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Developing a cost calculation model for inland navigation

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Abstract

The inland waterway transport sector in Western Europe is a competitive market with an excess of supply over demand. Overcapacity puts pressure on prices, and has caused a decline in profitability, particularly since the economic crisis of 2008. In this competitive environment, it is crucial for ship owners to have accurate information on the cost of their service in order to avoid setting freight rates at non-profitable levels. For this reason, a scientific instrument to calculate the cost of inland waterway transport is needed.

Following upon a literature review, the aim of the paper is to develop a new cost calculation model by vessel type, taking into account internal fixed and variable out-of-pocket costs, from the ship owner's perspective, as well as external cost elements of inland waterway transport. Subsequently, the methodology behind the input parameters, the model computations, and the output is discussed and supported with a case study.

The paper reveals that a model for use in the inland navigation sector needs to be based on company-specific input parameters. Due to the variety of ship types and dimensions, operation modes, contracts, and specific trip considerations, models based on average values seldom provide accurate results. The collection of averages, however, can serve scientific purposes, such as the analysis of investment decisions, or the effect of changes to the charter agreement. As such, the model proposed in this paper is capable of collecting and processing user input for the generation of average values, for further insights into the inland navigation sector.

Keywords: Inland waterway transport; cost model; external cost; ship owner perspective

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1. Introduction

The European inland waterway transport (IWT) industry is characterized by a fragmented market structure, intense competition, and a limited reinvestment ability. The market currently experiences an excess of supply over demand, in both the dry cargo and liquid bulk markets. The excessive supply particularly concentrates on major waterways, since most of the newly added capacity to the sector consists of larger vessels, incapable of navigating smaller rivers and canals. As such, price competition is intense on major routes, whereas smaller waterways become increasingly underutilized. Especially the financial crisis of 2008 and the subsequent recession led to a decrease in freight rates in the Western European IWT sector (Lendjel & Fischman, 2010; van Hassel, Vanelslander, & Sys, 2017).

Different measures have been proposed or legally enforced, respectively, according to which the sector could achieve sustainable profitability. These include increased cooperation, the abolition of freight rates below the cost of the service, as well as the availability of an instrument to calculate the cost of IWT (see, for instance, Lendjel & Fischman, 2010; Belgisch Staatsblad, 2013; van Hassel et. al., 2017).

A cost calculation instrument for IWT operators would provide insights into the costs incurred per trip. Consequently, ship owners would be better informed and less inclined to set freight rates too low to recover the cost of their service (Lendjel & Fischman, 2010). This could also possibly increase their negotiating power.

In other transport sectors, such as road transport, cost models which can be used by the transport operators already exist (ITLB, 2016). Comparable models for the IWT sector mostly focus on single, self-propelled vessels and do not take coupled trains[1] or smaller push-tows[2] into account (see, for instance, Kantoor Binnenvaart, 2000), or do not consider individual adjustments to relevant parameters for the cost calculation, such as the effect of the installation of a new engine on the capital cost per year (see, for instance, Rijkswaterstaat, 2015). Therefore, developing a scientifically sound model will fulfil a real need of the sector.

Besides the more practical need for such model, there is a scientific objective. In the literature, the heterogeneity of the IWT market was already underlined in van Hassel et al. (2017). This should also be reflected in the cost calculation models. There are significant differences in the technical, operational and cost aspects between inland vessels operating in the tank barge market and in the dry cargo sector. But also within the same sub-sector, different ship sizes are operating in different markets. And even the heterogeneity in the group of vessels of the same size and operating in the same sub-sector and market is large. This is reflected, for instance, in differences in crewing and in the purchase price of a vessel, which impacts on the fixed cost (van Hassel, 2015). Therefore, the newly developed cost model from this paper should incorporate this heterogeneity.

The cost model should also serve for the sector to increase their insights in the actual cost of operation. To that extent, also a comparison with other vessels that are sailing in the same market can be useful. This can be done by comparing the calculated cost with the benchmark average. This could give insights into whether a ship owner is above or below the benchmark average. By collecting and analyzing these data, the users of the model can steer their behavior or retrofitting and/or investment decisions, while for academia, more insights can be obtained in the heterogeneity in the cost for inland shipping.

Aside from obtaining more insight in the internal costs (private cost) for the ship owner, another important challenge for the IWT sector concerns the emission of air polluting gases, which has become particularly relevant with the rise of environmental policies focusing on the internalization of transport externalities, largely driven by European policymakers. Most of the internalization approaches are based on the polluter-pays principle, according to which external costs are attributed to the actual polluters, instead of making the society as a whole pay for transport externalities (EC, 2008, 2011, 2013). Generally, external costs are costs that a transport user causes to a third party and for which he does not pay (Blauwens & Van de Voorde, 1985).

Although inland navigation is generally assumed to be an efficient, safe and environment-friendly mode of transport, more stringent emission standards in the road transport sector are increasingly contesting the advantage in

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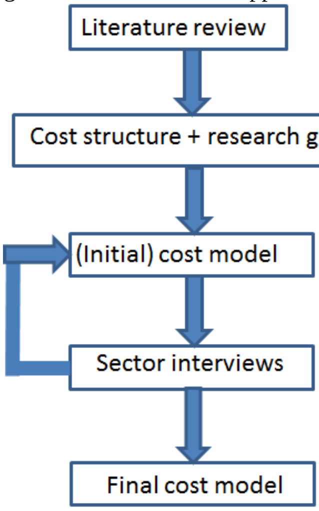
[1] Under a coupled train, the following is understood: a combination of a self-propelled ordinary vessel and unpowered barges, or two connected self-propelled vessels.

[2] A push-tow consists of one towboat ('pusher') and one or more unpowered barges.

the environmental sustainability of shipping goods on the waterway (Panteia et al., 2013). In case of a binding legislation on the internalization of transport externalities, external costs will be incorporated in the overall cost of shipping services. As such, a cost calculation instrument for ship owners in the IWT sector would not only need to include private costs, but also external costs of transport as a separate category. External cost calculations can also be of importance if the cargo owners have requirements on GHG and air polluting emissions due to green image ambitions. The approach for developing the IWT cost model is given in Figure 1. The methodology starts with a literature review, considering existing cost structures and applications, enabling to identify a research gap. Based on the available cost structures in the literature, an initial cost model was developed, which was presented to different IWT sector actors. These actors shared insights, which led to add-ons and more detailed cost calculations than could be found in the literature. These additions further contribute to differentiating the final model from the models found in literature.

Figure 1: Overview of the applied methodology



Source: Own illustration.

This contribution is structured as follows. Section 2 presents the literature review of existing cost models for IWT. Section 3 provides the results of in-depth sector interviews regarding the structure and the application of the cost model to check its validity and to align it with the current-day practice of operating an inland vessel. Section 4 gives an overview of the structure of a cost model, with general user input and specific adjustments to the calculation of individual cost elements. Section 5 presents a case study to show how the developed model functions. Ultimately, Section 6 addresses the implications of the cost model for managerial practice and discusses future research applications.

2. Literature review of cost models for inland waterway transport

In this section, a literature review of different cost models is performed. The purpose of this overview is twofold. The first objective is to determine the main characteristics of a selection of existing studies, models, and applications developed for calculating the overall cost of IWT. It specifically addresses the basic methodology behind the calculation of costs. Secondly, the review is to determine specific gaps in the current cost models.

