The performance of intermodal inland waterway transport: Modeling conditions influencing its competitiveness

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ABSTRACT

In Europe, numerous obstacles have been identified which prevent the (extensive) use of intermodal transport. A major motivation to promote intermodal transport is that its cost performance is often assumed better than road-only transport. Considering that the cost of transport services remains one of the most important criteria for the modal choice, the better cost performance of intermodal transport should be a major trigger to attract customers and to increase the market share of intermodal transport. However, despite that intermodal freight transport has developed into a mature industry over the last decades its market share is still modest. The relationship between costs and operations in the intermodal transport chain is often not well elaborated, leading to unclear results or even sometimes incorrect estimates. In this paper, we developed a model that is capable to calculate intermodal freight transport cost for any origin destination pair in Europe accessible by both intermodal inland waterway and road-only-mode road transport. Furthermore, we relate the level of transport cost to the effective transport operations (e.g. empty kilometers, capacity usage of terminals, etc.) in order to analyze the sensitivity of the respective transport cost elements for operations. By doing this it is possible to analyze to what extent intermodal freight transport is competitive with road-only transport in terms of transport cost and effective operations for any origin destination combination accessible by inland waterways and road.

KEYWORDS: intermodal transport, costs, competition, inland waterway

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1 Introduction

In the last decades, freight transport has increased enormously and this transport growth has been predominantly absorbed by road transport. While road transport counted for 65% of the total transport performance (in tonne-km) in the European Union in 1980, its share increased to 76% in 2008, leaving a share of rail and barge of 18% and 6% respectively (European Commission, 2003; Eurostat, 2011). However, besides many advantages road freight transport also contributes to congestion, accidents, air pollution and noise nuisance. Evidently, these conditions ask for an improvement of the performances of road freight transport, but they also address the need for a greater role of other modes. However, in Europe, a number of obstacles have been identified which prevent the extensive use of intermodal transport (European Commission, 2010): i) the lack of a coherent infrastructure network of modes and interconnections, ii) the lack of technical interoperability between and within modes, iii) a variety of regulations and standards for transport means, iv) and data-interchange and procedures. This identification of obstacles implicitly assumes that the position of intermodal freight transport versus single mode road transport is competitive and needs improvement in the identified problem areas in order to become even more competitive. A major motivation to promote intermodal transport is that its cost performance is often assumed better than single-mode road transport especially in optimization research (see e.g. Min 1991). Considering that the cost of transport services remains one of the most important criteria for the modal choice, the better cost performance of intermodal transport should be a major trigger to attract customers and to increase the market share of intermodal transport. However, despite that intermodal freight transport has developed into a mature industry over the last decades its market share is still modest. Scientific freight transport research confirms the importance of costs in the modal choice process (e.g. Barnhart and Ratliff, 1993; Boardman et al., 1997), although it indicates that other criteria (e.g. reliability, time, flexibility) also play a role, but a thorough analysis comparing the costs of road-only transport and intermodal transport is still lacking. Indeed several studies have been conducted on cost-break even distances (a review of these studies is given by Kim and Van Wee (2011)). The wide range of distances found in these studies can partly be explained by different conditions under which the cost performance of road transport and intermodal transport were compared, indicating that operational transport conditions are crucial. However, the relationship between costs and operations in the transport chain is often not well elaborated, leading to unclear results or incorrect estimates. That is to say, instead of including costs that reflect the specific case that is being studied the costs are often rather assumed to be an average of all operations in the intermodal transport sector Therefore, the problem definition of this paper is as follows: 'To what extent is intermodal freight transport competitive with road-only transport in terms of cost and what can be done to improve this?' First, the paper will briefly introduce intermodal transport. Secondly, cost theory will be analyzed. Thirdly, the costs of intermodal freight transport and road-only transport will be built into a model that is capable to generate cost calculations for any origin-destination pair that is accessible by IWW. The outcomes will be analyzed in detail for a number of representative cases. Finally, a number of conclusions will be drawn.

2 Intermodal freight transport and its position in Europe

Intermodal transport can be defined as the transfer of unit loads from the place of origin to the final destination by combining two or more different transport modes (road, rail, inland waterway, sea and air). Road transport is then often used for local collection and/or distribution only (www.hupac.com). Jones et al. (2000) define intermodal transport as 'the shipment of cargo involving more than one mode of transportation during a single seamless journey'. An important aspect in this definition is *a single seamless journey* that underlines one of the most important challenges for intermodal transport. Newman and Yano (2000a-b) define intermodal transport as 'the combination of modes, usually ship, truck or rail to transport freight'. Hayuth, (1987), defines intermodal transport as 'the movement of cargo from shipper to consignee using two or more different modes under a single rate, with through billing and through liability'. We combine the definition of Hayuth with *seamless* and that leads us to the definition of intermodal inland waterway transport (IIWT) that we use in this paper: 'the seamless movement of cargo from shipper to consignee using two or more different modes under a single rate, with through billing and through liability'.

In looking over the current role of IIWT in Europe it can be noticed that IIWT is still functioning almost exclusively as a hinterland transport system, i.e. containers are transported between seaports and inland locations. For this reason IIWT has mainly developed in the hinterland of North-European seaports as they are linked to the European waterway network. In 2010 the IIWT volume handled in Rotterdam was 2,4 million TEU and 2,3 in Antwerp. These volumes correspond with a market share in hinterland transport of respectively 33% for Rotterdam and 34% for Antwerp. In other seaports that are linked to inland waterways the volumes and share of IIWT are still modest (Le Havre: 170.000 TEU (7%), Marseille: 59.000 TEU (6%); Hamburg: 95.000 TEU (1%)). The total IIWT-volumes handled are significant (over 5 million TEU), but are still relatively small compared to total freight transport within Europe. Savy and Aubriot (2005) estimated that intermodal inland waterway and rail transport together do not account for more than 5% of the total surface traffic (in tonne-km) of goods in Europe as a whole.

