Intermodal Inland Waterway Transport: Modelling Conditions Influencing Its Cost Competitiveness

Bart WIEGMANS* • Rob KONINGS**

Contents

Abstract

In this paper a model is developed to analyse and compare the transport costs of intermodal inland waterway transport and road-only-transport. The influence of the economies of scale in inland waterway transport and terminal operations are taken into account in the analysis. In the model the transport costs are defined and related to different transport operations and conditions (e.g. share of empty kilometres, capacity usage of terminals, etc.) in order to analyse the sensitivity of the cost performance of intermodal inland waterway transport. By doing this it is possible to analyse to what extent intermodal freight transport is competitive with road-only transport in terms of transport costs and specific operations and conditions (both in shipping and terminal). The conclusions prove that roundtrips, drop & pick operations in pre- and end-haulage and smaller containers (20ft instead of 40ft) considerably improve the competitiveness of intermodal inland waterway transport, while the relative high cost operations in small terminals reduce the competitiveness of intermodal inland waterway transport.

Key Words : Inland Waterway Transport, Intermodal, Cost Competitiveness, Economies of Scale, Europe

* Senior Researcher, Department of Transport & Planning, Faculty of Civil Engineering and Geosciences, Delft University of Technology, The Netherlands, Email: b.wiegmans@tudelft.nl
** Senior Researcher, OTB - Research Institute for the Built Environment, Faculty of Architecture and The Built Environment, Delft University of Technology, The Netherlands, Email: j.w.konings@tudelft.nl

I. Introduction

In the last decades, European freight transport has increased enormously and this growth has been predominantly absorbed by road transport. While road transport counted for 65% of total transport (in tonne-km) in the European Union (EU-9) in 1980, its share in the EU-27 recorded 76% in 2010, leaving a share of rail and barge of 17% and 7% respectively (Eurostat, 2013). However, besides its many advantages road freight transport also causes congestion, accidents, air pollution and noise nuisance. Evidently, these conditions ask for an improvement of the performance of road freight transport, but they also call upon a greater role of other modes. Intermodal transport can be an alternative mode that can overcome the above-mentioned problems. A precondition to achieve this shift from road to intermodal transport is, however, that the performance of intermodal transport is competitive with road-only transport. In general, the cost of transport services remains one of the most important criteria in modal choice and this is also confirmed by scientific research (e.g. Bergantino et al., 2013; Danielis and Marcucci, 2007). Economies of scale are easier to achieve and can also be greater in inland waterway transport than in rail transport and hence intermodal inland waterway transport (IWT) can offer a more competitive cost performance to road transport. The cost performance of IWT is therefore often mentioned as the major trigger to shift from road transport to IWT. However, to what extent is IWT really cost competitive with road-only transport? Several studies have been conducted on cost-break even distances (see e.g. Niérat (1997), Platz (2009), Frémont and Franc (2010), Macharis et al. (2010) or Kim and Van Wee (2011)). However, the precise relationship between costs and operations in the transport chain is often not elaborated in detail, leading to unclear results or average cost estimates. That is to say, instead of including detailed costs that reflect the specific case that is being studied, the costs are often assumed to be an average of all operations in the intermodal transport sector. As a consequence, crucial data is usually not presented or described which makes it impossible to trace the results of cost comparisons between IWT and road-only transport. This paper models these intermodal transport problems and analyses the relation between costs and operations in the transport chain. In the analysis the influence of the economies of scale in inland waterway transport and terminal operations are taken into account and the level of transport costs is related to specific transport operations. The paper starts with an outline of an integrated framework to assign and measure costs of transport services. Next, the costs of IWT and road-only transport will be built into a model that is capable to show the conditions that influences competitiveness of IWT in different distance classes. The conditions and outcomes will be analysed in detail for a number of representative cases. Finally, the results are discussed and main conclusions are drawn.

II. Theoretical Cost Framework for the Analysis

1. Principles of Transport Cost Analysis

In principle, the costs of a transport service should reflect all costs that are needed to provide the transport service. Evidently the costs can include a wide range of cost drivers because providing a transport service may involve many activities. Moreover, prior to delivering the transport service investments (e.g. purchase of transport equipment) are needed that enable the delivery of a service. In the field of transport the allocation of costs has not been extensively studied which is remarkable given the importance of costs in selling transport services.

Criteria are needed to split costs into different categories. Important categorizations are (Cooper and Kaplan, 1999): 1) direct versus indirect costs 2) fixed costs versus variable costs; 3) completely individualized and restrained individualized costs; and 4) Activity Based Costing. In our analysis, the widely-accepted system of fixed and variable costs will be used. In transport services, these cost accounting principles (fixed and variable) mean that the number of business hours will be among the key factors to assign the fixed costs to the service. The total variable costs will depend on the number of delivered transport services, but the total variable costs of an individual service are also a function of the transport distance: a transport service over a longer distance will cause higher variable costs (e.g. fuel). Therefore, the major determinants in the cost calculation are the time spent in a transport trip and the distance covered. That is to say, if the total fixed costs and the number of business hours (e.g. on an annual base) are known the fixed costs per operating hour, i.e. an hour cost coefficient, can be calculated. In a similar way, a kilometre cost coefficient can be derived, which is the total variable costs (the sum of different types of variable costs) per kilometre. Table 1 summarizes how these coefficients are constructed. The costs of the transport service are obtained by multiplying the cost coefficients with the time spent in a trip and the trip distance.

