INTERMODAL COST FUNCTION: A PRACTICAL TOOL APPLIED TO EUROPEAN FREIGHHT CORRIDORS

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ABSTRACT

Intermodal transport is becoming more and more relevant in the European transport agenda, being considered a valuable option to road transport. The benefits that intermodal transport can provide are related both to environmental impacts and to cost aspects. On a European level the policy measures that have been taken and are currently developed focus on the implementation and support of this mode of transport while from the business point of view intermodal transport is not yet considered very appealing.

The purpose of this paper is to provide an analysis of the total intermodal cost function, taking into account the internal cost elements. When considering an intermodal journey several cost items need to be taken into account: the transport cost itself, the transhipment cost, the managerial costs related to the entire door-to-door service.

In the present paper a European intermodal corridor will be analysed. The focus will be on the intermodal corridor starting from the Port of Antwerp, in Belgium and ending in Basel, in Switzerland. The study aims at analysing the structure of a traffic corridor starting from this port and ending in one region/area in the centre of Europe. A methodology has been developed which is based on four steps. First a review of the literature about intermodal cost functions has been considered and used as a framework for the elaboration of the intermodal cost function presented. As a second step an analysis of traffic flows for a specific destination from the aforementioned port has been carried out. Subsequently the calculation of internal costs has been developed through the use of a calculation tool specifically improved for the paper purpose. As a conclusion some considerations and a proposal for further research are drawn. The results and the methodology of the present exercise can be considered as a possible approach for the calculation of the cost items composing the intermodal transport. This exercise can be useful when a complete and precise analysis is needed. This approach allows for a concentration on the typical aspects of intermodal transport, giving the possibility to focus on the critical aspects related to cost items and trying to intervene on these elements for improving the performance and quality of this mode of transport.

Keywords: intermodal transport, intermodal cost function, traffic flows, practical tool.

INTRODUCTION

In order to understand which elements can influence mode choice, it is important to investigate which variables characterise each mode of transport. According to the literature review, one of the most important criteria is related to the out of pocket money. Although there are also several qualitative attributes affecting the mode or intermodal choice of the shipper or freight forwarder, the monetary expense is an important decision factor. In this paper, the out of pocket costs for each mode of transport are considered and mutually compared, the analysis of the generalized cost function, including out of pocket and qualitative attributes will not be discussed further in this paper. Taking in considerations the costs items for each mode, it will be possible to observe their specific contribution to the total cost and to determine how they influence mode choice.
This paper considers the calculation of out of pocket costs, focusing particularly on a European freight corridor.
The paper is organized as follows. First a review of the literature about intermodal cost functions is given and used as a framework for the elaboration of the intermodal cost function presented in the methodological part. As a third step an analysis of traffic flows for a specific destination from the aforementioned port has been carried out. Subsequently the calculation of internal costs has been developed through the use of a calculation tool specifically improved for the purpose of this paper. As a conclusion some considerations and a proposal for further research are drawn. The results and the methodology of the present exercise can be considered as a possible approach for the calculation of the cost items composing the intermodal transport.

LITERATURE REVIEW ON COST FUNCTIONS

The competitiveness analysis of a mode of transport is unequivocally related to the pure cost of the service. Notwithstanding the fact that several authors show that the relevance of monetary cost is just a part of the entire set of variables that are considered, the out of pocket costs detain a key role in the mode choice. They constitute the first and tangible costs that the shippers or freight forwarders have to face in their ordinary business activity.
The review takes in consideration a series of studies that analysed the monetary cost structure of uni-modal and intermodal transport and the selection has been based on their methodologies. In Blauwens et al.[1]an analysis of cost calculation in transportation is presented. The authors classify transport costs in time costs and distance costs that are consequently associated to euro per hour and euro per kilometre covered and applies it to road transport and inland navigation transport. The cost items that are considered, on an hourly base, are: interest and depreciation, insurance, taxes, wages, other costs. The remaining costs are considered in relation to the kilometres covered: fuel, tyres and maintenance and repair. Depreciation can be expressed both in hourly cost and in kilometre cost, or the total amount can be split in two parts.
The total cost of transportation is the following:

[1] Blauwens et al, 2006.

$$\text{Total Cost} = uU + dD$$

Where:
u = hour coefficient
d = kilometre coefficient
U = time in hour
D = distance in kilometre

A study of Boardman,[2] compares truck/rail, truck/barge and rail/barge combinations for container transport, taking into consideration the total transportation cost. The main conclusions are related to the matching of the shipment characteristics and the possible choices of the shipper. It is pointed out that the mode choice is strongly influenced by the distance covered, road transport being the best alternative for short distances.
In his study Boardman defines the total transportation costs as follows:

$$\text{Total Transportation Cost} = T_m + D_m + T_{sm} + CC_m$$

Where:

T_m = transportation cost (in dollars) for mode *m*
D_m = dray cost (in dollars) for mode *m*
T_{sm} = transfer cost (in dollars) at terminal for mode *m*
CC_m = carrying cost (in dollars) for mode *m*

The calculation of the costs in €/loading Unit (LU) has been performed for each mode of transport and then compared.
A considerable contribution to the topic is provided by the European project Recordit[3], (Real cost reduction of door-to-door intermodal transport). This project considers some European corridors with the aim of analysing their cost structure; both uni-modal and intermodal, with the purpose to find the cost items that weigh more in the total cost and try to find solutions to minimize them. Cost are calculated in €/LU for each of the selected corridors.
A study carried out by the Flanders Institute for Logistics[4] highlights which are the cost components in total logistics costs. The categories considered are transport cost, loading/unloading costs, transport time, inventories costs, internal company costs and qualitative attributes. The cost items are allocated according to each mode of transport. Regardless the mode of transport some key cost items are listed: energy, maintenance and repair, depreciation, personnel costs, insurance of the vehicle, liability, other direct costs for the vehicle, financial costs, additional management costs.