The typical IIWT chain consists of the main transport between the maritime terminal (in a port such as Antwerp, Hamburg or Rotterdam) and an inland terminal and is performed by a barge (Zhang et al., 2009). The final element of this hinterland intermodal chain is the end-haulage by truck (see figure 1a).

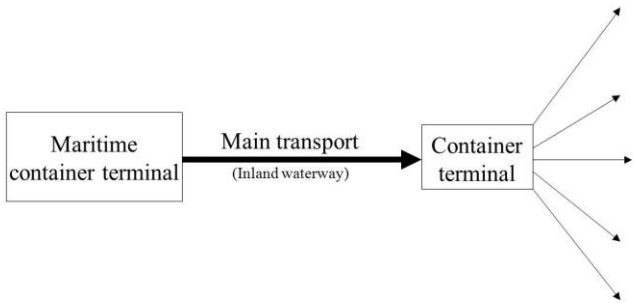

Figure 1a Hinterland intermodal freight transport based on a barge service calling at one terminal in the seaport

An alternative hinterland chain is formed by a solution where containers have to be collected at different terminals in a maritime port (the left part of Figure 1b). This chain structure is the leading principle for IIWT-services, since the volumes of one maritime container terminal are usually too small to offer a point-to-point service between a maritime and inland container terminal. Although consolidation of containers can also take place by visiting several terminals in the hinterland, traditionally the number of terminal visits in the seaport is much larger than in the hinterland.

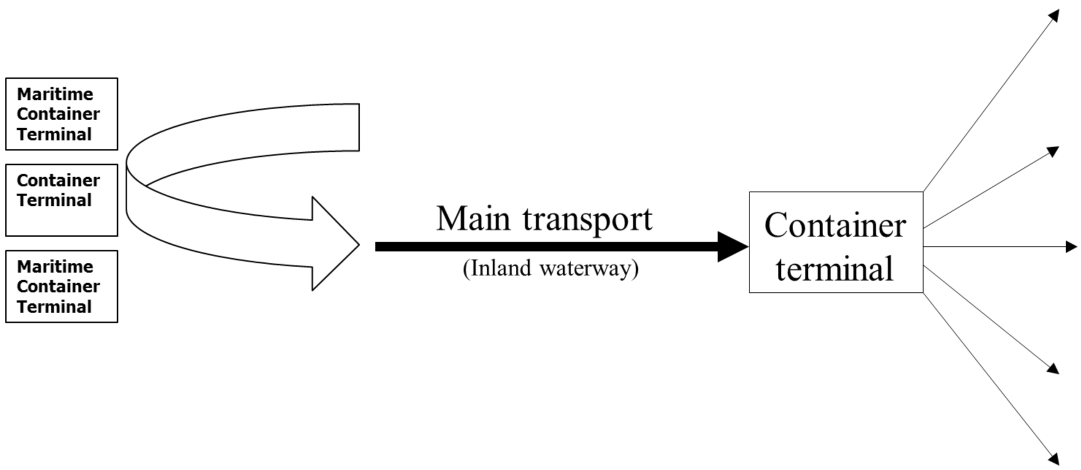

Figure 1b Hinterland intermodal freight transport based on a barge service calling at several terminals in the seaport

3 Theoretical cost framework for the analysis

3.1 Principles of transport cost analysis

In principle, the cost of a transport service should reflect all costs that are needed to produce the transport service. Evidently the cost price may include a wide range of cost drivers as offering a transport service may involve many activities. Moreover, prior to producing the transport service usually investments (e.g. purchase of transport equipment) are needed that enable to produce the service, and of course these investment costs should also be reflected in the cost price. Cost allocation in the area of transport has not been extensively studied which is remarkable given the importance of costs in transport service decision-making. 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 en restrained individualized costs; and 4) Activity Based Costing. All incurred costs have to be assigned in some way to transport services. For costs that can be easily (directly) assigned to transport services, so called *direct costs* this is not an issue, but for indirect costs which cannot be related straightforward to transport services (e.g. costs of offices and telecommunication) this is a problem by definition. This issue of dealing with *indirect* costs is a general challenge in cost accounting and is often solved by arbitrarily defined formulas to distribute these costs to transport services (see e.g. Horngren et al., 2011). In assigning costs correctly to transport services the distinction between *fixed and variable costs* is of particular interest, since these types of costs should be assigned differently. Fixed costs can be defined as the expenses that are not dependent on the level of services produced by the business, or, in other words, they do not change as a function of the activity of a business, within the relevant (considered) period. These costs tend to be time-related, because they occur when time goes by, even when no services are produced. Sometimes they are defined as capacity costs (see e.g. Blauwens et al., 2010). Fixed costs, however, are not permanently fixed, they may change over time. In contrast variable costs are expenses that change in proportion to the activity of a business, and hence they are volume-related: they increase for every quantity that is produced. *Completely individualized costs* can be significantly directed to cost centers. Significant means that there are quantifiable, causal relations between costs and cost centers. Restrained individualized costs are costs that cannot be adequately directed to cost centers. *Activity Based Costing* assigns indirect costs to services (or products) according to the degree of usage of supportive activities. Furthermore, it provides insight into the cost structure and into the activities that cause (produce) the costs. This method looks for causality between activities and costs, which may result in effective improvement programs.