<Table 1> Assignment of different costs to transport services

Variable costs	**Fixed costs**
Distance-related	Time-related
Variable costs / km: kilometre cost coefficient	Fixed costs / hours: hour cost coefficient

In other words, the costs of a transport service are on the one hand the result of the typical cost characteristics of the production factors needed to provide transport services (e.g. type of equipment, labour), i.e. factor costs. These factors will determine the hour and kilometre cost coefficients. On the other hand the costs are the result of the efficiency of using these production factors (type of operations) to provide transport services, since the type of operations may influence the time consumption and travel distances to deliver transport services. Both elements of the costs are elaborated in the next subsections.

2. Factor Costs in Intermodal Inland Waterway Transport

In describing the factor costs of intermodal inland waterway transport we have to distinguish the three links of the chain, i.e. the main haulage by IWT, terminal handling (transhipment), and pre- and/or end-haulage (PEH) by truck. The cost data relate to the situation of the Dutch transport industry, but can be assumed as representative for the European transport industry. This is due to the high capital costs involved in terminal operations and the competitive structure of the West European road freight transport and inland waterway transport.

2.1 Factor Costs and Operations in Inland Waterway Transport

The costs, which are split up in variable and fixed costs, are described for two different types (sizes) of vessels in order to analyse the economies of scale in ship size (see also Annex A table 1). The variable costs consist of fuel and maintenance and repair. The fixed costs include labour and capital costs. The labour costs are on the one hand influenced by the type of vessel and the length of a vessel and on the other hand by the type of operations: day operations (maximum 14 hours per day), semi-continuous (max. 18 hours/day) or continuous operations (24 hours/day). Capital costs include depreciation, interest, insurance, repair and maintenance, port dues, and other costs (administration, communication, certificates, overhead, other). Repair and maintenance costs are, however, only partially fixed, since these costs will increase if a vessel is more intensively used. Following NEA (2009) 50% of the total repair and maintenance costs are assumed to be fixed costs and 50% are related to the level of operations. Fuel costs are a function of fuel consumption and the price of fuel. Numerous conditions influence fuel consumption, i.e. sailing speed, size and shape of the vessel, force of the current, installed engine power and specific characteristics of the engine. As a result of some of these conditions fuel costs will vary at different waterways, which actually make fuel costs to some extent trip-specific. In addition, the load factor of the vessel is of particular importance for fuel consumption. In Annex A Table 1 we show the fuel costs of vessels that are completely loaded and empty.

The great importance of the fixed costs is typical for the cost structure of IWT. Moreover, these fixed costs consist largely of capital costs, in particular the depreciation and interest costs of the vessel. A consequence of the relatively high fixed costs is that a high load factor of a vessel is required to achieve low transport costs per load unit. Evidently operating larger vessels can potentially lead to economies of scale, but only if the demand for transport is sufficiently large. In addition to the load factor of a vessel the utilization rate of a vessel is highly important, and this rate is strongly related to the roundtrip time of a vessel. A short roundtrip time enables to have more roundtrips in the same period of time. As a result, the fixed costs are spread out over more transport services and, consequently, transport costs per load unit will decrease. Major determinants for the roundtrip time are the passage time of locks and bridges (if they need to be opened) and the handling and waiting times of vessels at terminals. Moreover, bridges may also influence the cost performance of IWT transport, since the bridge clearance may limit the number of layers of containers that can be transported. Therefore the specific route of an IWT service and the performance of the terminal will influence the cost performance of IWT transport.

2.2 Factor Costs and Operations in Pre–and End-Haulage by Truck

Annex A Table 2 provides an overview of the structure of the fixed and variable costs in PEH truck operations. The fixed costs for trucking comprise depreciation, interest, insurance, road taxes (including general taxes and Eurovignet) and the variable costs include fuel, tires, maintenance. An overview of the data used to calculate the fixed costs on an annual base and the variable costs per kilometre is given in Annex A Table 3.

In the cost structure of PEH both the variable or kilometre costs and the fixed or time costs are important (see Kreutzberger et al., 2006; Konings, 2008). Given the distinction between time and kilometre costs there are two driving forces for the execution of PEH trips. On the one hand this is the aim to maximize the productivity of resources (equipment and labour), or in other words, trying to execute paid trips as much as possible. On the other hand the aim is to minimize the number of empty vehicle kilometres in order to reduce the variable costs. The first goal is related to 'stay-with' or 'drop-and-pick' processes in PEH operations. The second goal refers to using opportunities to combine trips. *In the stay with-trips* the tractor remains coupled to the semi-trailer during stuffing or stripping of a container. After unloading at a customer three situations can occur: 1) the combination drives back to the terminal empty, 2) the container is loaded elsewhere and then the truck returns to the terminal or 3) the container is reloaded at the same address where it was unloaded and then transported to the terminal. The share of empty transport varies from 50% to 0%. The fixed costs of these trips are relatively high, because the tractor and driver are waiting during (un)loading the container. In daily practice situation 1 is most common. *In the drop-and-pick-trips* the tractor and semi-trailer of a truck are split at the shippers' location. During (un)loading of the container, the tractor returns to the terminal, with or without a new semi-trailer and container. It can also first move on to a second shipper to fetch another semi-trailer with a container. Semi-trailers with containers that are left behind are picked up by the tractor at a later moment. In these kinds of trips the time costs are in principle lower than in stay-with trips, but the kilometre costs are higher, because of more empty hauls. The share of empty trips can become 75%. When the transport distance is small, the costs related to the duration time at terminals and shippers will be relatively high and in these circumstances drop-and-pick trips become more attractive.