In the Vlaams Vrachtmodel[5], data for the analysis of the different components of each single mode of transport has been collected. The work considers the transportation costs and the costs related to loading/unloading activities. For each mode of transport the following costs are included:

[2] Boardman, B., et al, 1999.
[3] Recordit Project, 2000.
[4] VIL, 2006.
[5] Mint Consultant, KP Transport Consultant, 2009 (Confidential).

loading/unloading, wages, energy costs, taxes, depreciation and interests, repair and maintenance, tools, other costs.
From this brief overview it is clear that there are some common and regular components related to transport in the cost structure of a company. Moreover these variables are the ones selected for the development of this paper and inserted in the following calculations.
Transportation Costs

- Personnel,
- Energy and other consumption material,
- Insurance,
- Repair and Maintenance,
- Taxes and charges,
- Administration costs,
- Depreciation and interest /Renting/leasing,
- Other costs.

Transhipment Costs

- Loading/unloading cargo.

A further elaboration on each of the mentioned cost components is necessary, inasmuch as each of them is estimated in a different way, influenced by different drivers and affecting the final cost differently. A detailed description of each of these cost items will be provided further in the text.

APPLIED METHODOLOGY

The final aim of the methodology applied in this paper is to obtain the total out of pocket cost for each mode of transport and finally being able to compare the outcomes of the calculations; in order to do so the reported methodology will be applied. This analysis will be performed from the transport operator point of view; therefore considering his/her costs for the production of the service.
Most of the cost variables are calculated according either to the distance covered or to the time spent for the transport operation, thus the measurement are mainly in euro per kilometre, €/km, or in euro per hour, €/h. In order to obtain €/km or €/h, the calculation can be performed with either one of the following approaches: considering the annual cost divided by the annual amount of kilometres or hours, or taking the unit cost in € multiplied by the actual kilometres covered or hours spent. Although a distinction is made between transport and transhipment, there are some costs that belong to both categories.
Personnel cost refers to the cost that the company has to pay for the employment of the people that work in the company itself. This cost represents one of the main cost items; the people employed in a transport company are numerous and include trucks drivers.
The elements that need to be taken into account are the number of people employed, their net wage and the additional costs due to social security. All these cost items are calculated on the basis of average amount of working hours in a year. In our work the measurement is expressed in €/h.

Personnel cost (P):

[(Net yearly wage + Yearly costs for social security)/ number of operative hours in a year] * Number of people employed for the transport operation * Number of driving hours for the specific journey

The cost for fuel or energy is the cost of the consumption of energy for the production of the service. It can be related to the diesel or gasoline consumption for road, inland navigation and rail transport, or electric power in rail or combined transport. Fuel consumption or energy usage is affected by the market price of the material. The average fuel consumption per kilometre is required in order to obtain the real energy consumption for the kilometres covered.
The cost of the energy consumption is thus expressed in €/Km.

Energy costs (Fuel) (E):

[(Energy price per litre * average consumption per km)]* Number of kilometres for the specific journey

Energy costs (Electric power) (E):

(Energy price per kilometre)* (Number of kilometres for the specific journey)

For some cost items, like the cost of vehicle's insurance, the selection of the units of measurement is not straightforward. The cost is yearly spent and it is fixed according to specific characteristics of the vehicle. One can decide to consider the cost either per kilometre or per hours. In some cases the calculation is simply equally split in two parts. In this paper the calculation is done per operative hours, €/h. The insurance cost reflects all the expenses related to the civil liability for the vehicle.

Insurance costs (I):

[(Yearly costs for insurance)/ (Number of operative hours in a year)]* Number of hours for the specific journey

It is assumed that, in an operative year, there will be regular expenses related to the maintenance of the vehicles, while repair costs can occur also unexpectedly. The costs related to maintenance are the ones that occur periodically and are related to the ordinary up keeping, repair costs may occur if the vehicle has accidents or damages that need to be fixed. Maintenance and repair costs are related to the operative life of vehicles, thus they vary according to the age of the vehicle and the distance covered. They are expressed in €/Km.

Maintenance and Repair costs (M&R):

[(Yearly costs for maintenance and repair)/ (Number of kilometres covered in a year)]* Number of kilometres for the specific journey

A cost that all companies have to face is the capital cost based on depreciation, interest payments, renting or leasing costs related to the vehicles and other physical asset. The way in which the capital costs are calculated depends upon the type of ownership of the asset. When the asset belongs to the company, a depreciation rate is calculated according to the acquisition price and the passive interests

that need to be paid. In case the assets do not belong to the company, a fixed amount has to be paid for the use of it. The way of calculation for the yearly depreciation or renting payment can vary from the different approaches used. Generally these cost items are calculated in €/h.

Depreciation/Renting/Leasing costs (D/L):
[(Yearly costs for depreciation/rent/leasing)/ (Number of operative hours in a year)]* Number of hours for the specific journey

The cost associated to taxes, tools and charges are variable costs. There are specific taxes, tolls and charges for the different modes of transport; therefore it is quite difficult to determine the value of this element because they are strictly related to a mode of transport or to specific route. While taxes and charges are associated to vehicle use or ownership, tools are applied for specific access or transit to ports, bridges, channels or roads. The costs associated to those expenses can be expressed in euro per hour or per kilometre, €/h or €/Km. In the specific case of road transport, the amount of money spent for tolls will be in euro, €; taking as reference the calculation obtained from route planner tools.

Taxes/Charges costs (T):
[(Yearly costs *taxes/tolls/charges*)/ (Number of kilometres covered in a year)]* Number of kilometres for the specific journey

In addition to the costs strictly related to the service provided, there are overhead costs that the company has to bear. Overhead costs are fixed and exist regardless of the distance covered or the hours of work performed. They are an important cost item and comprise administrative costs together with costs for the daily operative work of the entire company. In this study, these costs are considered in €/h, according to hours of work of the company.

Overhead costs (OV):
[(Yearly overhead costs per vehicle)/ (Number of operative hours in a year)]* Number of hours for the specific journey

As an additional element it is necessary to include other costs of different nature, that does not belong to any of the categories listed above and that can occur sporadically. These costs can be calculated either in €/h or in €/Km.