Generally, the costs of the provision of a transportation service can be divided into time and distance costs. While time costs, often referred to as fixed or standby costs, do not change with the activity of the vehicle, distance costs are superimposed on time costs, and only occur in case of actual vehicle activity (Blauwens, De Baere, & Van de Voorde, 2010; Wiegmans & Konings, 2015).

Cost models for IWT have been addressed in a limited number of publications. Recent literature by researchers includes models and applications by Blankmann (2008a & 2008b), Beelen (2011), Hekkenberg (2012), Lu & Yan (2015), and Wiegmans & Konings (2015). Recent contributions by consultancies and special interest groups include

Kantoor Binnenvaart (2000), PINE (2004), Via Donau (2005), PLANCO (2007), BDS-Binnenschifffahrt (2008), NEA (2009) and Rijkswaterstaat (2015), as well as LogoS (2015). The different models can be further classified according to the main target group (such as researchers, policymakers, or IWT businesses), the main purpose of the calculation, the method to calculate costs, and the range of the input and output parameters considered. Another classification by Beelen (2011) distinguishes among theoretical, general cost models, also used for more elaborate studies, specific models or ad-hoc calculations used in the sector, and studies aimed at specific cases. Finally, models relying on average values and estimations can be distinguished from those wholly dependent on the user's input.

Blankmann (2008a & 2008b) provides an introduction into accounting practices for ship owners, and presents a generic cost function to calculate the cost per trip. An overview of different cost elements is given, distinguishing between the costs of personnel, fuel, depreciation, repair, insurance, administration, as well as overhead costs, in addition to other costs of shipping operations. Ultimately, a formula for practitioners is presented, which allows calculating a profitable freight rate.

The general cost calculation model by Beelen (2011), considers a variety of factors for modelling the internal costs of IWT, divided into fixed and variable components. Not taking push-tows or coupled trainsinto account, it simulates costs for eight typical classes of single, self-propelled, inland vessels, used in the Western-European inland navigation sector. The model also distinguishes among dry cargo and tanker ships, and a variety of other factors, especially concerning ship exploitation, such as different exploitation modes for different thresholds on the maximum hours of sailing allowed per day, as well as the self-employment of ship owners as captains aboard the vessels. It is applied for a series of analyses and case studies, not only taking internal but also external transport costs into account, based on values from the *Handbook on estimation of external costs in the transport sector*, resulting from the IMPACT study, conducted by CE Delft (Maibach et. al., 2008).

Another general scientific model, developed by Hekkenberg (2012), determines the optimal dimensions of inland vessels for the best competitive position of a self-employed ship owner. The model regards the dimensions of inland ships as variables, but takes upper limits for ship length, beam, and draught into account. Subsequently, systematic variation is applied for the generation of input ship types, which are compared to one another to determine the lowest cost per ton of cargo-carrying capacity. In the next step, the performance of the ships in a transport chain is assessed. The model does not only take the costs of waterborne transportation into account, but also considers the cost of handling, pre- and post-haulage via other transport modes, internalized external costs, as well as the total logistics costs, defined as the sum of all cost centers calculated. The costs of the waterborne segment of the transport chain are calculated as a minimum required ship rate, considering cargo-carrying capacity, round trips, and annual costs. Push-tows or coupled trains are not taken into account.

A model by Lu & Yan (2015) calculates the costs of road transport and inland navigation, considering both internal and external cost components, to determine the break-even distance between the two transportation modes. The model is applied for a case study on container transport in the Yangtze River delta in China. The application is based on estimated values, most of which particularly apply to the case studied. For IWT, the costs of drayage operations between the shipper's area and the inland port by trucks are considered in addition to those of line-haul operations on the waterway. The model application reveals that handling rates greatly affect the break-even distance between road and IWT. It also reveals that the break-even distance of road transportation clearly decreases in the case of internalized external costs. Since the research focuses on a particular region in China, however, its application in a Western-European context would likely result in different break-even distances. Additionally, the model does not take rail transport as another alternative to road transportation into account. Another limitation of the model concerns its focus on only one particular class of container ships. Consequently, the model applied cannot be classified as a general cost calculation model.

A similar application of another cost calculation model by Wiegmans & Konings (2015) is utilized to analyze and compare the cost of intermodal transport, with a main leg via IWT, and further on road-only transportation. The model makes use of factor cost estimations for the Dutch transport sector. Cost estimations by NEA (2009) are used for IWT, whereas estimated values by Dorsser (2005) are taken as a reference for cost figures on road transportation. The cost of terminal operations is also considered. External costs are not taken into account, however. The model application reveals that using roundtrips instead of single trips, drop- and pick-operations in pre- and end-haulage, as well as the utilization of 20ft instead of 40ft container units can all improve the competitiveness of intermodal WT. In contrast, relatively high costs of operations at smaller terminals are revealed to impact on the competitiveness of freight transport via inland waterways. While justified for the case study, the model considers only two types of self-propelled inland vessels, and container transportation only. As such, it cannot be considered a general cost calculation model.

In contrast to models developed and mostly aimed at researchers, Kantoor Binnenvaart (2000) developed a cost calculation instrument specifically for use by ship owners in the inland navigation sector. The instrument is based on the user's input for all calculations, and does not rely on any pre-defined average values or estimations. Its general input values concern the ship's year of construction and its tonnage capacity. The instrument is further divided into separate instruments for input relevant to calculate fixed and variable costs. Input parameters for the calculation of fixed costs include the ship's insured value, the interest expense, the depreciation period, the insurance premium, the ship crew's remuneration, maintenance costs, and miscellaneous expenses. The application relies on different input parameters to determine variable costs. These include the cost of commissions, fuel, lubricants, waterway, lock, and port charges, as well as other expenses related to the trip. In addition to input on the number of days of vacation and without service per year, information on the trip is also required. The instrument's output values are fixed, variable, and total costs of the trip, total costs per day, and costs per ton transported. The instrument calculates company-specific costs. External costs are not taken into account. Similarly, coupled trains or push-tows are not considered.

Other important contributions include studies and handbooks by PINE (2004), Via Donau (2005), and PLANCO (2007). General cost models are used, based on estimations and a collection of average values as well as on figures defined in regulations relevant to IWT.

PINE (2004) computes the cost for three types of similar-sized, single, self-propelled, vessels (ca. 80 x 9.5 x 2.5 m, and 1,250 tons maximum deadweight capacity), each operated in a different European inland waterway corridor, a large Rhine vessel (110 x 11.4 x 3.5 m, 2,850 tons maximum deadweight capacity), and a push-tow, licensed for the Danube corridor. Small inland vessels are not considered. Although the study compares external cost estimations from a number of specific studies (e.g. Black, Seaton, Ricci, & Enei, 2003; Nash, 2003), external costs are not considered in the actual calculation of the costs of IWT of the selected ship types or classes.