2.3 Factor costs and transhipment operations: terminals

Different types of equipment exist, ranging from multi-purpose to dedicated container cranes and from mobile equipment (cranes or reach stackers) to fixed equipment. Container terminals, however, usually comprise much more facilities to support container transhipment. For instance an area for temporary storage of containers, since direct transhipment between vessel and truck is often impossible. In practice, a wide variation of terminal configurations, i.e. number and types of equipment and lay out, can be found. We present the factor costs of transhipment at IWT terminals for different terminal profiles also in order to analyse possible scale economies. Fixed costs comprise of e.g. land, quay, equipment, while variable costs consists of fuel, ICT, overheads, etc.. The terminal profiles are defined based on handling capacity, terminal equipment, terminal surface and quay length (see Table 4 in Annex A).

Cost differences between terminals are caused by the use of different equipment (e.g. type of equipment or new versus second-hand equipment), but are often also the result of different circumstances, including a different development phase of the terminal, the service offerings, and related to the size of the terminal. These circumstances may for instance be influenced by government subsidies, making the net initial investment costs lower. Subsidy programs for the establishment of terminals (up to 25% of the total investment costs in The Netherlands, and 80% of investment costs of the quay in Belgium) have contributed to a rapid development of a dense terminal landscape in these countries (Decisio, 2002; Van Ham and Macharis, 2005). The possibility to rent the land to establish a terminal instead of buying the terminal area also makes a (large) difference in the real costs of transhipments. Noise and/or emission restrictions imposed by local governments might limit the terminal operating hours and this might result in a higher cost per handling as the equipment cannot be optimally used. Severe weather conditions might also influence efficient terminal operations due to temporary closures of the terminal. Terminal operations (and thus cost per handling) are also influenced by delays in inland waterway transport. If all equipment and employees are available and the vessel is too late this leads to additional waiting time of equipment and employees and thus additional costs. Congestion in terminal handling (e.g. the arrival of large inland vessels that must be unloaded or loaded quickly) will also lead to increased costs per handling. Finally, terminal operations are influenced by data (information) availability and the connection with pre- and end-haulage. Given the fact that fixed costs have a (very) large share in the total operational costs of a IWT container terminal, the number of moves strongly determines the cost per move (see Annex A Table 4).

III. Evaluation of the Economics of Intermodal Inland Waterway Transport

In this section we model and analyse the cost structure of intermodal inland waterway transport and compare it with the cost structure of road-only transport. For this purpose we have developed a model, based on intermodal transport distance, i.e. the sailing distance for the vessel and the driving distance for the truck in end haulage (EH) and based on the type of trip (single trip versus round trip and 20 ft versus 40 ft container transport) and *scenarios for the operations* in the different links of the chain, i.e. sailing, terminal handling and end-haulage (e.g. the decision on vessel size, the profile of a terminal and type of end-haulage operations).

1. Definition of the Base Scenario of Operations

The analysis focuses on a cost comparison between the IWT chain and road-only chain. The IWT chain is assumed to be a so called hinterland transport chain, which is the most common IWT chain. This chain starts at a seaport terminal and ends in the hinterland and has only one haulage by truck (i.e. at the end in the hinterland). Such a chain can obviously better compete with road-only transport than a chain that has a truck haulage at both sides of the IWT haul.

The costs of the handlings at the seaport terminals will differ due to differences in the processes and equipment used to put containers on vessels or trucks. However, since the deep sea line charges the shipper/consignee in the hinterland one rate for both types of handling (known as Terminal Handling Charges) there is no cost difference for the client of the hinterland transport service and hence the seaport terminal handling costs do not have to be included in the cost comparison between IWT and road-only transport. Relevant for the cost comparison between the IWT and road-only transport chain is the type of IWT service that is considered. The cost performance of a pure shuttle service, i.e. from one seaport terminal to one inland terminal will be different from a IWT service where containers have to be collected and distributed at several terminals in the seaport, due to the fact that the latter service is more time-consuming. Following current practice where almost all IWT services have these collection/distribution features in the seaport we consider this type of service as part of the base scenario of operations. Furthermore, the base scenario has the following characteristics of the operations in sailing, terminal handling and end-haulage:

- A vessel size that corresponds to a cargo capacity of 208 TEU. This vessel is the most common used unit in intermodal inland waterway transport.
- The average load factor of the vessel (in both directions) is 70%. This average load factor is close to what is generally considered as a minimum needed to operate break even (see Konings, 2009).
- Services are provided according to the business model of continuous operations, which is the leading business model for IWT container transport. Furthermore, the calculations are based on regular departure times of services, i.e. the departure time of a service is for every day of departure the same. This means that if the circulation time of a vessel in providing a service is close to (a multiple of) 24 hours, then there is not much idle time and the costs of the IWT service will be favourable;