Other costs (O):
[(Yearly other costs)/ (Number of operative hours in a year)]* Number of hours for the specific journey

There are also some specific cost items that are related to each mode of transport, such as the cost of the tyres in road transport or the cost for the use of the rail tracks and additional push locomotives in rail transport. Those costs items need to be calculated for the specific route where one of those modes is used. In the case of road transport the costs for tyres consists of the acquisition price and their maintenance costs. They are usually calculated per kilometres covered, €/Km. In rail transport, the

company that runs a service has to pay the use of the rail infrastructure to the infrastructure operator, this is the rail tracks cost. The cost for using the infrastructure between two points and for a certain number of kilometres, is expressed in €/Km. This cost can be considered as a specific charge for rail transport.
The push locomotive cost may occur when the power of a single locomotive is not sufficient to carry the whole load of the train. This cost need to be added just on some specific routes, where the surface slope is high and does not allow the operations with a single locomotive. Normally the costs is calculated in €/h.

Tyres costs (TY):
[(Yearly costs for acquisition and maintenance of a tyre)* (Number of tyres)]/ (Number of kilometres covered for life time)* Number of kilometres for the specific journey

Rail Tracks costs (RT):
(Average cost for rail track)* Number of kilometres for the specific journey

Push Locomotive *costs (PL):*
Hourly cost for the use of a push locomotive * Number of hours for of use

The second category of costs that are included in the intermodal cost function is the one related to transhipment operations during the entire door-to-door chain. The operations taken in consideration are the ones of loading and unloading the loading unit from one mode of transport to another, or from a mode of transport to the ground and then from the ground to the second mode of transport.
Loading and unloading costs are measured in relation to the time needed to complete the operation, to be more precise the total cost of utilization of the vehicle used for loading and unloading the cargo, the workforce, and the required fuel. The total hourly cost has to be calculated for the actual time needed to carry out the procedure, thus this cost item is calculated in €/h. In most of the cases the terminal operator charges the cost for unit loaded/unloaded. The cost can change according to the type of loading unit but nonetheless the difference in cost does not vary substantially.

Loading/Unloading costs (L/UNL):
(Hourly cost for each loading/unloading operation)* Number of hours needed for the entire operation

In rail transport, the cost of shunting operations needs to be taken into account. Those operations are the ones related to the placement of the locomotive and wagons on the correct track. This cost item is usually expressed in €/h, considering the time needed to carry out the shunting.

Shunting operations costs (SH):
(Hourly cost for shunting operations)* Number of hours needed for the entire operation

Once all the cost items are listed and explained, the next step is to develop a cost function that can incorporate all the previous costs. The reasoning behind the construction of each cost function is the same for each mode of transport, although each of them is characterized by their specific technical nature. For each mode of transport, road, rail, inland navigation and intermodal transport a calculation of the total cost, € and the cost per tonnage, €/ton has been executed according to the following cost functions:

***Total Cost Road Transport**:*
P + E+ I + M&R + D/L + T+ OV + TY + O + L/UNL

***Total Cost Rail Transport**:*
P + E+ I + M&R + D/L + OV + RT+ O + SH + L/UNL + PL

***Total Cost Inland Navigation Transport**:*
P + E+ I + M&R + D/L + T+ OV + O + L/UNL

***Total Cost Intermodal Transport (Road +Rail)**:*
ROAD *(P + E+ I + M&R + D/L + T+ OV + TY + O + L/UNL) +
RAIL *(P + E+ I + M&R + D/L + OV + RT+ O + SH + L/UNL) + PL

***Total Cost Intermodal Transport (Road +Inland Navigation)**:*
ROAD *(P + E+ I + M&R + D/L + T+ OV + TY + O + L/UNL) +
INLAND NAVIGATION *(P + E+ I + M&R + D/L + T+ OV + O + L/UNL)

With these cost functions it is possible to calculate the costs for the different modes of transport, in order to obtain a comparison among modes for the same origin/destination of the goods.
To implement such functions data on the cost components need to be collected and inserted in the mathematical formulas. The implementation of a tool that can easily produce reliable outcomes is a fundamental step in the research process. A detail description of the tool implementation process is reported in annex 1.

CASE STUDY DESCRPTION

The focus is on the port of Antwerp which is the main Belgian port. As we consider a case study for a freight corridor related to this port, a preliminary overview of its nature and characteristics is provided.
Antwerp is one of the main ports in the Hamburg - Le Havre range and it is constantly competing for increasing its volume and its market share. In Europe the Port of Antwerp is among the firsts for each typology of goods moved in its docks. The main part of its business activities is related to container traffic. In 2008 Antwerp was the third port in Europe for TEU moved, with an amount of 8.664 Million of TEU. The Hamburg-Le-Havre range, in which Antwerp is located, had a share of 44.3% of the total European container traffic in 2008. In the non-containerized trade general cargo takes a dominant share. In 2006 the port of Antwerp had the best performance in general cargo, with a share of 5.7% of

the top twenty ports in Europe. In the top list of the main liquid bulk and dry bulk ports, Antwerp is located respectively on the 6th and 5th place with a share of 2.4% and 2.5%.
An important factor for the success of the port of Antwerp is its connectivity with the hinterland, which is affected by environmental concerns, infrastructural problems and congestion problems. Antwerp's Port Authority publishes annual figures on the total modal split for three modes of transports: road transport, rail transport and inland navigation transport. In general, there have been no large shifts during the last years, the share or road and inland navigation transport is similar and predominant, while rail transport is lagging behind. For inland container movements road transport is the most popular mode of transport but during the last 14 year, the share of road transport diminished to advantage of inland navigation and rail transport. However, still more than half of the traffic to and from the port is by trucks. Rail transport has difficulties in establishing itself as a competitive substitute to road.
For what concerns the traffic flows from/to the port, some relevant catchments areas can be identified in the centre of Western Europe, such as South France, South Germany or Switzerland. Those regions contain current destinations for traffic flows from the Port of Antwerp. A detailed analysis will therefore consider the freight corridor from/to the Ports of Antwerp to Basel, in Switzerland.