Via Donau (2005) provides average values for three classes of self-propelled vessels, a towboat and a pushed barge, each operating under a specific exploitation mode, with a maximum of 14 or 24 operating hours per day. It distinguishes between ships operated by self-employed ship owners and those used by shipping companies. Average data and legally defined values are also provided for transit times on common routes, water levels, the percentage of empty movement, loading and unloading times, fairway dues for different types of freight, and port fees. Transport externalities are not specifically addressed. The collected data is used in an associated Microsoft Excel application to calculate the cost per voyage.

PLANCO (2007) mostly relies on averages for the calculation of the overall costs for a wide range of inland ships. It considers nine tonnage classes of dry cargo and tanker vessels, in addition to six different tonnage categories of barges[1] and five types of towboats[2], each with a different engine power. The costs of depreciation and capital, labor, consumption, insurance, and administration are computed. External costs are calculated for selected transport relations in Western and Central Europe, but are not provided for each of the specified ship types or classes.

A Microsoft Excel application by BDS-Binnenschifffahrt (2008) allows calculating the total cost of a specific voyage and the cost per ton, based on a range of input parameters. Average values are used for two pre-defined classes of self-propelled vessels with a capacity of 1,300 and 2,000 tons, respectively. A ship exploitation of 14 hours maximum per day is assumed. Most of the adjustable input concerns trip parameters, such as the tonnage transported, the sailing time with and without freight on board, the time for load and discharge, the fuel consumption in liters per hour, port fees, and other trip-related fixed costs. External costs of transport are not explicitly addressed.

NEA (2009) provides cost figures for a range of different ship types and classes. The study has resulted in a cost calculation instrument developed for the Dutch Ministry of Infrastructure and the Environment (Rijkswaterstaat, 2015). This instrument, which functions as a Microsoft Excel application, distinguishes among a range of cost components, and provides values for the costs per ton-km and TEU-km. The cost categories considered include depreciation, interest, labor, insurance, repair and maintenance, port tariffs, and other expenses. The calculation is

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[1] Barge: Ship without own propulsion, usually pushed by a towboat.

[2] Towboat: Also referred to as pusher boat, small-sized ship pushing one or more barges.

based on average values from the inland navigation sector, mostly in The Netherlands, although alternative transport relations, such as via the Rhine river through Germany or southwards to France are also taken into account. The application by Rijkswaterstaat (2015) does not calculate the cost of transport externalities, although external cost values for various ship types and classes are provided in NEA (2009).

Since the calculated results of the application by Rijkswaterstaat (2015) are based on pre-determined average values from the sector, company-specific factors are not taken into account. These might concern aspects such as the self-employment of the ship owner, relevant for the cost of labor, or exact information on the value of the ship, relevant for the calculation of capital costs. Another possible limitation concerns the computation of port fees as fixed costs, based on estimated values on a yearly basis, depending on the ship's cargo-carrying capacity. Beelen (2011) considers this cost element to be variable, whereas Blauwens et. al. (2010) do not attribute it to either time or distance costs, but consider it separately.

According to the demo shown on its website, the online application LogoS (2015) relies on the user's specification of the trip, concerning the points of origin and destination as well as the distance between them, the average speed, the type and tonnage of the freight transported, and the freight rate per ton, to calculate the revenue per trip and year. The calculation utilizes the user's information on the ship used. In contrast to cost calculation models, the instrument focuses on pricing and revenue. It does take cost into account, by indicating the level of profitability of a freight rate specified by the user. Since LogoS (2015) requires a subscription, only available to ship owners with a valid ship registration ID, the instrument's functionality cannot be assessed in this paper.

Table 1 summarizes the main characteristics of a selection of studies, models, and applications developed for the calculation of the overall cost of IWT. It specifically addresses the basic methodology behind the calculation of costs.

Table 1. Models and applications to calculate the overall cost of IWT

Source	**Main target group**	**Aim of the calculation**	**Ship types and classes considered**	**Consideration of external costs**
Models based on exact user input				
Kantoor Binnenvaart (2000)	IWT businesses	Determining the cost per trip, or minimum required freight rate	No pre-defined ship types, calculation for single, self-propelled vessels	None
Blankmann (2008)	IWT businesses, researchers	Provision of a practical, generic cost formula for ship owners	No particular ship types considered	None
Models based on average values, estimations, and legal requirements				
PINE (2004)	Researchers and policymakers	Determining the cost structure for different types of inland ships and push-tows	Dry cargo ships only, four types of single vessels in the range of 1,190-2,850t, push-tow with 6,000t capacity	Comparison of external cost estimations for IWT from a number of studies, not applied for calculation
Via Donau (2005)	IWT businesses	Determining the cost per trip, or minimum required freight rate	Three types of self-propelled vessels, ranging from 1,300t to 2,000t capacity, a towboat, and a pushed barge with 1,700t capacity	None
PLANCO (2007)	Researchers and policymakers	Comparison of costs between IWT, rail, and road transport for a number of selected transport relations	Nine types of single, self-propelled dry cargo and tanker vessels, ranging from less than 400t to more than 3,000t capacity, six types of barges, ranging from less than 650t to more than 2,500t, five types of towboats, ranging from 300hp to more than 3,500hp	Calculation of external costs for selected ship types and classes on selected transport relations
BDS-Binnenschifffahrt (2008)	IWT businesses	Determining the cost per trip, or minimum required freight rate	Two classes of self-propelled vessels, with capacities of 1,300t and 2,000t	None

Source	Main target group	Aim of the calculation	Ship types and classes considered	Consideration of external costs
NEA/ Panteia/ Rijkswaterstaat (2009/ 2015)	Researchers and policymakers, IWT businesses	Determining the cost per trip, or minimum required freight rate	All classes of self-propelled vessels, coupled trains, and push-tows according to a classification by Rijkswaterstaat (2011), four different freight types	Consideration of external costs in NEA (2009), but no inclusion of external cost calculation in Rijkswaterstaat (2015)
Beelen (2011)	Researchers	Study of the effects of decisions on investment and operations in the IWT sector	Eight types of single, self-propelled vessels (dry cargo and tankers), ranging from 350t to 4,500t of capacity	Consideration of external costs for a series of case studies
Hekkenberg (2012)	Researchers	Analysis of the effect of different ship dimensions on building costs, operating costs, and total logistics costs	Variable input on ship types, created for a calculation of building cost, as well as operational and total logistics costs, consideration of single, self-propelled vessels only	Consideration of external costs for the analysis of the impact of an internalization on optimal ship dimensions
Lu & Yan (2015)	Researchers	Calculation of break-even distance between road and IWT	Container vessel with a capacity of 252 TEU, used for sea-river-through transportation	Consideration of external costs for a study of internalization effects on the break-even distance between road and IWT
Wiegmans & Konings (2015)	Researchers	Comparison of the costs of intermodal IWT with road-only transportation	Two self-propelled dry cargo vessels, used for container transport, with capacities of 208 TEU and 90 TEU, respectively	None
Models without a known methodology				
LogoS (2015)	IWT businesses	Calculation of revenue per trip and year	No information available	No information available

Source: Own composition (based on the listed sources).

The review reveals that despite the availability of different cost calculation models and applications, there is still a need for an instrument for use in the sector, which would allow calculating company-specific costs and combine this functionality with a benchmark, based on estimations and average values for different types of ships and operations.