- Time spent in the seaport to visit several terminals to collect and distribute containers is assumed 10 hours. This time consumption covers the waiting time at seaport terminals (on average 1 hour per terminal visit and 8 terminals to visit) and the additional sailing time involved in visiting several terminals (see Konings, 2009).
- Routes of the inland vessels do not to include locks or low bridges, which means that the transit time of services do not include additional time to pass locks or low bridges.
- The handling costs at an inland terminal are based upon the performance of a medium-sized inland terminal (see Annex A table 4). Most of the inland IWT container terminals in Northwest Europe (i.e. Netherlands, Belgium and Germany) have a handling capacity in the range of 30.000 to 80.000 containers;
- The utilization rate of the terminal is on average 80% (see Annex A table 4). Usually a rate of about 80% is considered as a preferred utilisation rate, because it usually still enables to handle peak volumes at the terminal smoothly (i.e. avoiding delays), (Drewry Shipping Consultants Ltd., 2010)
- the operations in end-haulage are ‘stay with’ processes (see also section II.2.2)

These base scenario operations are assumed when we look at different representative chains to compare the cost performance of IWT versus road-only transport. The chains are defined based on: 1) Sailing distance (or road-only distance): 50 km, 200 km and 600 km; and 2) EH distance: 5 km, 20 km and 40 km. The combinations of sailing and EH distances provide 9 basic possibilities for the IWT chains. In the analyses, a *single trip in IWT* consists of the following activities: sailing from seaport to the inland terminal, container handling from vessel to truck, a truck haulage from the terminal to the customer and after the container has been stripped returning the container to the inland terminal. The single trip in road-only transport consists of driving from the seaport to the customer in the hinterland and when the container is stripped the container is delivered at the depot of the inland terminal. In the *roundtrip of IWT* the container that was stored after finishing its single trip is handled again to put it on a vessel and sailed to the seaport. In the roundtrip of road-only transport the container is immediately returned to the seaport after it has been stripped at the customers' Premise.

The model results show that for all operations in the distance class 50 km road-only transport is the most cost efficient option. The model results also show that for all operations the distance class 600 km intermodal transport is the most cost efficient option. Since the outcomes in the 200 km distance class are less clear we will focus on these results in the next paragraph.

2. Cost Performance Evaluation for Different Operations on Medium Distance

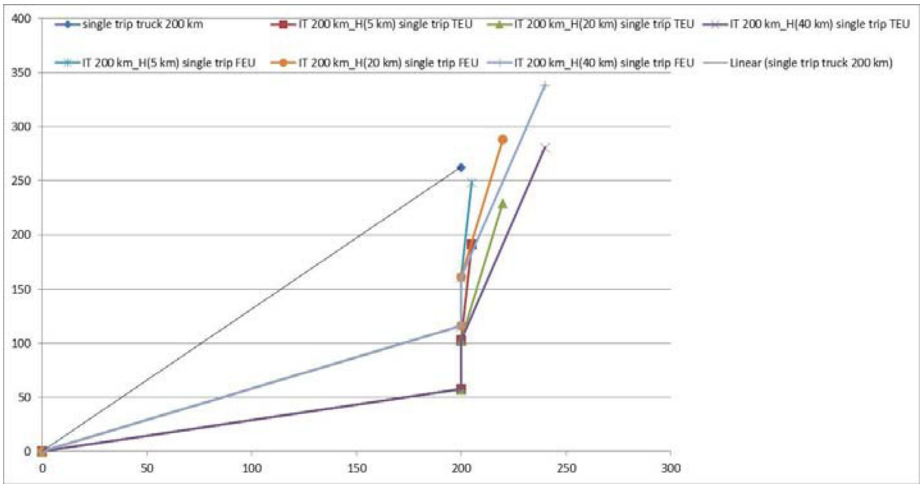
1) Cost Performance of Single Trip versus Round Trip

Single-trip; At long distance (600 km) and middle-long distance (200 km) the intermodal costs are lower than road-only transport costs. The high PPH costs, however, are striking: at a sailing distance of 200 km a relative large PPH distance (40 km) may result into absorption of the cost advantage of IWT. At short sailing distance (50 km) the high PPH costs will be killing for IWT. *Round-trip*; IWT has an even more favourable cost performance in case of roundtrips (as compared to single-trips), in particular at longer distances (600 km). The major explanation is that the low sailing costs compared to the trucking costs in road-only transport have a much more profound impact on the total cost bill when a roundtrip is made.

2) Cost Performance of 20 Ft versus 40 Ft Container Transport

The size of the load unit has a large impact on the cost competitiveness of IWT compared to road-only transport. Transport of 20 ft containers provides a relatively more favourable cost performance for IWT than transporting 40 ft containers (see figure 1). When instead of a 20 ft container a 40 ft container is transported the sailing costs will double since the required slots on the vessel double. On the other hand the costs of trucking a 20 ft or 40 ft container are the same unless a truck would be able to carry two 20 ft containers. However, carrying two loaded 20 ft containers is in practice rather uncommon, since this is only allowed if the total gross weight tonnage does not exceed the maximum allowed tonnage in road transport.