Antwerp-Basel Corridor

This corridor is leaving from the Port of Antwerp to the city of Basel in North West Switzerland, and vice-versa. The distances between the two locations are different according to the mode of transport used, namely: 609 km for road transport, 625 km for inland navigation and 718 km for rail transport.[6]

Figure 1: Antwerp-Basel corridor
Source: own elaboration based on internet sources

For the organizational of the transport chain several alternatives are available and the data refers to spring 2010. The main source for the collection of this type of information is the site of the Antwerp Port Authority. In its "multimodal" section links to each mode of transport are presented. The site offers the possibility to check available services for rail and inland navigation from the Port of Antwerp to

[6] Sources: for road transport: http://www.viamichelin.it/, for rail and inland navigation transport: interviews with transport operators.

several destinations in Europe, defining the operator that runs the service, the frequency, the typology and other useful information.[7] Taking this site as a starting point, additional information has been found on each operator's web site.

As far as inland navigation is concerned, the amount of services offered on this route is quite high; 5 operators offer services from Antwerp to Basel and 6 operators on the way back. It can also be observed that the frequency of these services varies from two to six services a week, with an average transit time of 4 days. The route goes from the Antwerp's channels to the river Rhine up to Basel. The companies operating the services have their headquarters in Belgium, The Netherlands, Germany and France. To the best of our knowledge, only two companies perform rail transport between these two points. Of course, it is possible that other rail or intermodal companies provide rail services between different origins/destinations located very near to Antwerp and/or Basel. Two intermodal operators provide shuttle services, with a frequency of 5 services a week, covering the full distance in approximately 16/18 hours from Antwerp to Basel. These two operators have their head offices respectively in Belgium and in Switzerland.

For each mode of transport a detailed description of the data collection procedure will be presented, including the sources used, the information gathered from the transport operators and the final values used to perform the calculation.

Road Transport

Among the different transport modes, road is the one with relatively good data and information sources, consisting of reports, academic publications or research projects.

The main sources consulted were the following:

- Cost calculations for road freight transport, 2010 data. NEA consulting group;
- Technical note for Vlaams Vrachtmodel- Cost Model, 2009 data, Mint and K+P consulting group;
- Recordit, 2000 data, European Project.

These sources gave us a relatively broad-spectrum of the road cost figures, therefore the contacts with road transport operators were few and the scope of the interviews was to capture some insight from experts. The operators contacted are independent road operators, providing services in Europe. Their experience and activity is in heavy freight road transport.

The calculations and costs figures refer to a heavy good vehicle, i.e. road tractor + semitrailer of 40 tonnes gross vehicle weight and a loading capacity of 25 tonnes.

Some technical assumptions are reported table 1.

Table 1: Technical characteristics road transport

Cost Item	*Unit*	*MIN*	*Max*	*Average*
Average speed	km/h	67	70	69

[7] **www.containerafvaarten.be**, http://www.portofantwerp.com/**Railways Departures List**.

Days of operation	n	230	250	240
Loading capacity	tonnes	24	26	25
Number of tyres	n	12	14	
Performance per year tyres	km/year	60.000	90.000	75.000
Performance per life tyres	km/life	180.000	200.000	190.000
Performance per year truck	km/year	119.800	130.000	124.900
Working hours year	h/year	2.200	2.500	2.350

Source: own elaboration

As it can be seen from table 1, minimum, maximum and average values are reported. In this paper, for each cost item, the calculation of unit cost has been developed using the mean values of the technical characteristics; the minimum, maximum and average values are independent form each other and one can decide to select the appropriate scenario for each cost item.
For road transport the costs considered for the out of pocket calculation are:

- Personnel and social security,
- Energy and other consumption material,
- Insurance,
- Repair and Maintenance,
- Taxes and charges,
- Overhead costs,
- Depreciation and interest,
- Tyres,
- Other costs,
- Loading/unloading activities.

In regard to the *personnel costs* we will assume that the truck drivers will be hired under Western Europe rules and legislations, and that the maximum allowed driving hours is 9.
For the *Energy consumption* three alternatives of fuel consumption are considered; a minimum, maximum and average level. The minimum fuel consumption for covering 100 km is 34.30 litres, while the maximum value is 36 litres per 100 km.
For the *Taxes and charges* we have to consider both items separately. While for the taxes the cost is considered in €/hour, the figures for the calculation of tolls are obtained by some route planner tool available on line. The use of such instruments allows us to be more accurate in defining the precise amount of toll, in relation to specific origin/destination route. In our research different route planners have been used and compared, such as ViaMichelin[8], Mappy[9],Routes Tomtom. [10]

[8] http://www.viamichelin.it/
[9] http://it.mappy.com/
[10] http://www.routes.tomtom.com/t/#/

The costs attributed to *depreciation and interest* for the tractor and semitrailer can be calculated with different methodologies and they can vary upon variations of interest rates. In this thesis the depreciation period for the trailer was assumed to be fixed at 6 years, while for the semitrailer it is 10 years.
The costs for *tyres* are based on the assumption that there are twelve tyres per truck. In the cost per kilometre the purchasing costs and the maintenance cost are included.
Finally a short description is given of the costs related to the operations for *loading and unloading* the truck. The common practises envisage a calculation for loading unit moved. The movement consists of two operations: the loading of the loading unit from the ground or from another mode of transport on the truck and the unloading from the truck to the ground or to a different mode of transport. The average declared time for the operation can vary from 5 to 10 minutes for loading unit. A summary of all the cost items considered and their values is reported in table 2.

Table 2: Cost items and values for road transport

Cost Item	*Unit*	*MIN*	*Max*	*Average*
Depreciation semi trailer per hour	€/hour	3,00	5,00	4,00
Depreciation tractor per hour	€/hour	6,00	8,00	7,00
Fuel consumption per 100 km	l/100 km	34,30	36,00	35,15
Fuel price	€/l	0,50	1,00	0,75
Loading and unloading per hour	€/hour	150,00	350,00	250,00
Loading and unloading per LU	€/LU	30,00	50,00	40,00
Other costs per hour	€/hour	3,00	4,00	3,50
Overhead per hour	€/hour	7,00	9,00	8,00
Repair and maintenance per km	€/km	0,05	0,10	0,08
Salary per hour	€/hour	12,00	16,00	14,00
Social security costs per hour	€/hour	5,00	7,00	6,00
Taxes per hours	€/hour	0,30	0,80	0,55
Tyres cost	€/km	0,001	0,002	0,0015
Tyres purchasing price	€	350,00	450,00	400,00
Vehicle Insurance per hour	€/hour	1,50	3,00	2,25

Source: own elaboration

Rail Transport

The sources for reliable information on rail transport costs are rather scarce; in addition the ones reported for road transport an other one has been consulted.