Moreover, although the external costs of IWT are addressed in various models and studies, the calculation of transport externalities has not yet been included in any instrument for ship owners in the inland navigation sector. A conceptual design of the cost calculation needed for such an instrument was established by Al Enezy et al. (2016). This initial model was based on literature, and calculated, by default, cost values based on average data for different ship types, exploitation modes, and voyage specifications. Findings from a number of personal interviews with representatives from the inland navigation sector reveal, however, that a calculation which starts from average values is not the desired solution to be used by ship owners. The calculation would instead need to be based on company-specific data, while average values need to be incorporated to support a benchmark with other ships operating in the sector.

3. Obtaining sector insights

During interviews with different stakeholders in the European inland navigation sector, the initial cost model was discussed. Among the interviewees were individual ship owners in the dry cargo, tanker and push barge sub-sectors, as well as inland shipping associations and infrastructure managers, as well as insurance brokers and underwriting agents. The general consensus was that an application to serve the needs of the market should make less use of average values and rather be based on the user’s company-specific data. As will be revealed in this section, the same calculation cannot be applied for all ships operating in the European IWT market. This is due to the heterogeneous nature of inland navigation with a variety of different ship types and classes, different dimensions and capacities. Although cost calculation models exist which are supported by average cost figures for different ship classes, freight types, and operation modes, their calculated output is not likely to present applicable cost figures. Table 2 presents the parameters used in the initial cost model of Al Enezy et al. (2016), as well as the changes to it, based on the feedback received. Most of the changes concern all sub-sectors of the inland navigation market, including the dry bulk, tanker, and push-barge sector. Changes specifically concerning a particular sector are highlighted as shown in the legend.

Table 2. Input parameters in initial and updated cost calculation model for the inland navigation sector.

Input parameter/ cost component	**Initial parameters of cost model by Al Enezy et al. (2016)**	**Input parameters of updated cost model and methodology after feedback from the sector**
Ship parameters	Use of average and legally mandatory values for ship, exploitation, and voyage parameters	Use of company-specific values for all input
	Input on the ship supported by a ship classification by Rijkswaterstaat (2011)	Ship classification further divided into different ship classes per waterway class (based on CEMT values)
	Consideration of push-tows with up to nine barges (P)	No consideration of push-tows with more than two barges, sine larger tows serve different markets and do not operate as family businesses (P)
Exploitation parameters	Collection of input related to overtime remuneration	Overtime remuneration not a common practice in the sector
Charter party (C/P) parameters	No consideration of different charter types	Consideration of time and voyage charters, and further specification of cost components to be incurred by the ship owner in a voyage charter agreement (fuel costs, port fees, fairway dues, costs of commissions, handling and cleaning costs)
Fixed costs	No collection of user input on fixed costs beforehand, standard calculation based on customizable average values	Collection of user input on fixed costs, including capital, personnel, insurance, repair and maintenance, and other fixed cost components per annum
Capital cost	Capital cost calculation limited to assumptions from literature	Refined calculation of capital costs, enabling separate calculations for the ship and a new engine or any other new investment in the

Input parameter/ cost component	Initial parameters of cost model by Al Enezy et al. (2016)	Input parameters of updated cost model and methodology after feedback from the sector
		ship, consideration of any depreciation period between 5 and 25 years
Labor cost	Standard calculation of personnel cost based on legal manning requirements and minimum salaries for the Belgian inland navigation sector	Suggestion of legally mandatory values for crew requirements and minimum salaries per month, consideration of personnel hired through an agency, and other cost components such as the cost of food, personnel transport, training, and safety (T) per month
Insurance cost	A single input field for the average value for the total insurance cost	Multiple input fields on different types of insurance, including hull, protection and indemnity (P&I), loss of use, and guaranteed income
Cost or repair and maintenance	Consideration of average values for the cost of repair and maintenance	Collection of user input on the total and fixed cost of repair and maintenance, automatic calculation of variable cost
Other fixed costs	Use of one average value for other fixed costs	Distinction between multiple categories of other fixed costs, collection of annual data on the cost of ship necessities, administration and communication, accounting and banking services, withholding tax, municipal tax, exploitation permits, credit insurance, food supplies, company cars, and office equipment.
Voyage parameters/ variable costs	Use of averages and estimations as well as user input to calculate the time of sailing, loading, and unloading	Collection of data on the time of sailing, loading, and unloading as user input, in addition to other data, depending on the charter agreement, including the price and consumption of fuel and lubricants, the amount of port fees and fairway dues per trip, and the percentage of commission costs in relation to the freight rate
	No consideration of the actual freight rate per ton	Collection of data on the freight rate per ton, for a comparison between the cost and price of a particular trip under a voyage C/P

(P) = Aspects particularly concerning the push-barge sector.

(T) = Aspects particularly concerning the tanker sector.

Source: Own composition (based on literature and interviews with professionals from the inland navigation sector).

According to the feedback from the sector, the cost calculation model has been restructured. The calculation is now, by default, no longer based on average values, but rather on company-specific data. As such, the calculated output for each cost component is directly linked to the users' input, which makes the results more accurate for each case. Generally, ship owners prefer using their own annual costs for the input of cost parameters, and are usually aware of the technical characteristics specific to their ship.

4. The cost calculation model

The new cost calculation model proposed in this paper is to serve as an application calculating company-specific costs, while taking average values and estimations into account, for a benchmark of own costs with those for the same or similar ship and operations types in the sector. The model can be utilized as an instrument for applications such as:

- Cost calculations for a certain trip and comparing these with a benchmark which can be derived.
- Changing from one sub-market to another (from transporting coal to containers for example).
- Changing freight contract (from voyage charter to time charter for example).

- Making investment analyses for installing a new engine or retrofitting investment.

The developed cost model consists of the following main blocks:

- Ship data (input)
- Exploitation data (input)
- Charter data (input)
- Fixed cost elements
- Voyage parameters and variable cost elements
- Cost calculations

Since ship parameters, such as dimensions or tonnage capacity, influence both exploitation as well as voyage specifications, they are required to be specified first. Exploitation parameters, which can affect the duration of voyages over certain distances, are to be specified thereafter. Subsequently, charter parameters are collected. Next, fixed cost elements, including details on capital, personnel, insurance, repair and maintenance costs, and other cost components are requested from the user.

Consequently, voyage parameters and variable cost data need to be specified. Due to the dependencies on the other categories of input, voyage data is collected at the final stage of the collection process of necessary information for the cost calculation. Furthermore, since dependencies between different specifications also occur within the categories of ship and exploitation parameters, more than one form is used for the user to specify input on ship or exploitation data.

All data that needs to be filled-in can be saved in a user profile. This allows the user of the model to retrieve this data and to speed up the process of making cost calculations and investment simulations. The next sub-sections describe the various model building blocks more in detail.

4.1 Ship data

The first input form for ship parameters asks the user to provide information on the type of freight (other dry bulk, containers, or liquids), and to choose between a single, self-propelled vessel, a push-tow, and a coupled train. Based upon this input, a particular class of waterway (CEMT) and ship, as defined by Rijkswaterstaat (2011), is to be specified and dimensions are to be adjusted. The user also needs to provide information on the type of equipment, according to the standards S1 and S2, as defined by the Central Commission for the Navigation of the Rhine (CCNR), and communicated by the United Nations Economic Commission for Europe (UNECE, 2002). Futhermore, information on the purchase value, the year of construction and the year of purchase of the vessel is requested from the user. Similar data is collected for new engines installed, or other investments made in the vessel after its purchase.