<Figure 1> Impact of the size of the load unit on cost competitiveness of intermodal inland waterway transport



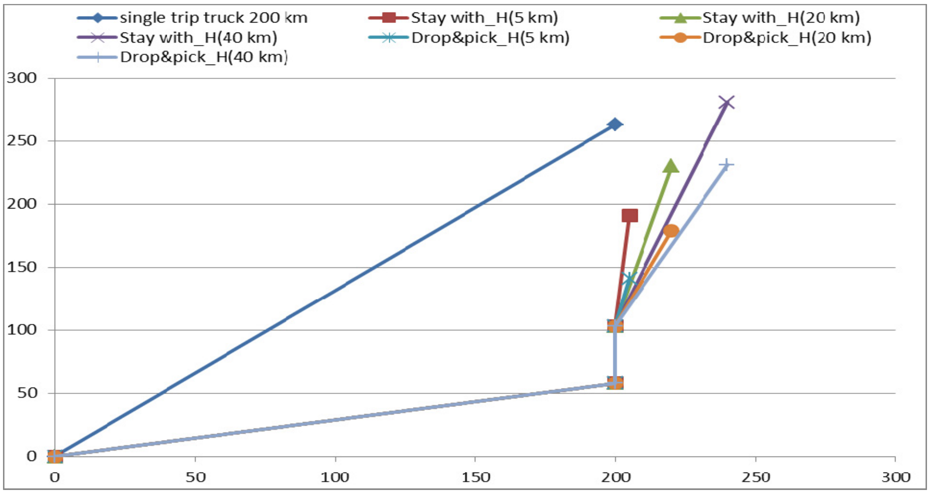
3) Cost Performance of Different Vessel Sizes

In the representative chains that were analysed so far the IWT operations are performed by a vessel that has a capacity of 208 TEU. In practice, this is a common-used vessel size, although much larger vessels and also smaller vessels are used. The decision about the vessel size is on the one hand influenced by the transport demand (available container volumes) and on the other hand by physical limitations imposed by the waterway infrastructure. Figure 6 illustrates the cost performance of IWT for situations in which a vessel having a capacity of 90 TEU is operated. IWT can compete (very) well with road-only transport at long distance (600 km) and middle-long distance (200 km). When compared to figure 4 the conclusion can be drawn that a larger vessel has always a better performance (when it has the same load factor as a small vessel, here assumed 70% of the vessel capacity), but its relative cost advantage becomes more manifest at longer distances.

4) Cost Performance of Different End-Haulage Operations

In the road-only transport chain, the truck waits until the container is stripped. This process can be similar in the EH part of the IWT chain, but to make the truck more productive (or cost efficient) the tractor of the truck can be uncoupled from the trailer with container and perform other trips while the container is stripped and return later to pick up the trailer with container again. The effect of these different operations on the IWT chain costs are shown in figure 2 in comparison with the costs of the road-only transport chain.

<Figure 2> Impact of different end-haulage operations on cost competitiveness of intermodal inland waterway transport

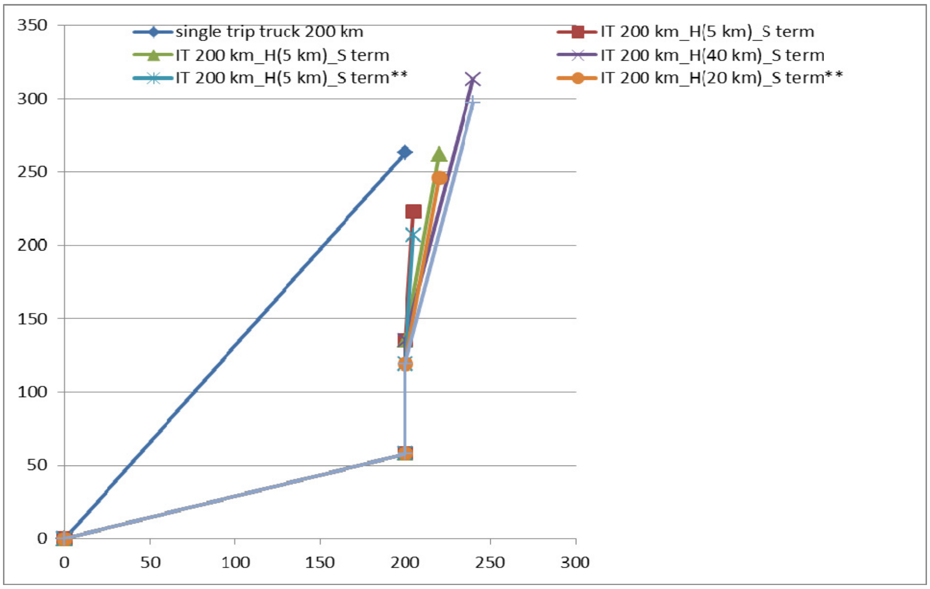


It is clear that drop & pick operations can lead to significant cost savings in EH. In view of the high share of EH costs in the total chain costs – that increases if the IWT distance decreases – the possibility to perform drop & pick operations is of great importance for the cost competitiveness of the IWT chain. The figure also shows that the largest savings in drop & pick operations can be achieved on the shorter end-haulage distances. These results also suggest that for shorter total distances ranging from 50-200 kms, where single mode road transport is more competitive, 'drop & pick' operations instead of 'stay with' operations enable intermodal transport to be more competitive.

