for the producers of beer. Palletized beers and palletized drinks more generally, do also meet the above stated favourable characteristics. Both sectors can be identified as target sectors for the concept. And they already are, like we could read in the introduction of this paper. The choice for those sectors to be pioneer sectors was mainly based on common sense, more than on hard research. Our research does now underpin this choice with more concrete figures.

4. Conclusion.

This research adds three insights to the existing knowledge. Firstly, we identified the optimal locations and the optimal composition of the network of transhipment hubs. Based on European transport data for the year 2011, a network of thirty-one transhipment hubs – mostly located near the main European industrial areas (production) and large city regions (consumption) – obtains the most cost-efficient results.

Those costs are calculated through the incorporation of a Total Logistics Cost model into the existing LAMBTOP. The TLC-model itself, is our second add to the existing knowledge, as it is constructed specifically to research the potential of a modal shift of palletized goods. The new insights derived from the incorporation are at first look not in favour of a modal shift. The standard analysis did not reveal any cost-efficient volume. However, one of the advantages of the incorporation is that it allows more profound research. Those in-depth analyses enabled us firstly to identify the characteristics of the palletized commodities and of the supply chain, which influence the feasibility of a modal shift. Also, the extent in which they influence this feasibility has been calculated. The results show that only large, uniform volumes of low value goods characterized by low depreciation rates and long shelf-life show profitable potential to be shifted to the inland waterways. A variety of palletized goods does not meet those characteristics. This however does not mean that the concept is unrealisable. Still, large volumes can be found which do meet them.

Finally, two main sectors on which the concept is focusing now do meet the favourable characteristics. Those sectors are the construction sector and the sector of palletized drinks. Our theoretical outcome confirms the choice of transport experts for those two sectors to be the pioneer sectors of this concept. However, our results do not show many other roll-out possibilities to other commodities which are not meeting the favourable characteristic.

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