- Price and costs in the railway sector, Baumgartner, J.P., Litep 2001.

A substantial help, in gathering information, came from the operator's interviews; more precisely two rail companies have been interviewed, an Italian one and a Swiss one.
We took in consideration a single wagon train; the gross train capacity will be 1300 tonnes, while the loading capacity is between 600 tonnes and 800 tonnes.
Some additional indicators about the assumed technical requirements are reported in the table below.

Table 3: Technical characteristics rail transport

Cost Item	*Unit*	*Min*	*Max*	*Average*
Average speed	km/h	40,00	50,00	45,00
Days of operation	n	250,00	300,00	275,00
Loading capacity	tonnes	600,00	800,00	700,00
Performance per year locomotive	km/year	166.666,67	180.000,00	173.333,34
Performance per year wagon	km/year	50.000,00	150.000,00	100.000,00
Wagons in a train	n	18,00	32,00	25,00
Working hours year	h/year	2.200,00	2.500,00	2.350,00

Source: own elaboration

Some cost items already described for road transport are present also in the analysis of rail costs, but some comments have to be added.
Specific Rail transport costs are:

- Rail Track,
- Shunting operations,
- Push locomotive cost.

The *Personnel costs* are affected by national and/or European legislation. The European legislation allows for a driver for each train. This is commonly applied in the European countries, with some exceptions, e.g. Italy.
Energy consumption in rail transport can be either referring to electric power or to diesel fuel. In most of the European main train paths electricity is used, due also to the higher cost of diesel fuel.
In the case of rail transport the costs for *repair and maintenance* of the vehicle are related both to the locomotive and to the wagons that compose the train. To this regard in table 4 a distinction is made between repair and maintenance cost for the locomotive and for the wagons, both expressed in €/km.
The cost of *rail track* refers to the price that the rail operator has to pay to the infrastructure manager in order to be able to use the rail track or path. The main rail path will have higher costs, while the secondary ones will be less costly. Rail tracks are assigned by the infrastructure manager normally once a year, but exceptions and extraordinary distributions can occur on-the-spot.
Shunting operations are the movement of the locomotives and wagons in order to place the train in the right direction, loading/unloading place or in the exact area. In most of the cases in Europe there are dedicated companies that provide the service for the rail operator, in this case the cost can vary according to different components.
The costs attributed to *leasing or rent* of the locomotive and wagons reflects the yearly expenses for using a locomotive and the wagons. In our calculation we decided to use t leasing costs due to the fact

they better represent the current situation on the European scene. This is not in contradiction with the fact that some rail companies own locomotives, and therefore the yearly asset cost is the depreciation and the interest rate. Wagons can be either owned by the rail company or rented.
The costs of the operations for *loading and unloading* the train are normally expressed in euro per movement of the loading unit. Taking into consideration the technical specifications of the train and the average time for loading and unloading a train, a calculation in €/hour has been applied.
For the *vehicle insurance, overhead costs, other costs* the same remarks as for road transport hold.

Table 4: Cost items and values for rail transport

Cost Item	*Unit*	*Min*	*Max*	*Average*
Energy price electricity	€/km	2,50	3,30	2,90
Fuel consumption km	l/ km	5,00	7,00	6,00
Fuel price	€/l	0,50	1,00	0,75
Leasing/Rent per hour	€/h	170,00	320,00	245,00
Loading and unloading per hour	€/h	150,00	500,00	325,00
Loading and unloading per LU	€/LU	27,00	40,00	33,50
Loading/unloading hours	hours	4,00	8,00	6,00
Number of drivers	n	1,00	2,00	1,50
Other costs per hour	€/h	3,00	4,00	3,50
Overhead per hour	€/h	7,00	10,00	8,50
Push locomotive	€	500,00	2.000,00	1.250,00
Repair and maintenance loc per km	€/km	0,12	0,20	0,16
Repair and maintenance wag per km	€/km	0,03	0,07	0,05
Salary per hour	€/h	20,00	40,00	30,00
Shunting operations 2 operations	€	600,00	2.500,00	1.550,00
Social security costs per hour	€/h	5,00	7,00	6,00
Track	€/km	2,50	5,00	3,75
Vehicle Insurance per hour	€/hour	10,00	14,00	12,00

Source: own elaboration

Inland navigation transport

The literature on cost elements and cost values for inland navigation is not extensive. Also for this case a valuable input for the cost data collection came from the face to face interviews.
The main additional references are:

- Onderzoek costen per huur in de binnenvaart, 2003 NEA consulting group.
- Wasser und Schifffahrtsverwaltung des bundes, 2007, PLANCO Consulting GmbH.

The additional cost data collected were obtained from focused interviews with inland navigation operators in Belgium. The two companies interviewed provide services in Belgium, France, The Netherlands and Switzerland.
The type of barge used for the simulation is a container barge of 2000 gross tonnes, and being able to carry up to 1900 tonnes of goods, some specifications can be found in table 5.

Table 5: Technical characteristics inland navigation transport

Cost Item	*Unit*	*Min*	*Max*	*Average*
Average speed	km/h	9,00	12,00	10,50
Days of operation	n	280,00	288,00	284,00
Gross tonnes	tonnes	2.000,00	2.000,00	2.000,00
Loading capacity	tonnes	1.600,00	1.900,00	1.750,00
Performance per year	km/year	70.000,00	80.000,00	75.000,00
Working hours year	h/year	3.920,00	6.912,00	4.544,00

Source: own elaboration

The cost items inserted in the cost function and used for the elaboration of the indicators are the ones listed above, as for road transport, excluding the tyres.
The costs for *Personnel and social security* depend mainly on the size and composition of the crew which is related to the type and size of the barge. For our barge typology a minimum of four members is required, while the maximum is normally five. The wages will be determined by the experience, technical knowledge and specific tasks of the crew members. For the calculation of personnel and social security costs we considered an average of those wages, without differentiations among them.
In Europe there are some rivers and channels where *tolls* are due to the national or local authorities. This is not the case on the main western European river, the Rhine. This explains why the amount of taxes taken into consideration in this specific case study is rather low.
Concerning the other costs included in the calculation, no particular remarks need to be added and the comments presented above for the other modes of transport are still valid.