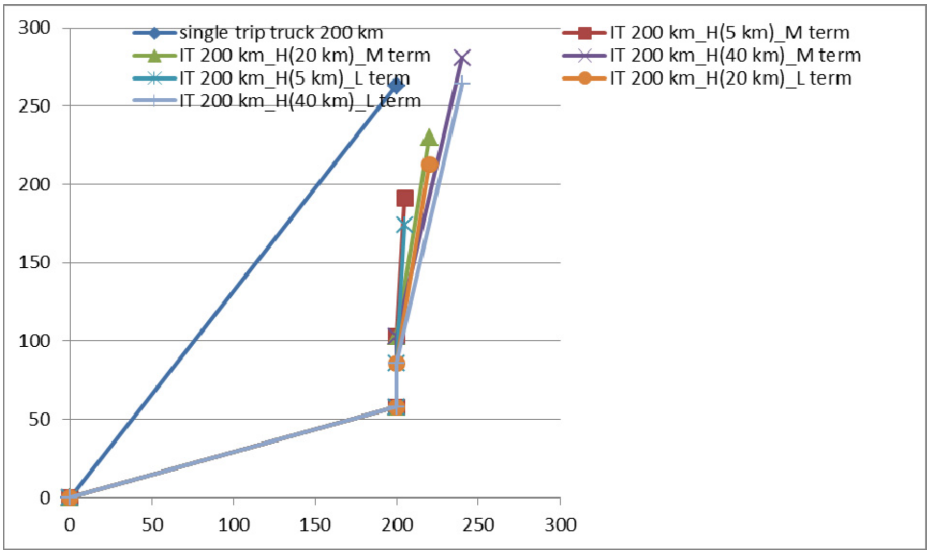
5) Cost Performance for Different Terminal Sizes

The features of a terminal in terms of land use, capital (including number and type of equipment) and labour needs will influence the cost performance of a terminal and hence will affect the cost competitiveness of the IWT chain. In order to evaluate the impact of the cost performance of terminals, different scenarios for terminals, so called terminal profiles, have been developed. Since the size, i.e. handling capacity of a terminal is a key feature of the profiles, the terminal profiles have been labelled as 'S-term'(small terminal, max. 20.000 containers throughput per year), 'M-term'(medium-size terminal, max. 50.000 containers throughput per year) and 'L-term' (large terminal, max. 125.000 containers throughput per year). Annex A table 4 gives a complete description of the terminal profiles. In addition to 'S-term' also an 'S*-term' is included. This is a small terminal, where simple and low cost, i.e. second hand, equipment is being used (see also Annex A table 4). The overview of terminals in this Annex indicates that significant economies of scale can arise. However, due to the large share of fixed costs the utilization rate of the terminal is also a major factor that determines the costs per handling. As can be expected, a comparison between figure 3a and 3b shows that if the intermodal transport distance decreases the handling costs carry more weight in the total chain costs. Moreover, figure 3a illustrates that the share of handling costs can even exceed the share of sailing costs. This situation is most manifest for the handling costs in small terminals. Knowing that the utilization rate has a strong impact on the costs per handling, it underlines the importance to have sufficient throughput in small terminals to make the IWT chain competitive.

<Figure 3a> Impact of terminal size on cost competitiveness of intermodal inland waterway transport



<Figure 3b> Impact of terminal size on cost competitiveness of intermodal inland waterway transport



IV. Discussion and Conclusions

The freight transport customer perceives road haulage as the benchmark for freight transport in Europe: it is in general cheap, reliable, and flexible and succeeds continuously in improving the quality of services and controlling costs. An important motivation to promote intermodal transport is that its cost performance is often assumed better than road-only transport. In this paper, we developed a model to analyse and compare the transport costs of intermodal inland waterway transport and road-only-transport. The results show that the claim that intermodal transport is competitive with single mode road transport is much more diverse and complicated than often assumed.

In the analysis the influence of the economies of scale in inland waterway transport and terminal operations are taken into account. Furthermore, we relate the level of transport cost to specific transport operations (e.g. empty kilometres, capacity usage of terminals, etc.) in order to analyse the sensitivity of the respective transport cost elements for operations. By doing this it is possible to analyse to what extent intermodal freight transport is competitive with road-only transport in terms of transport costs under specific operations (both in shipping and terminal). This leads to a number of conclusions about the competitive position of intermodal inland waterway freight transport as compared to road-only transport in cost terms:

- specially the cost of end-haulage influences the competitiveness of IWT negatively on short and medium distances;
- roundtrips considerably improve the competitiveness of IWT as compared to road-only transport;
- for certain terminal profiles (in an IWT solution) the share of handling costs can even exceed the share of sailing costs. This situation is most manifest regarding the handling costs in small terminals;
- the possibility to perform drop & pick operations in end-haulage is of great importance for the cost competitiveness of the IWT chain;
- transporting FEUs (instead of TEUs) reduces the cost competitiveness of IWT (especially in sailing) as compared to road-only transport;
- the break-even distance in intermodal freight transport (as in a single point) does not exist. It is a multi-point phenomenon.