4.2 Exploitation data

The first form for user input on exploitation parameters begins with the choice of a standard for the mode of exploitation, namely A1, A2, or B. These standards refer to the maximum number of hours allowed for sailing per day, as defined by the CCNR (UNECE, 2002). They do not only specify the duration a ship can sail per day, but also give an indication of the time the crew is given to rest, which is usually presumed to be at night.

The types of equipment and operations have both been implemented in national legislation on IWT in European countries (for Belgium, see Belgisch Staatsblad, 2007). They affect the number of crew members per function on board of a ship, push-tow, or coupled train. Not exceeding the maximum levels as defined by the exploitation modes, different values for the sailing hours per day can be specified. Detailed adjustments can also be made on a separate input form, concerning the number of effective days and hours per year, as well as hours of sailing per year.

Moreover, the user is asked to specify whether the vessel, push-tow, or coupled train, is operated by a hired captain, or its owner. In the case of a self-employed captain, commonly referred to as owner-operator (see, for instance, Beelen, 2011), the user is also asked to specify whether the owner's partner works as a crew member. Additional data to be provided in such cases concerns the type of remuneration for self-employment, with options for a fixed remuneration per year or an opportunity cost based on the salary of an employee in the same function.

An important parameter on the second input form on exploitation considers the option for sailing a ship manned only by its captain. This option is only available in case all requirements for sailing alone are met. Aside from the equipment standard S2, sailing alone is only possible on dry cargo ships with a length of up to 55m, and on tanker vessels which do not exceed 35m in length. The mode of exploitation needs to be A1 in such cases, with a maximum of 12 hours of sailing per day (Belgisch Staatsblad, 2007). Another important parameter concerns payment of the crew according to systematic sailing. This refers to an alternative remuneration scheme, applicable for crews who do not only work but also live on the ship. In these cases, crew members work on an 'on/off'-basis, and have an equal amount of working and resting days on board, resulting in an overall increase of the number of working and resting hours (BTB, 2013).

4.3 Charter data

Data on the type of charter agreement is requested from the user. This is to determine which particular cost components are to be incurred by the ship owner and taken into account for the cost calculation. The two general options are time and voyage charters.

In the case of a time charter, the ship owner only incurs the fixed costs of operations, in addition to the variable costs of repair and maintenance. In contrast, variable costs also play a role in voyage charter agreements. Here, the model allows distinguishing between a range of variable cost components to be considered for the calculation, including fuel costs, port fees, fairway dues, commission costs, and the costs of loading and unloading goods and cleaning the ship.

4.4 Fixed cost data

Data needs to be specified to calculate fixed costs, per hour, day, year, and trip. The input is divided into data on capital, personnel, and other costs, including insurance, repair and maintenance, and additional cost parameters. The capital cost calculation is largely based on Beelen (2011). Aside from the purchase value, and the year of construction and acquisition of the ship, additional data is needed to compute the capital costs. This includes information on the depreciation method (linear or annuity) and period (between 5 and 25 years). Additionally, a residual value of a certain percentage of the ship's purchased value is assumed and requested to be provided by the user. Another important aspect concerns the weighted interest rate, based on the rate on the share of own, personal capital invested and on that of a loan, as well as the respective interest rates.

In general, the cost of labor on an inland ship is the sum of the products of the number of crew members of a particular function onboard and the cost of each of them (see, for instance, Beelen, 2011, Hekkenberg, 2012). As such, the user is asked to provide the number of crew members per function as well as their monthly costs, consisting of their monthly salaries and the employer's contribution to their social insurance. Additional data captured includes the cost of crew members hired through a recruitment agency, and other costs such as the those of food, personnel transport, training, and safety, all per month. For insurance costs, the user is asked to provide values per year for the insurance on hull, protection and indemnity (P&I), loss of use, and guaranteed income. For repair and maintenance, data is captured on the total annual costs and the amount of fixed costs only. Variable costs of repair and maintenance are computed accordingly. Other costs to be specified on an annual basis include ship necessities, administration and communication, accounting and banking services, withholding tax, municipal tax, exploitation permits, credit insurance, food supplies, company cars, and office equipment.

4.5 Voyage parameters and variable cost data

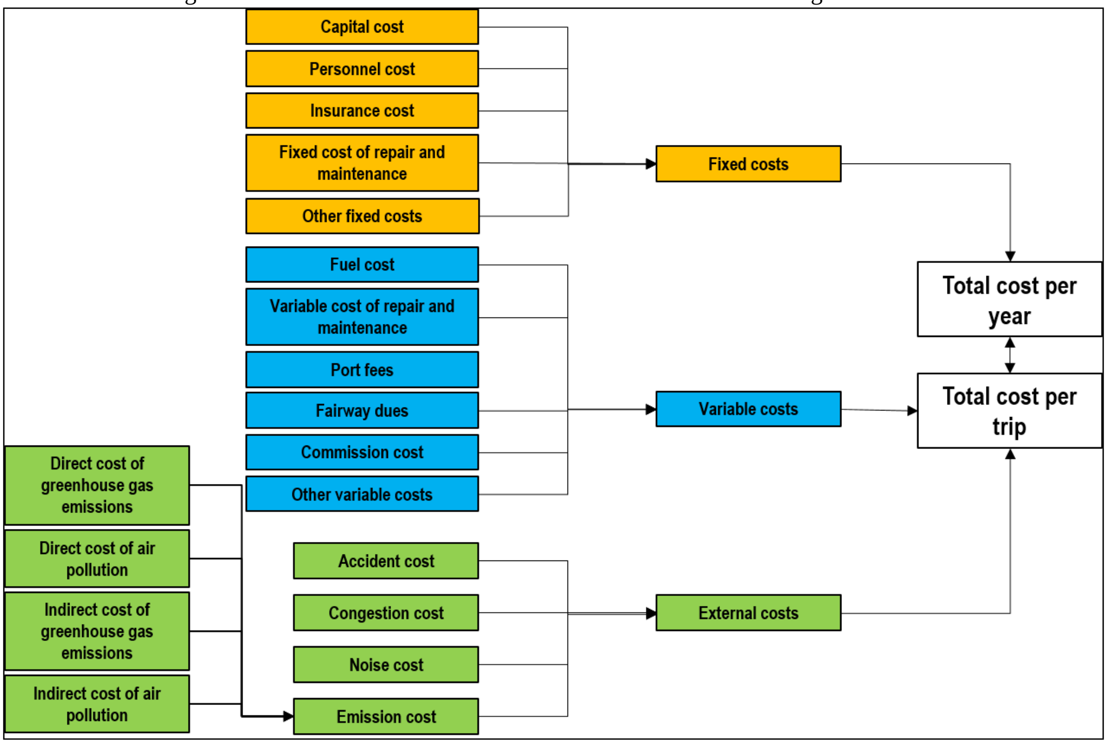
Voyage parameters, dependent on ship, exploitation, and charter specifications are entered last. Regardless of the charter agreement, they concern the specification of the time for sailing, loading, and unloading. In case of voyage charters, the distance of the movement is also captured, along with information on the places of origin and destination, and the tonnage transported, along with the amount of TEUs in the case of container transport. If applicable as specified in the charter agreement, data required to calculate the cost of fuel and lubricants is collected. It includes information on the consumption of fuel and lubricants in liters per hour and their respective prices in EUR per liter.