Table 6: Cost items and values for inland navigation transport

Cost Item	*Unit*	*Min*	*Max*	*Average*
Fuel consumption km	l/ km	10,00	15,00	12,50
Fuel price	€/l	0,35	0,70	0,53
Leasing/Rent barge	€/hour	30,00	100,00	65,00
Loading and unloading per hour	€/hour	249,00	625,00	437,00
Loading/unloading hours	hours/vessel	16,00	24,00	20,00
Number of drivers	n	4,00	5,00	4,50
Other costs per hour	€/hour	2,00	6,00	4,00
Overhead per hour	€/hour	7,00	10,00	8,50
Repair and maintenance	€/km	0,06	0,10	0,08

per km				
Salary per hour	€/hour	13,00	16,00	14,50
Social security costs per hour	€/hour	5,00	7,00	6,00
Tolls per km	€/km	0,003	0,005	0,004
Vehicle Insurance per hour	€/hour	4,00	6,50	5,25

Source: own elaboration

Intermodal road/rail transport and intermodal road/inland navigation transport

The characteristics and cost data for the two intermodal solutions are similar to the ones already presented for each single mode of transport and therefore the cost values and the technical requirements are the same.

ANALYSIS OF THE RESULTS

Taking in consideration the previous specifications for each cost item, it is possible to perform the cost calculations in order to obtain some results for our freight corridor.
The distances and total transport time per mode are:

- Road transport: 609 km, 7 hours;
- Rail transport: 718 km, 15 hours;
- Inland navigation: 625 km, 80 hours;
- Intermodal transport road + rail: 678 km by rail and 40 km by road, 14 hours by rail, 1 hour by road;
- Intermodal transport road + inland navigation: 585 km by inland navigation, 40 km by road, 72 hours by inland navigation and 1 hour by road.[11]

The costs are calculated for the transport of 1000 tonnes, taking into account the loading capacity of each mean of transport. If the shipment of 1000 tons from Antwerp to Basel is entirely by road an average of 40 trucks will be employed, if it is entirely by rail it will require 2 trains, and if it goes by inland waterways 1 barge will be used.
Table 7 gives the total costs for each of the different modes and the intermodal solutions.
For each scenario, MIN, AVE and MAX it is possible to observe the cheapest and most expensive mode of transport. The scenario determines the values of the cost components used for the calculation: MIN defines that the values inserted are the minimum values in the range considered; AVE stands for average and MAX are the maximum values that the cost items could have.

Table 7 Total cost comparison Antwerp-Basel

	MIN		**AVE**		**MAX**
Iww	11426,88	**Iww**	17823,13	**Road**	23566,83

[11] The source are: for road transport: http://www.viamichelin.it/, for rail and inland navigation transport: interviews with transport operators

				iww	
Road-iww	13329,96	**Road-iww**	18482,24	**Iww**	23788,13
Rail	18433,32	**Rail**	22783,16	**Rail**	27133
Road	18792,06	**Road**	24013,19	**Road**	29094,24
Road-rail	20259,32	**Road-rail**	24838,96	**Road rail**	29409,4

Source: own elaboration

When looking at the total cost that a client has pay to the different transport operators, it is important to bear in mind that a percentage of mark up has to be added. In all our cases we consider the final costs without mark-up, which allows us to be consistent in the comparison; nonetheless this aspect has to be kept in mind.
From the table 7 it is clear that the cheapest solution is provided by inland navigation for the first two scenarios; while for the last one the intermodal solution road-inland navigation seems to be the favourite, money wise.
Between these two extremes the cost difference is varying from almost 9.000 €, in the minimum scenario, to 6.000 € in the maximum. Apart from these extreme figures, what comes out of table 7 is that for two scenario over three inland navigation is cheaper than the other two uni-modal solutions. The intermodal solution road-inland navigation costs less than road-rail intermodal transport.
As the amount of goods considered for this case is 1000 tonnes, one can easily calculate the transport cost per tonne.

Table 8 Cost per tonne comparison Antwerp-Basel

	MIN		**AVE**		**MAX**
Iww	11,426875	**Iww**	17,82313	**Road iww**	23,56683
Road-iww	13,329955	**Road-iww**	18,48224	**Iww**	23,78813
Rail	18,43332	**Rail**	22,78316	**Rail**	27,133
Road	18,79206	**Road**	24,01319	**Road**	29,09424
Road-rail	20,25932	**Road-rail**	24,83896	**Road rail**	29,4094

Source: own elaboration

In order to better understand the relevance of each cost item on the final total cost an investigation for each mode and for each scenario will be presented.
The calculation has been done considering the total cost as equal to 100 and looking at the share of each cost item, in percentage. Starting from road transport, it is observed that for all the scenarios, the cost item that counts more is the fuel price, going from around 23% up to 31% in the maximum scenario.

The second cost item, in decreasing order, is personnel cost, having a slightly bigger impact in the minimum scenario. Depreciation is also relatively important in road transport, accounting for around 13% of the total cost.

Table 9: Weight of each cost item on the total cost for road transport (percentage of the total cost)

Road transport	Min	Ave	Max
Fuel price	22,95	27,53	30,98
Personnel cost	18,46	16,80	15,82
Social security costs	7,69	7,20	6,92
Tyres	1,61	1,88	2,07
Vehicle insurance	2,31	2,70	2,97
Maintenance and repair	6,69	8,35	8,60
Taxes	0,46	0,66	0,79
Tolls	13,84	10,80	8,90
Overhead	10,77	9,60	8,90
Depreciation	13,84	13,20	12,86
Other costs	1,38	1,26	1,19
Total	100	100	100

Source: own elaboration

What is reported in table 10, shows how the different costs weight in rail transport. The main costs are the track costs, the leasing of the locomotive and wagons and the cost for the use of energy.
The main component is cost for rail track that the operator has to pay to the infrastructure manager for obtaining the train paths. The share of relevance is higher in the minimum scenario that in the average or maximum.