In our analysis, the widely-accepted system of fixed and variable cost 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 cost price of the service. The variable costs will change in function of the number of delivered transport services, but the level of variable costs of an individual service is also a function of the transport distance[3]: a transport service over a longer distance will cause higher variable costs (e.g. fuel). Therefore, the major determinants in the cost price calculation are the time spent in a transport trip and the distance covered in this trip. 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 kilometer cost coefficient can be derived, which is the total variable costs (the sum of different types of variable costs) per kilometer. Table 1 summarizes how these coefficients are constructed. Multiplying the cost coefficients with the time consumption of a trip and the trip distance results into the cost price of the transport service[4].

Table 1 Assignment of different costs to transport services

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

Considering these elements of the cost price of a transport service it is evident that the cost price is on the one hand determined by the typical *cost characteristics of the production factors* needed to offer transport services (e.g. type of equipment, labor), i.e. factor costs. These factors will determine the hour and kilometer cost coefficients. On the other hand is the cost price determined by the *efficiency of using these production factors* (type of operations) to offer transport services, since the type of operations may influence the time consumption and travel distances to deliver transport services[5]. Both elements of the cost price are elaborated in the next subsections.

3.2 Factor costs in (intermodal) freight transport modes

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 barge, terminal handling (transshipment), and end-haulage by truck, as it concerns different types of services. 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 cost involved in terminal operations and the

[3] Fuel costs are variable costs. The total fuel costs is the sum of the fuel costs incurred by all delivered services, but the transport distance in a transport service will be a main determinant for the fuel consumption, and hence the fuel costs of each transport service. Note, however, that fuel consumption per kilometer can be a determinant as well, depending for instance on the type and quality of the road (an allowed speed) and behavior of the truck driver.

[4] In addition to this cost price of a service, trip-specific costs may need to be added, for instance toll to pass a tunnel or bridge by truck or toll road costs. In the latter case these costs can be considered and included as a variable cost.

[5] Transport distances to customers are evidently fixed, but for instance bundling of two shipments may reduce the total travel distance for the deliveries, and hence the transport costs per delivery.

market structure of perfect competition in European road freight transport and inland waterway transport. The data used apply to the European situation and most data components that we were able to obtain we used by taking the average or median of several sources.

3.2.1 Factor costs of inland waterway transport

As regards IIWT the costs, split up in fixed and variable costs are described for two different types (sizes) of vessels that are common used vessels in container transport (see Annex A table 1). The fixed costs include labor costs and equipment costs, i.e. the material costs of the vessel. The variable costs consist of fuel costs and maintenance and repair costs of the vessel. The labor costs are defined as the sum of gross wages, social costs, pension plans, and extra additions. The labor costs are on the one hand influenced by the type of vessel and the length of a vessel[6] and on the other hand by the type of operations: day operations (maximum 14 hours of operation per day), semi-continuous (max. 18 hours/day) or continuous operations (24 hours/day). Material (vessel) costs include depreciation, interest, insurance, repair and maintenance, port dues, and other costs (administration, communication, certificates, overhead, other). As regards repair and maintenance 50% is considered as a fixed cost, while the remainder is related to the level of operations, i.e. are included as variable costs (NEA, 2009). Including port dues as a fixed cost is debatable, as they are rather a trip-specific cost. Assuming fixed costs is justified when all services are faced with port dues. The fuel costs are a function of fuel consumption and the fuel rate. Evidently, numerous conditions influence fuel consumption, i.e. sailing speed, size and dimension 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 loading degree of the vessel is of particular importance for fuel consumption. In Annex A Table 1 we show the fuel costs of completely loaded vessels and empty vessels. These cost data reflect the average costs for different waterway classes (see NEA, 2009).

3.2.2 Factor costs of end-haulage by truck

Annex A Table 2 provides an overview of the structure of the fixed and variable costs in end-haulage truck operations. In view on the discussion on types of operations later on in this paper it is useful to make a distinction between the cost structure of the main units of a truck: the tractor and trailer. The fixed costs for trucking comprise depreciation, interest, insurance, road taxes (including general taxes and Eurovignet) and the variable costs include fuel, tires, maintenance.

[6] Gross salaries of staff differ for different types of vessels (i.e. motor dry freight vessels, motor tank vessels, motor vessel-push barge combinations and push boat-pus barge formations) and prescribed crew

An overview of the data used to calculate the fixed costs on an annual base and the variable costs per kilometer is given in Annex A Table 3.

3.2.3 Factor costs of transshipment: terminals

To enable exchange of containers between barge and truck handling equipment is needed. Different types of equipment exist, ranging from multi-purpose to dedicated container cranes and from mobile equipment (cranes or reachstackers) to fixed equipment. Container terminals, however, usually comprise much more facilities to support container transshipment. For instance an area for temporary storage of containers, since direct transshipment between barge 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. Since the costs of the transshipment service depend on the terminal configuration we present the factor costs of transshipment at barge terminals for different terminal profiles. 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).