Overall, our conclusions prove that roundtrips, drop & pick operations in pre- and end-haulage and smaller containers (20ft instead of 40ft) considerably improve the competitiveness of IWT. The competitiveness of IWT is reduced by the relative high cost operations in small terminals. In this competitive field, IWT must determine its market position and further improve transport costs and transport operations. Further research might also include pre-haulage and maybe more complicated intermodal chains (for example with 2 terminals). It is also interesting to further analyse the range of 50-200 kilometres to understand under which conditions IWT can be cost competitive.*

* Date of Contribution; January 13, 2015
Date of Acceptance; May 1, 2015

References

BERGANTINO, A.S., BIERLAIRE, M., CATALANO, M., MIGLIORE, M. and MOROSO, S. (2013), "Taste heterogeneity and latent preferences in the choice behaviour of freight transport operators," *Transport Policy*, Vol.30, pp.77-91.

BLAUWENS, G., DE BAERE, P. and VAN DE VOORDE, E. (2010), Transport economics, De Boeck, Antwerp.

COOPER, R. and KAPLAN, R.S. (1999), The design of cost management systems, Prentice Hall, 2nd edition, Upper Saddle River, New Jersey.

DANIELIS, R. and MARCUCCI, E. (2007), "Attribute cut-offs in freight service selection," *Transportation Research Part E: Logistics and Transportation Review*, Vol.43, No.5, pp.506–515.

DECISIO (2002), Tussenevaluatie Subsidieregeling Openbare Inland Terminals, Eindrapportage, Amsterdam.

DORSSER, C. (2005), Amsterdam Barge Shuttle, Economische haalbaarheid van het AMSbarge project, afstudeerscriptie, Zwijndrecht.

DREWRY SHIPPING CONSULTANTS LTD, (2010), Container terminal capacity and performance benchmarks, London, Drewry Shipping Consultants.

EUROPEAN CONFERENCE OF MINISTERS OF TRANSPORT, United Nations Economic Commission for Europe & Statistical Division and European Union Eurostat (1997), Glossary for transport statistics, http://www1.oecd.org/cem/online/glossaries/.

EUROSTAT (2013), Key figures on Europe; 2013 digest of the online Eurostat yearbook, Publications Office of the European Union, Luxembourg.

FRÉMONT, A. and FRANC, P. (2010). "Hinterland transport in Europe: combined transport versus road transport" *Journal of Transport Geography*, Vol.18, No.4,pp.548-556.

HORGREN, C.T., DATAR, S.M. and RAJAN, M. (2011), Cost accounting; A managerial emphasis, Prentice Hall, New Jersey.

KIM, N.S. and VAN WEE, B. (2011), "The relative importance of factors that influence the break-even distance of intermodal freight transport systems," *Journal of*

Transport Geography, Vol.19, No.4, pp.859-875.

KONINGS, R. (2008), Drayage and the competitiveness of intermodal freight transport, Proceedings of the 87th Annual Transportation Research Board Annual Meeting, Washington.

KONINGS, R. (2009), Intermodal Barge Transport: Network Design, Nodes and Competitiveness, TRAIL Thesis Series nr. T2009/11, TRAIL Research School, Delft.

KOTLER, P. (1997), Marketing management; analysis, planning, implementation, and control, 9th edition, Prentice Hall International, Inc., Upper Saddle River, New Jersey, USA.

KREUTZBERGER, E., KONINGS, R. and ARONSON, L. (2006), Evaluation of the cost performance of pre- and post-haulage in intermodal freight networks: analysis of the interaction of production models and demand characteristics, in: B. Jourquin, P. Rietveld and K. Westin (eds.), Towards better performing transport networks, Routledge, Taylor & Francis Group, pp.256–284.

MACHARIS, C., VAN HOECK, E., PEKIN, E. AND VAN LIER, T. (2010) "A decision analysis framework for intermodal transport: Comparing fuel price increases and the internalisation of external costs," *Transportation Research Part A: Policy and Practice*, Vol. 44, pp.550–561.

NEA, (2009), Kostenkengetallen binnenvaart 2008, Eindrapport, NEA, Zoetermeer.

NIÉRAT, P. (1997), "Market area of rail-truck terminals: Pertinence of the spatial theory," *Transportation Research Part A: Policy and Practice*, Vol.31, No.2, pp.109–127.

PLATZ, T.E. (2009), The efficient integration of inland shipping into continental intermodal transport chains, TRAIL Thesis Series nr. T2009/7, TRAIL Research School, Delft.

VAN HAM, H. and MACHARIS, C. (2005), Intermodaal vervoerbeleid in Nederland en België, in: Duurzame mobiliteit: hot or not?, Colloquium Vervoersplanologisch Speurwerk 2005, Rotterdam.

ZHANG, M., WIEGMANS, B.W. and TAVASSZY, L.A. (2009), 'A comparative study on port hinterland intermodal container transport: Shanghai and Rotterdam', 5th Advanced Forum on Transportation of China, AFTC 2009; Beijing; 17 October 2009 through 17 October 2009, IET Conference Publications, Volume 2009, Issue 560 CP, pp. 15-25, www.hupac.com.