Additional parameters collected here, depending on the charter party, include the amount of port fees and fairway dues paid per trip.

4.6 Cost calculations

Figure 2 presents the structure of the model which forms the basis for the cost calculation instrument. The model considers internal fixed and variable cost components, as well as external cost elements. Fixed cost elements include capital, labor, and insurance costs, as well as the fixed share of repair and maintenance costs, port fees calculated on an annual basis, and other fixed cost components. Variable cost elements comprise fuel costs and variable costs of repair and maintenance, as well as port fees, fairway dues, and commissions and other variable costs per specific trip. Total annual costs and the cost per individual trip can be calculated by taking both fixed and variable components into account. Since freight rates between given origin and destination points are usually negotiated per ton or TEU transported, the model also provides information on the cost of transporting one ton or TEU on a certain voyage. This figure is finally compared to the actual freight rate, to show the profitability of a trip.

Figure 2. Structure of the cost calculation model for the inland navigation sector.



Source: Own composition (based on NEA, 2009; Beelen, 2011; MINT, 2013, and feedback from the IWT sector).

Additionally, external costs are calculated. They are the basis to study the effects of internalization policies, which are becoming increasingly relevant in the European Union (EC, 2008, 2011, 2013).

External costs are calculated on the basis of estimations of direct and indirect costs of climate change and air pollution (MINT, 2013) per vehicle-kilometer. Direct costs account for the emissions during the operation of a vehicle, whereas indirect costs refer the emissions during the production of fuels. In studies on transport externalities, such as Korzhenevych et al (2014), indirect costs of climate change and air pollution are usually addressed as costs of up- and downstream processes.

Information on the external accident costs of IWT is generally lacking (Maibach et. al., 2008). This is largely due to the comparatively rare occurrence of accidents on this transport mode (Eurostat, 2014).

In parallel to Korzhenevych et. al. (2014), it is assumed that the European inland waterways either do not face any capacity constraints, or that such constraints heavily depend on local conditions, mostly resulting in bottlenecks at locks or in ports (Schade et. al., 2006; Nash et al. 2008).

For the quantification of noise costs, data on the population exposed to it is required. Strategic noise maps are needed for this purpose (EC, 2002). In the case of inland navigation, noise costs are considered negligible. Compared to other transport modes, noise emission factors are low since most activities occur outside densely populated areas (Maibach et. al., 2008).

The option to adjust the level of company-specific external costs is not available, since the instrument's user is not expected to have accurate data on own emission levels. As such, the calculation is based on input on the tonnage capacity of the vessel, the tonnage loaded, and the distance of the trip (see Table 3).

Table 3. Overview of input parameters for the calculation of external costs

Input parameter	Default values	Data source
Ship class (defining dimensions)	To be specified	User input
Tonnage capacity	Automatically attributed to classes, possible to be adjusted	Rijkswaterstaat (2011) for standard values for each class, user input for adjustments to dimensions
Tonnage loaded	To be specified	User input
Sailing distance	To be specified	User input

Source: Own composition.

Alternative studies to MINT (2013) can be additionally integrated into the model at a later development stage, to compare the different estimations on external costs (see, for instance, Maibach et al., 2008; Korzhenevych et al., 2014). Depending on differences in methodologies, the calculated results are expected to vary. MINT (2013) has been selected as the preferred methodology, since the values it provides are particularly applicable to Belgium, where the cost calculation model has been tested. Advantages of other studies, particularly Korzhenevych et al. (2014), relate to the fact that they provide emission values in liter per hour of a particular fuel type consumed. In contrast, the values provided by MINT (2013) relate emissions to vehicle-kilometers. A general challenge about emission values and calculations in literature results from the fact that the various available calculation tools apply different indicators and often have different application scopes, making the results hardly comparable with one another (GLEC, 2016).

The duration of the round trip in the model is calculated as the sum of the time of sailing and the time spent for loading and discharging at inland ports and terminals. An allocation of the cost to an individual shipper served on a round trip is only possible in the case of differential cost. This describes the additional cost of adding a shipper to a trip which would have to be made in any case, to serve other shippers on an already existing route. The sum of the differential cost for each shipper on a given route, however, is usually below the total cost of the round trip, for the reason that the trip's joint costs are not taken into account in such a calculation (Blauwens et. al., 2010).

The possibility to adjust a wide range of parameters allows for a series of analyses and research applications to be conducted. These will be further explored in Section 5.

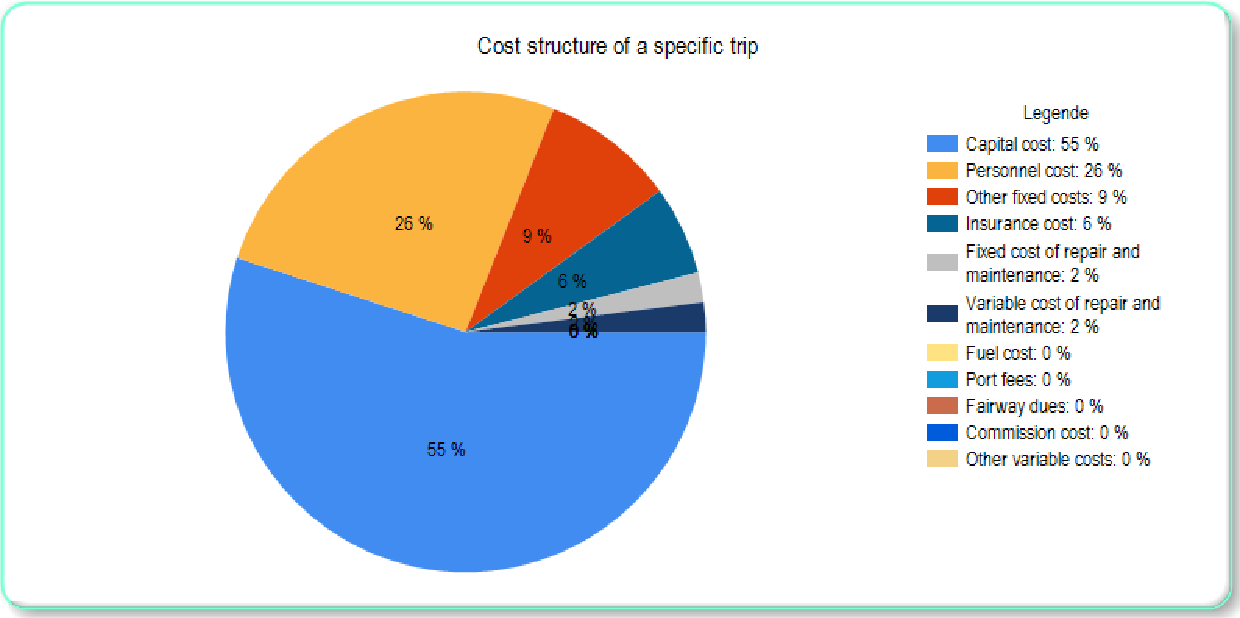
5. Case study

The final cost calculation model is applied in this section for a case study with a dry cargo ship (135m length, 11.4m beam) capable of carrying both dry bulk and containerized cargo, operating with time charter agreements. As such, only fixed costs are computed, with the exception of the variable cost of repair and maintenance. The ship and exploitation parameters as well as fixed cost components are presented in Annex 1.