3.3 Type of operations in intermodal inland waterway freight transport

3.3.1 Inland waterway transport operations

Typical for the cost structure of IIWT is the great importance of the fixed costs, and the capital costs, i.e. depreciation and interest of the barge, in particular. An inland vessel is an expensive asset and although it has a long lifetime it has high capital costs. These costs can only substantially reduce when a vessel remains in operation after the book-keeping depreciation term has expired, and this can sometimes be observed in practice. A consequence of the relatively high fixed costs is that a sufficient loading degree of a barge is of major importance to achieve low transport costs per load unit. This means that although operating larger barges can potentially lead to economies of scale much depends on the available cargo flows taking also a minimum required service frequency into consideration. Furthermore, the characteristics of the inland waterway (including dimensions of locks) may limit the size of the barge that can be operated. In addition to the loading degree of a barge the utilization rate of a barge is highly important, and this rate is strongly related to the roundtrip time of a barge. 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 as well as bridges (including waiting times) as well as the handling and waiting times of barges at terminals. Moreover,

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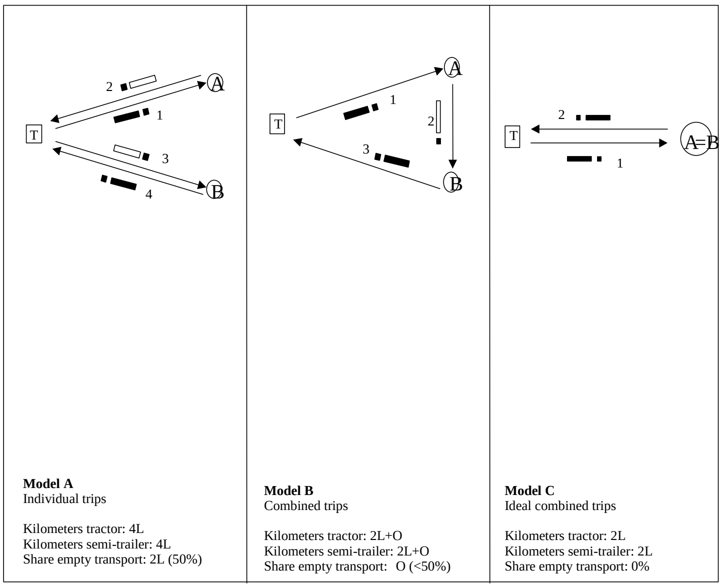
composition varies between vessel type. At a larger vessel a larger crew is required. The prescribed crew is based on the following categories of vessel lengths: L >= 70 m., 70 m < L <= 86 m and L >= 86 m.

bridges may also influence the cost performance of barge transport, since the bridge clearance may limit the number of layers of containers that can be transported. Therefore the specific route of a barge service as well as the performance of the terminal will influence the cost performance of barge transport.

3.3.2 End-haulage operations

In the cost structure of end-haulage both the variable or kilometer costs and the fixed or time costs are important (see Kreutzberger et al., 2006; Konings, 2008). Their importance varies with the exact characteristics of the transport company (short distance, long distance or mixed focus). Given the distinction between time and kilometer costs there are two driving forces for the execution of end-haulage trips. On the one hand this is the aim to maximize the productivity of resources (equipment and labor), or in other words, trying to execute paid trips as much as possible. This enables to reduce the fixed costs per trip. On the other hand the aim is to minimize the number of empty vehicle kilometers in order to reduce the variable costs. The first goal is related to, in literature well known, 'stay-with' or 'drop-and-pick' processes in end-haulage 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: a) the combination drives back to the terminal empty, b) the container is loaded elsewhere and then the truck returns to the terminal or c) 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% (see figure 2). The fixed costs of these trips are relatively high, because the tractor and driver are waiting during (un)loading the container and therefore they are unproductive. In daily practice situation A is most common, because when containers are stripped they are temporary stacked in depots in the hinterland to wait for a new job or they are returned empty to the seaport. Situation B may occur, but situation C is a rather theoretical option since many companies have either inbound container cargo flows or outbound container cargo flows.

Figure 2 'Stay with' production model (tractor and semi-trailer of a truck stay together): three basic patterns



Legend:

T = terminal

A = customer A

B = customer B

= tractor/semi-trailer combination with loaded container

= tractor/semi-trailer combination with empty container

1,2,3,4 = numbers indicate the order of activities

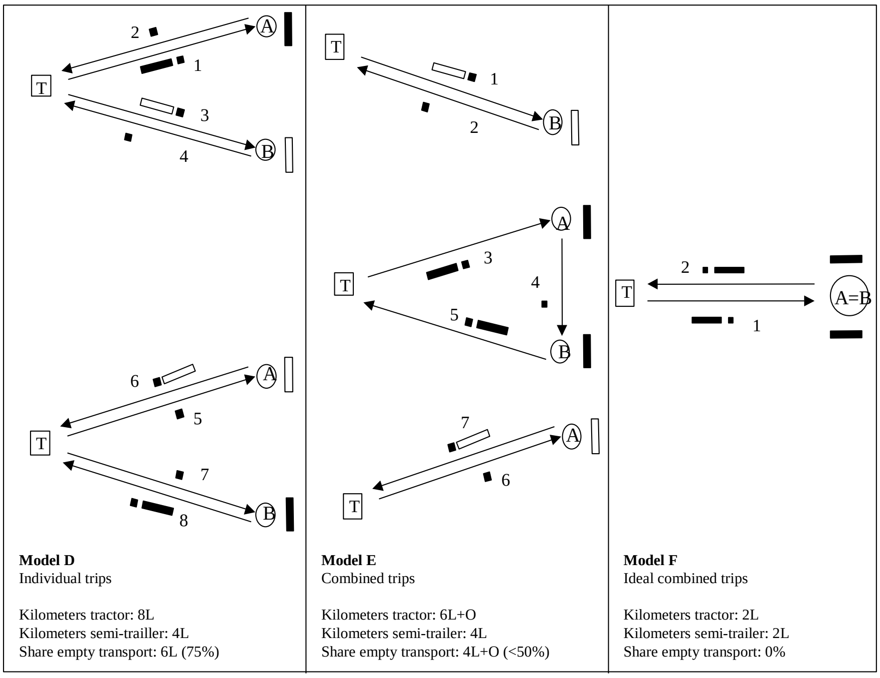
L = distance from terminal to customer

O = distance between customers

Source: Konings, 2008

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 kilometer costs are higher, because of more empty hauls. The share of empty trips can become 75% (see figure 3).