Annex A: Table 1 Factor costs in inland waterway transport (reference date: 2008)

	measure	**Rhine vessel (Class Va)**	**Rhine-Herne vessel (Class IV)**
Vessel characteristics:			
Type of vessel		motor dry freight vessel	motor dry freight vessel
Capacity	TEU	208	90
Dimensions (L x W x D)	meters	110 x 11,40 x 3,60	86 x 10,50 x 3,20
Tonnage	tons	3.500	2.000
Fixed costs:			
Capital costs	€ / year	784.750	350.000
Labor costs			
a. day operations	€ / year	140.000	120.000
b. semi-continuous operations	€ / year	285.000	250.000
c. continuous operations	€ / year	660.000	510.000
Variable costs:			
Fuel costs			
a. loaded vessel	€ / km	10	7,54
b. empty vessel	€ / km	4,78	3,62
Repair and maintenance costs	€ / km	0,72	0,37
Overheads	€ / year	n.a.	n.a.
Business hours:			
a. day operations	hours/year	3.500	3.500
b. semi-continuous operations	hours/year	4.500	4.500
c. continuous operations	hours/year	7.800	7.800
Direct cost hour coefficient			
a. day operations	€ / hour	264	134
b. semi-continuous operations	€ / hour	238	133
c. continuous operations	€ / hour	185	110
Kilometer cost coefficient			
a. loaded vessel	€ / km	10,72	7,91
b. empty vessel	€ / km	5,50	3,99

Source: adapted from NEA, 2009

Annex A: Table 2 Factor costs of road transport in end-haulage (reference date: 2011)

	measure	Tractor	Trailer
Fixed costs:			
Capital costs	€ / year	18.161	3.090
Labor costs	€ / year	57.750	-
Variable costs:			
Fuel costs	€ / km	0,44	-
Repair and maintenance costs	€ / km	0,05	0,02
Tires	€ / km	0,01	0,01
Overheads	€ / year	n.a.	n.a.
Business hours	hours/year	2.625	2.625
Direct cost hour coefficient	€ / hour	28,92	1,18
Kilometer cost coefficient	€ / km	0,50	0,03
Direct cost hour coefficient (truck + trailer)	€ / hour	30,10	
Kilometer cost coefficient (truck + trailer)	€ / km	0,53	

Source: Adapted from TLN, Dorsser, 2005

Annex A: Table 3 Data to define the factor costs of truck haulage (reference date: 2011)

	Tractor	Trailer
Purchase price	75.000	23.000
Depreciation period (in years)	7	12
Rest value (in % of purchase price)	10	10
Number of tires	6	6
Purchase price of tire	380	380
Lifetime of tire (in km)	200.000	200.000
Repair + maintenance (per km)	0,05	0,02
Insurance costs (per year)	4.000	215
Motor road taxes (per year)	768	-
Eurovignet (per year)	1250	-
Other costs	p.m.	-
Fuel consumption (liter/km)	0,4	-
Fuel rate (in Euro) (dated Jan. 2011)	1,10	-
Interest rate (in %)	5	

Source: Adapted from TLN, Dorsser, 2005

Annex A: Table 4 Factor costs of transhipment at inland waterway container terminals (reference date: 2011)

	measure	**Small**	**Small (low profile)**	**Medium**	**Large**	**Very large**
Terminal profile						
Handling capacity	Container throughput /year	20.000	20.000	50.000	125.000	200.000
Terminal equipment	units	1 MS 1 RS	1 MS* 1 FL	1 MS 1 RS	1 PC 1 MC 2 RS	2 PC 3 RC
Surface	ha	1,5	0,75	3	3	7
Quay length	meters	200	100	200	240	300
Fixed costs:						
Land	€ / year	88.000	66.000	200.000	264.000	616.000
Quay	€ / year	75.000	37.500	75.000	90.000	113.000
Equipment (cranes + transport)		163.000	29.700	163.000	373.000	445.000
Labor costs	€ / year	200.000	200.000	400.000	600.000	1.200.000
Interest		272.000	272.000	368.000	598.000	957.000
Variable costs:						
Fuel costs (diesel + electricity)		100.000	100.000	150.000	300.000	600.000
Repair and maintenance costs		22.000	12.000	28.000	42.000	65.000
Office	€ / year	10.000	10.000	10.000	10.000	10.000
ICT	€ / year	100.000	100.000	100.000	100.000	100.000
Other costs	€ / year	83.000	83.000	110.000	111.000	118.000
Other	€ / year	22.000	12.000	28.000	42.000	65.000
Management fee		100.000	50.000	150.000	300.000	500.000
Transhipment costs:						
Cost at 60% terminal utilization	€/ handling	103	81	60	38	40
Cost at 80% terminal utilization	€ / handling	77	61	45	28	30
Cost at 100% terminal utilization	€ / handling	62	49	36	23	24

MS: mobile crane, RS: reachstacker, PC: portal crane,

MS*: second hand mobile crane, FL: forklift (18 tonne)

The other indirect costs include lighting, security (guards and fences), insurance, terminals taxes (licenses).

Sources: various