The trip is calculated for a distance of 150 km, with 3,000 tons of iron ore onboard. A sailing time of approximately 18 hours is assumed, while 6 hours are assumed for loading, and 10 hours for unloading the vessel.
The calculated cost per trip amounts to EUR 3,126. The cost per ton amounts to EUR 1.04. The application generates a pie chart of the different cost elements (Figure 3). The total annual cost amounts to EUR 556,092, which is equal to EUR 1,655 per day of exploitation. The result supports previous observations from literature (see, for

instance, Beelen, 2011), according to which capital and labor cost account for the highest share of fixed cost components. The share of personnel costs is lower than usually stated in literature, since two members of the crew are hired through a recruitment agency, which results in lower costs compared to regular salaries in the inland navigation sector in Belgium.

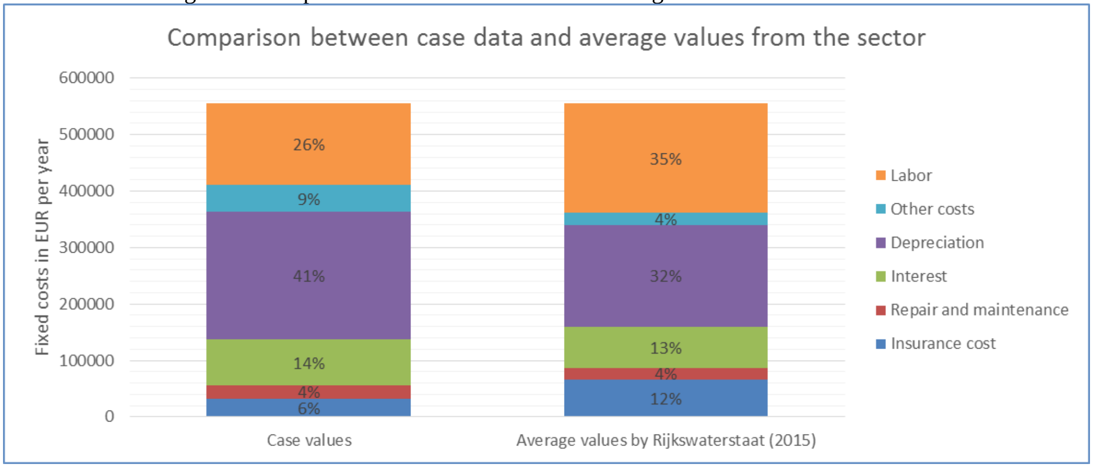
Figure 3. Case study result: Cost structure of a specific trip via inland ship.



Source: Own model and interview with ship owner operating in the dry bulk and container sector.

A comparison between the calculated values and the averages provided by Rijkswaterstaat (2015) reveals that the total annual cost, computed based on actual data, is very close to the given estimations for the same ship class (see Figure 4). Due to the time charter agreement in this case study, however, estimated average values for port fees and fuel costs have not been taken into account. The composition of the total cost is vastly different between the case study and the estimations.

Figure 4. Comparison between case data and average values from the sector.



Source: Own illustration based on case values from the sector and data from Rijkswaterstaat (2015).

The share of labor cost is significantly lower in the case studied, compared to the industry average. This is, most likely, linked to the fact that two crew members onboard the ship are hired through a recruitment agency, which receives a lump sum for their employment, likely below the regular tariffs for workers in the sector, including social contributions.

Depreciation and interest costs in the case studied exceed the corresponding average values from the sector. This could be due to a shorter depreciation period, or a lower residual value of the ship hull after the depreciation period in the studied case. Other possible reasons include different interest rates, or a different share of own capital invested in relation to the amount of the loan from the bank.

The cost of insurance in the case study is clearly below the sector's average. In general, hull insurance premia can vary by as much as 60%, depending on when the insurance contract is signed and who the ship owner is. For this reason, average values are hardly applicable for individual cases.

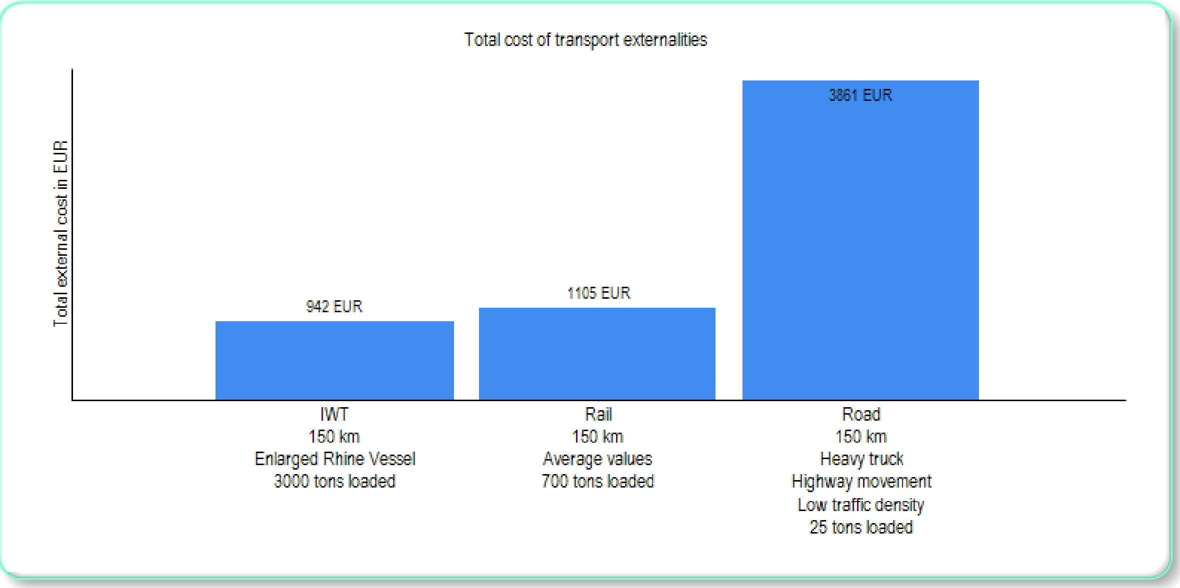
Values for repair and maintenance in the case study are at approximately the level of the sector's averages. For other fixed costs, the values in the studied case exceed those provided by Rijkswaterstaat (2015).

In general, the comparison reveals that an application to calculate the cost of IWT, to be used in the sector, needs to be based on company-specific data. The differences in vehicle dimensions, capacity, propulsion, operations, and investment make inland navigation a very heterogeneous market, for which a cost calculation instrument largely based on average values is hardly applicable.