Figure 3 **'Drop and pick' production model (tractor and semi-trailer of a truck are split): three basic patterns**



Legend:

T = terminal
A = customer A
B = customer B
= tractor/semi-trailer combination with loaded container
= tractor/semi-trailer combination with empty container
= semi-trailer with loaded container
= semi-trailer with empty container
= tractor
1,2,3,4 = numbers indicate the order of activities
L = distance from terminal to customer
O = distance between customers

Source: Konings, 2008

Since the total cost of the truck haul is not only determined by the cost of driving, but also by costs related to the trip time (including the time spent at terminals and customers) a trip production model that results to less kilometers is therefore not always the most efficient solution. 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. Since the costs of trips with empty containers have to be taken into account in the truck haul rates offered to customers, the number of empty hauls is (very) relevant. The share of empty hauls can be reduced by combining trips.

3.3.3 Transshipment: terminal operations

The costs of transshipment in inland waterway container transport are different in the seaport and at terminals in the hinterland due to different types of operations as well as different types of equipment that are used. At inland terminals transshipment costs may also vary between terminals. These cost differences 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 (big) difference in the real cost price of transshipments. 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 barge 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 IWW barges that must be unloaded or loaded quickly) will also lead to increased costs per handling. Finally, terminal operations are also influenced by data (information) availability and the connection with end-haulage. Given the fact that fixed costs have a (very) large share in the total operational costs of a container barge terminal, the number of moves strongly determines the cost per move (see Annex A Table 4). In other words, if the number of containers transshipped increases the cost per container can considerably decrease.

4 Evaluation of the economics of intermodal inland waterway transport

In this section we quantify the cost structure of intermodal inland waterway transport and compare its cost performance with the costs of road-only transport. For this purpose we have developed a model, based on intermodal transport distance, i.e. the sailing distance by barge and the haulage distance by 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 barge size, the profile of a terminal and type of end-haulage operations).

4.1 Definition of the base scenario of operations

In the evaluation of cost competitiveness of IIWT, the focus is on the hinterland transport chain. Since IIWT has so far only developed as a hinterland transport system this chain is the most relevant chain for comparison with road-only transport. It means that the IIWT chain has only one haul by truck (end-haulage) and only one inland terminal visit is included. Of course the chain also includes a terminal visit in the seaport. This terminal visit is also part of the road-only transport chain. The costs of these handlings at the seaport terminals will differ due to differences in the processes and equipment used to put container on barges 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 IIWT and road-only transport.

Very relevant for the cost comparison between the IIWT and road-only transport chain is the type of barge service that is considered. The cost performance of a pure shuttle service, i.e. from one seaport terminal to one inland terminal (as represented in figure 1a) will be different from a barge service where containers have to be collected and distributed at several terminals in the seaport (as represented in figure 1b), due to the fact that the latter service is more time-consuming. Following current practice where almost all barge services have these collection/distribution features in the seaport we consider this type of service as part of the base scenario of operations. In addition, it is relevant to know other characteristics of the chain activities that are assumed to form the base scenario for the operations. The base scenario of operations covers the following characteristics:

Sailing:

- size of the vessel that is considered implies a loading capacity of 208 TEU;
- average loading degree of the vessel (in both directions) is 70%;
- services are produced according to the business model of continuous operations, which is the leading business model for container barge 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 similar. This means that if the circulation time of a vessel in offering a service is close to (a multiple of) 24 hours, then there is not much idle time (i.e. the vessel is not inactive for many hours) and the costs of the barge service will be more favorable;

- 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 (i.e. processing and waiting time).
- terminal handling: cost of handling at an inland terminal are based upon the performance of a medium-sized inland terminal (see Annex A table 4);
- the utilization rate of the terminal is 80% (see Annex A table 4).

End-haulage:

- the operations in end-haulage are 'stay with' processes (see also section 3.3.2)

These base scenario operations are assumed when we look at different representative chains to compare the cost performance of IIWT versus road-only transport. The representative 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 possibilities for the IIWT chains. However, the combination of 50 km sailing distance and 40 km EH distance is excluded in the analyses, because the relative distance of the truck haul is too large compared to the main haul by barge (see also section 2).

In the analyses, a *single trip in IIWT* consists of the following activities: sailing from seaport to the inland terminal, container handling from barge 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 (i.e. container depot). 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 IIWT* the container that was stored after finishing its single trip is handled again to put it on a barge 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.

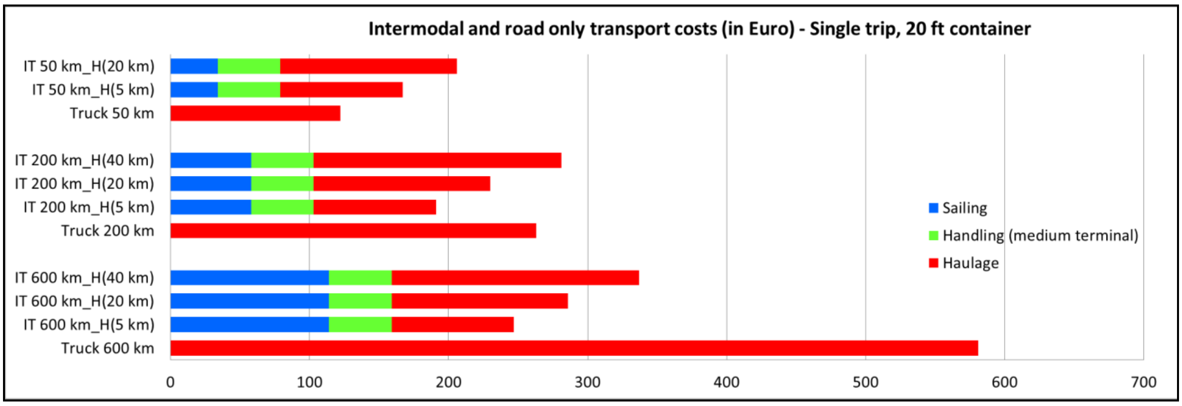
4.2 Cost performance evaluation for different chains