Table 10: Weight of each cost item on the total cost for rail transport

Rail transport	Min	Ave	Max
Energy price	19,48	18,28	17,47
Personnel cost	3,25	3,95	4,42
Social security costs	0,81	0,79	0,77
Vehicle insurance	1,63	1,58	1,55
Maintenance and repair locomotive	0,93	1,01	1,06
Maintenance and repair wagons	5,84	7,88	9,26
Overhead	1,14	1,12	1,11
Average track cost	31,16	25,21	21,17
Other costs	0,49	0,46	0,44
Leasing rent	27,67	32,26	35,38

Shunting operations	7,59	7,46	7,37
Total	100,00	100,00	100,00

Source: own elaboration

Considering the composition of inland navigation transport cost, it appears that the costs weights changes among the different scenarios; nonetheless the three main costs are always the same: fuel price, personnel cost and leasing or rent of the barge.
In the minimum scenario personnel cost has a share of 36,4% on the overall cost, while the leasing of the barge is counting for 21%, followed by fuel price. The composition changes for the average scenario, within the costs for the leasing are the highest, 29%, followed by personnel costs and fuel price, respectively 26% and 23.2%; to conclude, in case the values of the costs are maximum, we notice that leasing and rent, together with fuel price constitute the two main costs.

Table 11: Weight of each cost item on the total cost for inland navigation transport

IWW transport	Min	Ave	Max
Fuel price	19,14	23,23	27,59
Personnel cost	36,41	26,03	24,52
Social security costs	14,00	10,77	9,42
Vehicle insurance	2,80	2,36	2,19
Maintenance and repair	0,33	2,81	0,26
Tolls	0,02	0,01	0,01
Overhead	4,90	3,82	3,36
Leasing/rent	21,00	29,18	33,63
other costs	1,40	1,80	2,02
Total	100	100	100

Source: own elaboration

The comments about the two intermodal solutions are similar to the previous ones; in intermodal road-inland navigations the major costs are related to the main part of the trip, thus inland navigation. The share of barge leasing cost goes from 16% to 30% in the maximum scenario, followed by the personnel costs, between 20% and 28%, to conclude fuel costs, from 15% to 17%.
For road-rail intermodal transport, the rail track costs, the leasing or rent and the energy consumption are the most important costs items. The relevance of rail track percentages vary from 18% to 26%; while, on average, a 16% is due to the electric energy.

Table 12: Weight of each cost item on the total cost for intermodal road/inland navigation transport

Intermodal road/iww	Min	Ave	Max
Fuel price road	2,06	2,28	2,44
Personnel road	3,60	3,03	2,72
Social security costs road	1,50	1,30	1,19
Tyres	0,14	0,16	0,16
Vehicle insurance road	0,45	0,49	0,51
Maintenance and repair road	0,60	0,69	0,68
Taxes road	0,09	0,12	0,14
Tolls road	8,10	5,84	4,58
Overhead road	2,10	1,73	1,53
Depreciation road	2,70	2,38	2,21
Other costs road	0,90	0,76	0,68
Fuel price barge	15,36	16,78	17,38
Personnel barge	28,09	22,59	19,55
Social security costs barge	10,80	9,35	8,55
Vehicle insurance barge	2,16	2,05	1,99
Maintenance and repair barge	0,26	0,25	0,25
Tolls barge	0,01	0,01	0,01
Overhead barge	3,78	3,31	3,06
Leasing/rent barge	16,20	25,32	30,55
Other costs barge	1,08	1,56	1,83
Total	100,00	100,00	100,00

Source: own elaboration

Table 13: Weight of each cost item on the total cost for intermodal road/rail transport

Intermodal road/rail	Min	Ave	Max
Fuel price road	1,35	1,70	1,96
Personnel road	2,36	2,25	2,17
Social security costs road	0,99	0,96	0,95
tyres	0,09	0,12	0,13
Vehicle insurance road	0,30	0,36	0,41
Maintenance and repair road	0,39	0,51	0,54
Taxes road	0,06	0,09	0,11
Tolls road	5,32	4,34	3,67
Overhead road	1,38	1,29	1,22
Depreciation road	1,77	1,77	1,77
Other costs road	0,59	0,56	0,54

Energy price rail	16,70	15,81	15,20
Personnel rail	2,76	3,38	3,81
Social security costs rail	0,69	0,68	0,67
Vehicle insurance rail	1,38	1,35	1,33
Maintenance and repair lococomotive rail	0,40	0,44	0,46
Maintenance and repair wagons rail	5,01	6,82	8,06
Overhead rail	0,97	0,96	0,95
Average track cost rail	26,72	21,81	18,43
Other costs rail	0,41	0,39	0,38
Leasing rent rail	23,45	27,58	30,44
Shunting operations	6,90	6,84	6,79
Total	100,00	100,00	100,00

Source: own elaboration

So far we considered the pure transportation cost, but another important component, when wanting to analyse the total cost is the loading and unloading cost of the goods.
From our analysis of the literature and mainly from the interviews information, it seems that the loading costs are calculated on the loading units moved; this is the case for all the modes. It is also true, that there were no substantial differences in the unit cost for movement for each different mode of transport. The cost range was between 27 and 40 euro per loading unit; the main difference is of course in the timing that will be definitely slower for a truck, than for a train or a barge.
The table below reports the total cost, composed by the transport cost and the loading/unloading cost. As it is possible to notice there is a single value per mode associated to loading/unloading operation; the value considered is the average value.
The different scenarios can be performed inserting the different levels of values; the one reported is an example.