Since the case study considers a time charter agreement, variable costs are not incurred by the ship owner. As the costs of transport externalities also changes with the distance travelled, we assume them to be variable. Their value, however, can still be determined in the model, based on figures per vehicle-kilometer, as stated in MINT (2013), and compared with those of road and rail transport for the same amount of goods transported on a the same trajectory. The carrying capacities of the two alternative transportation modes are estimated at 25 tons per truck, and at 700 tons per train (Grosso, 2011).

The calculated output (see Figure 5) in this case reveals a large difference in transport externalities between IWT and road transport. The difference is much smaller in the case of comparing IWT with rail transportation. Since the model takes vehicle capacity and economies of scale into account, however, generalizations cannot be made for transport modes as such, especially since the capacity of ships sailing on European waterways can range from 250 to more than 5600 tons per vessel (Rijkswaterstaat, 2011).

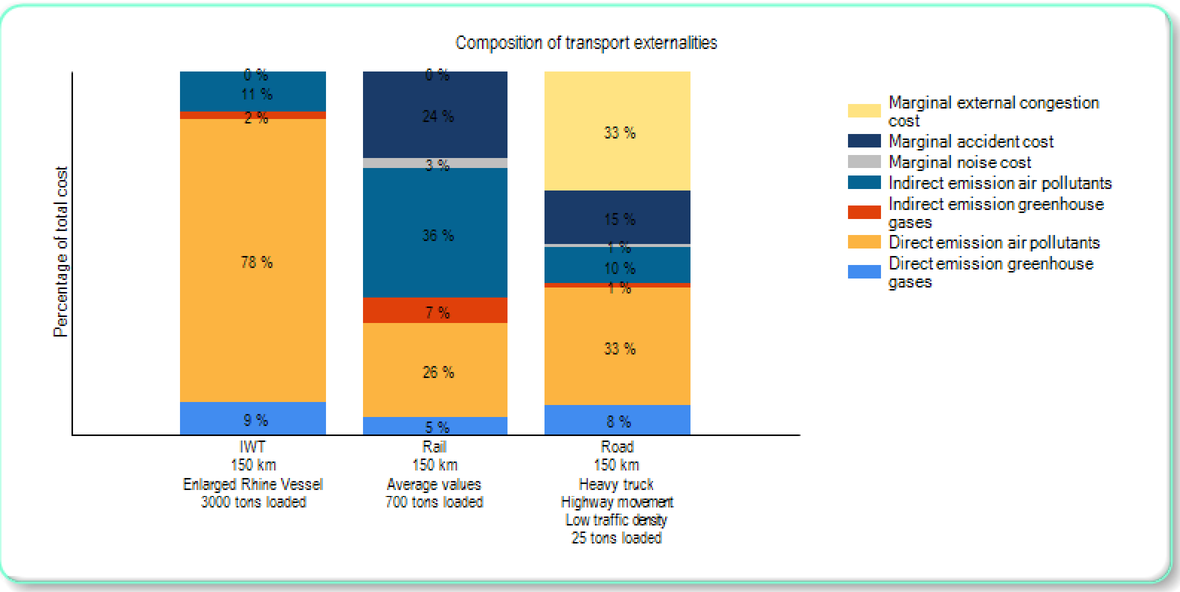
Figure 5. Comparison between total external cost values in the studied case.



Source: Own illustration based on case values and data from MINT (2013) and Grosso (2011).

The composition of the external costs for the three alternative transport modes is highly different as seen in Figure 6. The costs of accidents, congestion, and noise seldom apply and are hardly quantifiable in the case of inland navigation (see Section 4.6).

Figure 6. Composition of the external cost values for the three alternative transport modes in the studied case.



Source: Own illustration based on case values and data from MINT (2013) and Grosso (2011).

6. Conclusions

This paper presents the process to establish an instrument for the calculation of company-specific costs of IWT, from the ship owner's perspective, similar to those used in the road transport sector.

6.1 Implications for managerial practice

A review of existing models and applications to calculate the cost of inland navigation reveals three shortcomings. First, external cost elements are not considered in applications to calculate company-specific costs. Consequently, the available instruments for the sector cannot facilitate possible internalization strategies. Secondly, currently available models do not take different charter agreements into account. Third, applications to calculate company-specific costs do not offer utilities to benchmark own costs with average values for comparable operations in the sector.

Following upon the literature review and the collection of feedback from the IWT sector, this paper develops a generic cost calculation framework for a web-based instrument, addressing the identified shortcomings.

The paper also reveals that the variety of inland ships, regarding dimensions and capacities, equipment, and operations necessitates a cost-calculation methodology based on company-specific data, supported by information from ship owners' annual accounts as well as technical documentations on their vessel. Models largely based on average values are not likely to be applicable for the majority of cases, even in case of distinctions being made between different ship types and operations.

The new cost calculation model utilizes a range of input parameters concerning ship, exploitation, charter, and voyage characteristics. Individual cost centers are calculated separately. These include the cost of capital, labor, insurance, repair and maintenance, port fees and fairway dues, fuel, and commissions, and other fixed and variable costs, in addition to the cost of transport externalities The ultimate output considers the total cost per year as well as the cost of an individual voyage. For a better comparison between the cost and price of the transportation service, information on the cost per ton moved on a given trajectory is also provided to the user.

The model is linked to a database, where the users' values can be stored for reasons of convenience. The data can also be used to study operations in the IWT sector, and to establish average values for a range of different ship, exploitation, and charter characteristics.

6.2 Contribution to scholarly knowledge

The development processes of the cost calculation model revealed that models largely supported by average values are hardly capable of calculating accurate costs of IWT operations. This is due to the heterogeneity of the sector, with its variety of different ship types, equipment, and operations. As such, company-specific data is required to be used for the actual scientifically correct calculation, whereas average figures are recommended to only be utilized for benchmarking purposes.

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Annex

Annex 1. Case study parameters.

Ship parameters	
Type of vessel:	Dry cargo vessel, capable of transporting dry bulk and containerized cargo
Ship dimensions:	135m length, 11.4m beam, 3.76m draught (CEMT Class Vb)
Tonnage capacity:	4,232 tons
Engine power:	2,130 hp, 1,588 kW
Propellers installed:	2
Equipment type:	S2
Year of construction and purchase (new building):	2008
Purchase value:	EUR 5,300,000
Exploitation parameters	
Exploitation mode:	A2, 18 exploitation hours per day
Effective days per year:	336
Effective hours per year:	6,048
Sailing hours:	3,628
Self-employment:	Ship owner and wife self-employed onboard
Compensation for self-employment:	Fixed amount, EUR 75,000 per year
Fixed costs per year	
Depreciation method:	Linear
Depreciation period:	15
Depreciation cost:	EUR 226,460
Interest cost:	EUR 80,300
Personnel cost (2 hired crew members through recruitment office):	EUR 49,200
Cost of replacing personnel (during vacation, hours off work):	EUR 20,000
Insurance cost:	EUR 32,000
Maintenance cost:	EUR 12,000
Repair cost:	EUR 12,500
Withholding tax (ship owner):	EUR 16,000
Credit insurance (ship owner):	EUR 7,000
Cost of bookkeeping services:	EUR 7,500
Cost of company cars:	EUR 7,500
Cost of ship necessities (incl. paintjob):	EUR 5,000
Administration and communication cost:	EUR 5,000

Source: Personal Interview with ship owner operating in the dry bulk and container sector.