4.2.1 Cost performance of single trip versus round trip

Figure 4 shows the cost comparison between the IIWT and road-only transport chain in a 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

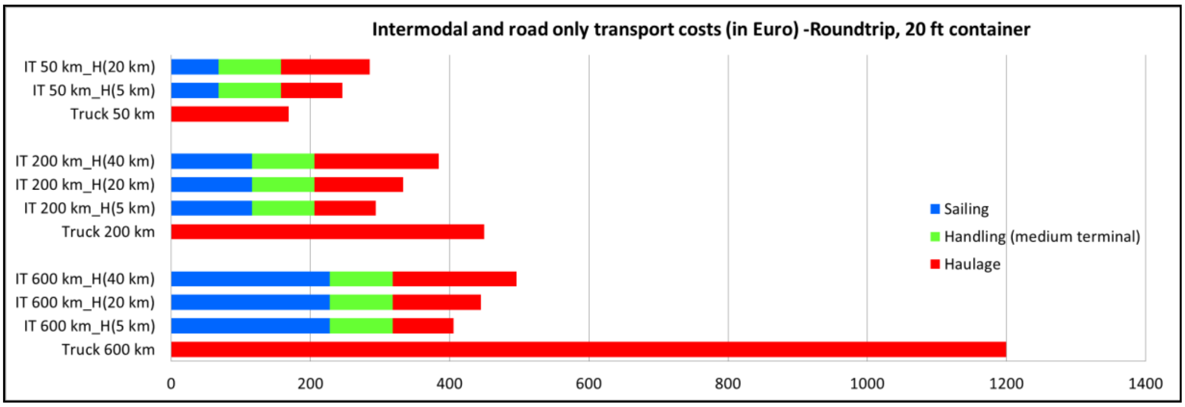
200 km a relative large PPH distance (40 km) may result into absorption of the cost advantage of IIWT. At short sailing distance (50 km) the high PPH costs will be killing for IIWT.

Figure 4 Cost competitiveness of intermodal IWT (20 ft containers): single trips



As figure 5 demonstrates, IIWT has a relatively more favorable cost performance in case of roundtrips, 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.

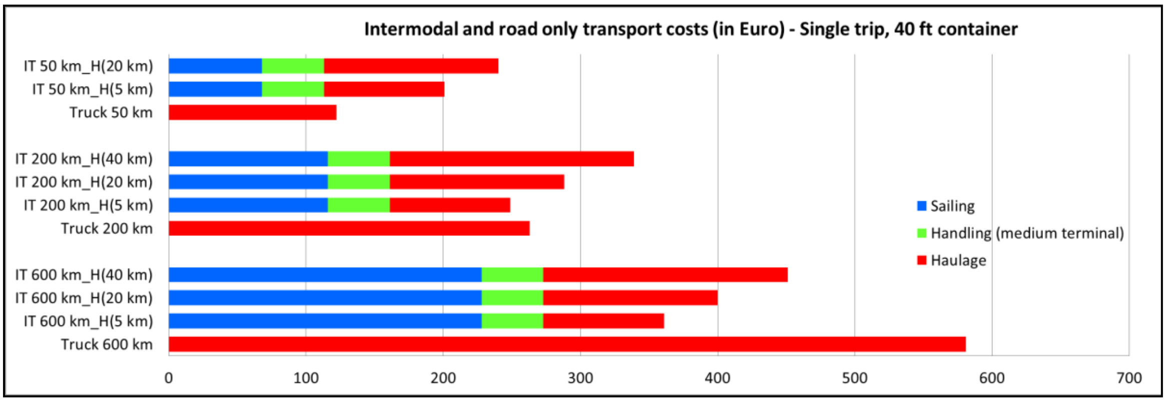
Figure 5 Cost competitiveness of intermodal IWT (20 ft containers): roundtrips



4.2.2 Cost performance of 20 ft versus 40 ft container transport

The size of the loading unit has a large impact on the cost competitiveness of IIWT compared to road-only transport. Barging 20 ft containers provides a relatively more favorable cost performance than barging 40 ft containers (see figure 4 and 6). When instead of a 20 ft container a 40 ft container is transported the sailing costs will double since the required slots on the barge 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 (i.e. it is only possible for light-weight cargo).