Table 14: Comparison of total cost (transportation cost and loading/unloading cost)
a)

MIN	**Transportation cost**	**Loading/unloading cost**	**Total**
IWW	11426,88	4000	15426,88
road-iww	13329,96	5600	18929,96
Rail	18433,32	2345	20778,32
Road	18792,06	1600	20392,06
road-rail	20259,32	3945	24204,32

b)

AVE	**Transportation cost**	**Loading/unloading cost**	**Total**
IWW	17823,13	4000	21823,13
road-iww	18482,24	5600	24082,24
Rail	22783,16	2345	25128,16
Road	24013,19	1600	25613,19
road-rail	24838,96	3945	28783,96

c)

MAX	**Transportation cost**	**Loading/unloading cost**	**Total**
road iww	23566,83	5600	29166,83
IWW	23788,13	4000	27788,13
Rail	27133	2345	29478
Road	29094,24	1600	30694,24
road rail	29409,4	3945	33354,4

Source: own elaboration

When looking at the uni-modal solutions, loading/unloading costs are higher for inland navigation, while quite small in case of road transport. In the case of intermodal solutions the loading and unloading activities play a key role in determining the total cots. This component can interfere considerably in the previous result obtained. Nonetheless, in our example, the previous rankings remain valid also with loading/unloading costs included. In the maximum scenario inland navigation is the cheapest solution, even with the inclusion of transhipment costs.

CONCLUSIONS AND FURTHER RESEARCH

All the considerations emerged from the analysis of the results bring us to make some general reflexions about modes of transport and their cost functions. Road transport, even being the most expensive mode for the whole shipment, has a comparative advantage in terms of hours needed for the whole shipment, with 7 hours driving. In our case we also have to remember that for the shipment of 1000 tonnes, an average of 40 trucks are required.
Inland navigation, being the slowest solution, can guarantee a cheaper payment, although the loading and unloading operations constitute a crucial aspect to take into account.
The intermodal solution, road-inland navigation appears to be an attractive solution in respect to the total cost of the shipment.
Rail transport, finally is the one with worst performance, in general, due to high total costs even thought preferable to road transport. Time wise rail transport is an in-between solution. To conclude,

the performance of the intermodal solution road-rail appears to be rather costly compared to the others. In both intermodal cases, road-inland navigation and road-rail transport a relevant component is the loading/unloading part that has to take place twice in the entire door to door trip.
Interesting, although, not surprising is the pattern about the relevance of the cost items in the total transport cost. Regardless the mode of transport, energy costs, personnel costs and depreciation or leasing are the costs items that influence more the final cost of the operator.
This can lead us to some observations; those three aspects have different nature, while personnel costs and depreciation or leasing are more related to the company business and structure, for the energy cost, both diesel fuel or electric power, the company can not directly intervene in changing or adjusting significantly this cost.
Starting from energy cost, what can be argued is that the transport operator has minimum power in adjusting or deciding the fuel price or the electricity price; some commercial agreements can take place, but the haggling control of the transport operator, regardless its company dimension and power, will be rather negligible.
With regards to personnel costs, legislative and social rules enforce the transport operator to conform to, at least, minimum levels of wages and social security contributions. Albeit irregular practises in relation to the actual number of working hours are already rather habitual in the transport sector, reductions in the perceived salary could be unfair form a welfare point of view.
The possible interventions, from a business approach, could be to intervene on the personnel management, in order to re-structure the company organizational chart.
To conclude, the depreciation costs and the leasing costs for assets represent a considerable expense for the transport operators. The capital cost is an economic element that belongs to the business activity that the company itself has to control. With respect to this, each company should be well aware of their production factors and intervene, if possible, to optimise it.
An interesting exercise will be to perform a sensitivity analysis replacing with new values for those three variables; it can be still assumed that the relative weight of those cost items on the overall transport cost will remain similar. An other aspect, that will be worth to investigate, is related to the capacity utilization that in this paper has been assumed equal to 100% of the vehicle capacity; moreover the calculation can be performed taking into account also the return trip, and analysing the effects on the total cost.

REFERENCES

Baumgartner, J.P. (2001). Price and costs in the railway sector, Litep.

Blauwens, G., De Baere, P., Van De Voorde, E. (2006). Vervoers Economie, Standaard Uitgeverij, Antwerp.

Boardman, B., Trusty, K., Malstrom, E. (1999). Intermodal Transportation Cost Analysis tables, Department of Industrial Engineering, University of Arkansas.

Mint Consultant (2009). KP Transport Consultant, Vlaams vrachtmodel, technical note. (Confidential).

NEA Consulting Group (2003). Onderzoek Kosten per huur in de binnenvaart.

PLANCO Consulting GmbH (2007). Wasser und Schifffahrtsverwaltung des bundes.

Vernimmen, B., Dullaert, W., Willem, P., Witlox, F. (2008). Using the inventory-theoretic framework to determine cost-minimizing supply strategies in a stochastic setting, Int. J. Production Economics 115 248– 259.

VIL (2006). Totale logistieke kosten beslissingsondersteunend bij de bepaling van de optimale modal split.

Weinreich, S. et al. (2000). *"Real cost reduction of door-to-door intermodal transport (Recordit)"*, Deliverable 1: Accounting framework for the analysis of the cost structure of door-to-door intermodal freight transport services.

www.containerafvaarten.be
http://www.portofantwerp.com/
http://www.viamichelin.it/
http://it.mappy.com/
http://www.routes.tomtom.com/t/#/

ANNEX 1

Tool development procedure

Using Excel Programme, Office package, a simple but clear procedure for the construction of the calculation tool has been developed. The method for the construction of the Excel tool envisages different steps, program knowledge and capability of Visual Basic for Applications, (VBA) programming.
The steps for the elaboration of the tool are the following and are developed in subsequent order; nonetheless interrelated adjustments are always possible.
Construction of the model:

1. Creation of an excel sheet and naming.
2. Insertion and naming of the variables considered.
3. Insertion of the cost values corresponding to the variable considered.
4. Insertion of the step unit that the program has to consider during the elaboration.
5. Use of the Macro function.
6. Creation of a Macro for the specific purpose of the tool.
7. Running of the Macro function and test of the outcome.
8. Sensitivity analysis.
9. Applications.