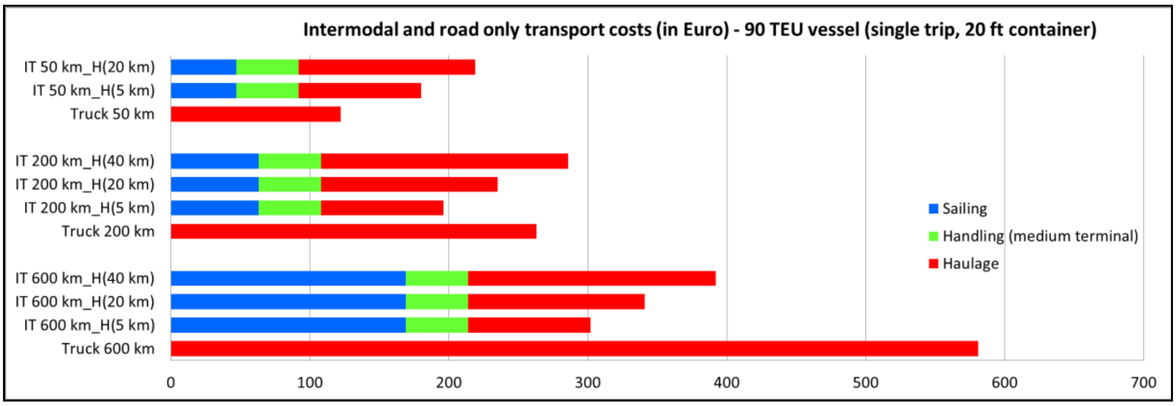
Figure 6 Impact of load unit size on cost competitiveness of intermodal IWT



4.3.1 Scenario's for sailing

In the representative chains analyzed so far the barge 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 as well as smaller vessels are used. The decision regarding the size of a vessel is on the one hand determined by the transport demand (available container volumes) and on the other hand by physical limitations imposed by the waterway infrastructure. Figure 7 illustrates the cost performance of IIWT for situations in which a vessel of 90 TEU capacity is operated. IIWT 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 loading degree as a small vessel, here assumed 70% of the vessel capacity), but its relative cost advantage becomes more manifest at longer distances.

Figure 7 Impact of vessel size on cost competitiveness of intermodal IWT



4.3.2 Scenario's for terminal handling

The features of a terminal in terms of land use, capital (including number and type of equipment) and labor use will influence the cost performance of a terminal an hence affect the cost competitiveness of the IIWT 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 labeled as 'S-term'(small terminal, max. 20.000 containers/year), 'M-term'(medium-size terminal, max. 50.000 containers/year) and 'L-term' (large terminal, max. 125.000 containers/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 determining the costs per handling. As can be expected, a comparison between figure 8 and 9 shows that at shorter intermodal transport distance the handling costs carry more weight in the total chain costs. Moreover, figure 9 illustrates that 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. 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 IIWT chain competitive.

Figure 8 Impact of terminal size on cost competitiveness of intermodal IWT (at 600 km)

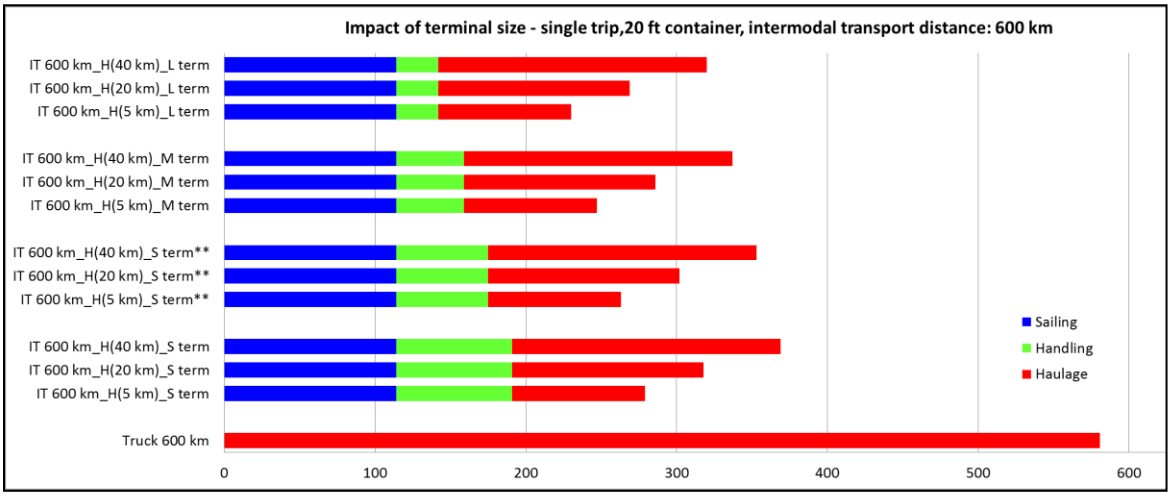
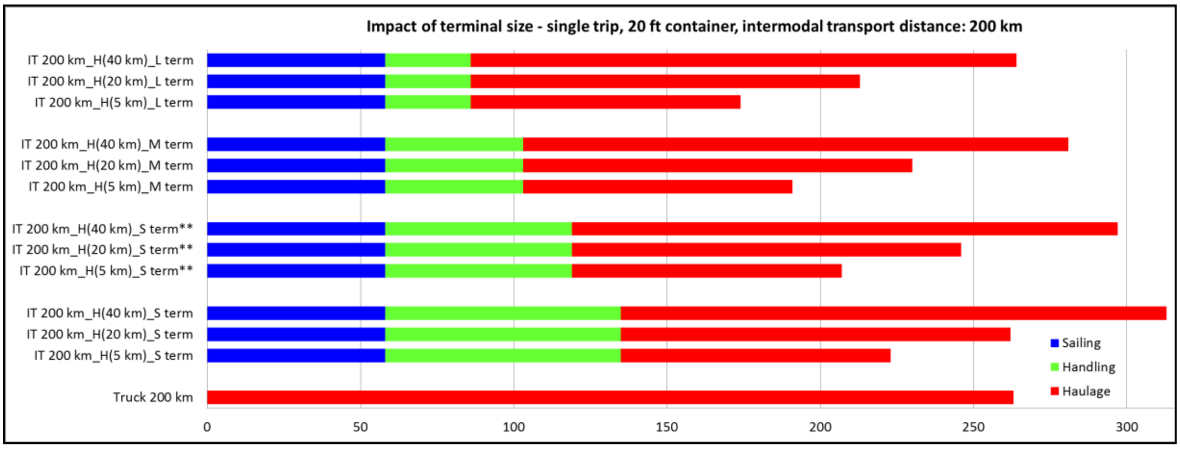


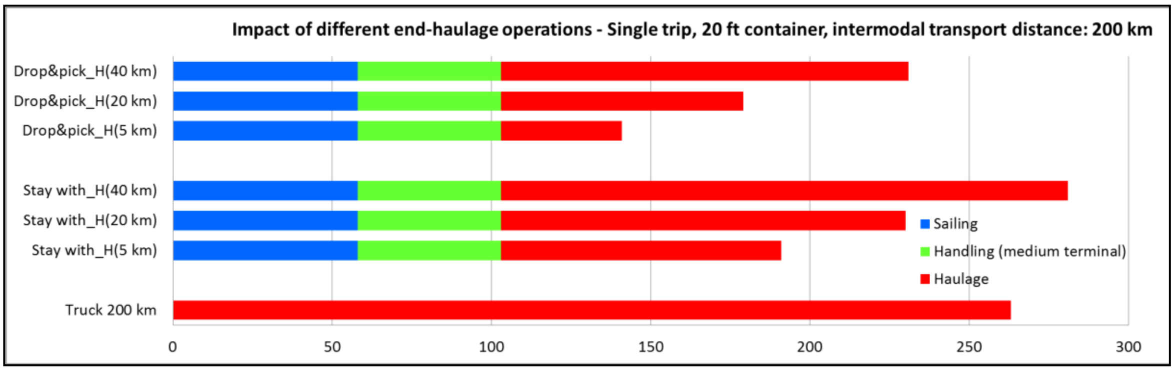
Figure 9 Impact of terminal size on cost competitiveness of intermodal IWT (at 200 km)



4.3.3 Scenario's for end-haulage

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 IIWT 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 IIWT chain costs are shown in figure 10 in comparison with the costs of the road-only transport chain.

Figure 10 Impact of different end-haulage operations on cost competitiveness of intermodal IWT (at 200 km)



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 intermodal transport distance decreases – the possibility to perform drop & pick operations is of great importance for the cost competitiveness of the IIWT chain. The figure also shows that the largest savings in drop & pick operations can be achieved on short distances.

5. Conclusion and discussion: cost strategies in intermodal transport

The freight transport customer perceives road haulage as the benchmark for freight transport in Europe: it is competitive, reliable, and flexible and continues to improve service performance and reduce costs. This shapes the competitive environment for IIWT solutions and leads to service and cost requirements that must be met by the industry competitors. An important motivation to promote intermodal transport is that its cost performance is often assumed better than road-only transport. This paper shows that this claim is much more diverse and complicated than often assumed. The analysis shows that also in many representative chains road-only transport has lower costs than IIWT and combined with high quality services this leads to a strong service package offering by road-only transport. In this paper, the focus has been on a number of intermodal freight transport chains for which the transport cost have been calculated (both intermodal inland waterway and road-only transport). Furthermore, the sensitivity of the respective transport cost elements for operations has been analyzed. 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:

- Especially the cost of pre- and end-haulage influences the competitiveness of IIWT negatively on short and medium distances;
- Roundtrips considerably improve the competitiveness of IIWT as compared to road-only transport;
- Transporting FEUs (instead of TEUs) reduces the cost competitiveness of IIWT (especially in sailing) as compared to road-only transport;
- Larger vessels are more cost-efficient than smaller vessels especially on long and medium-long distances
- On short distance, handling costs carry more weight in the total IIWT chain costs;
- For certain terminal profiles (in an IIWT 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 pre- and end-haulage is of great importance for the cost competitiveness of the IIWT chain.

Overall, the analysis shows that IIWT is competitive with road-only transport in transport cost and efficient operations under certain conditions. However, also many chains exist (with certain conditions) where road-only transport is the best option in transport cost terms (even without paying attention to quality). This means that a strategy is needed in order to further improve the competitiveness of IIWT in terms of transport cost and efficient operations. Company strategies towards the marketplace may have different foci (Kotler, 1997, p12): production, product (or service), selling, or marketing. These foci influence the way a company is organized and also in the end determines the outcomes in terms of costs, prices and profits. Each company must have a plan in order to realize its long term goals and several different approaches exist: *Cost leadership* where companies strive for cost reductions. Investments in plant modernization in order to lower costs and improve quality, in R&D and in marketing are made. In the IIWT market, this is a strategy that is often found. An *innovation focused* company strives to lead the industry through innovation. This often lead to companies with a higher quality image and allows to charge higher prices (price leadership). *Nichemanship* is the strategy where a company looks for specialty markets. In order to pursue this strategy needs great skills in picking and exploiting niche markets. When a company excels in a certain niche market it might be possible to charge higher prices (e.g. chemicals). In certain parts of the IIWT market this might be a successful strategy (e.g. chemicals, oil). *Diversification* is a strategy where a company also operates in other industries besides (intermodal) transport. This can also be observed as deep-sea container carriers enter intermodal transport markets, port authorities operating inland terminals and logistics service providers entering transport markets. In this competitive field, IIWT must determine its market position and improve transport cost and transport operations.

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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:			
Material (vessel) 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:			
Material (truck) 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 transshipment at container barge terminals (reference date: 2011)

	measure	**Small**	**Small (low profile)**	**Medium**	**Large**	**Very large**
Terminal profile						
Handling capacity	containers/ 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 COST						
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