WP7: System integration and assessment

D7.2: Feasibility

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ABSTRACT

Inland waterway vessels are considered the cleanest land based transport mode on a per ton-km basis. However other modes are quickly catching up and speeding up is needed to maintain the IWT green character. One reasons for IWT to lag behind other modes is the long technical and economic lifetime of ships, which can easily extend 50 years. The replacement rate of the fleet is therefore rather low. This means, by modernising just through replacing older vessels by newer ones, the sector may become bypassed by other transport sectors soon. Therefore, action is needed targeting the existing IW fleet. To improve the performance of the inland waterway sector especially the existing fleet should be modernized. Currently there is insufficient knowledge about how to modernize the inland waterway fleet efficiently.

The Move-it! project aims to develop concrete applications that can be installed on existing ships. The possible retrofit options were formulated in task 7.1. In this task the technical feasibility is assessed and technical feasible option are the starting point of task 7.2.

The following table provides an overview of the retrofit options considered for the five vessels in the project. The ship owners indicated that duration of the pay back period is crucial in their decision making process. For each of the options analysed, is determined whether the option is highly feasible from the perspective of the ship owner (payback period between 1-4 years), the option could be considered (payback period between 5-10 years) or the retrofit option is not a viable option (payback period of more than 10 years).

Table A Summary of the proposed retrofit options

		Very desirable option	Option to be considered	No option
Dunaföldvár	Removal flanking rudders + installation bow thruster	√		
	New engines (6 barge)			√
	New engines (9 nine barge)	√		
Herso 1	Lengthening of the vessel with 20%	√		
	Installation of trapezes		√	
	Installation of Ship Studio Solution		√	
Inflexible	Installation of Ship Studio Solution		√	
	Replacement of rudders.			√
	Removal of struts from nozzle propellers			√
Veerhaven X	Installation of SCR			√
Carpe Diem	2-rudder solution			√
	Shortening of gondola			√

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1 Executive Summary

1.1 Problem Definition

Inland waterway vessels are considered the cleanest land based transport mode on a per ton-km basis. However other modes are quickly catching up and speeding up is needed to maintain the IWT green character. One reasons for IWT to lag behind other modes is the long technical and economic lifetime of ships, which can easily extend 50 years. The replacement rate of the fleet is therefore rather low. This means, by modernising just through replacing older vessels by newer ones, the sector may become bypassed by other transport sectors soon. Therefore, action is needed targeting the existing IW fleet. To improve the performance of the inland waterway sector especially the existing fleet should be modernized. Currently there is insufficient knowledge about how to modernize the inland waterway fleet efficiently.

The Move-it! project aims to develop concrete applications that can be installed on existing ships. The possible retrofit options were formulated in task 7.1. In this task the technical feasibility is assessed and technical feasible option are the starting point of task 7.2.

The aim of this task is to estimate the consequences on the costs and benefits once the vessel is modernized. In the consortium five shipping companies are included and each company has put one vessel at the disposal of the consortium to use as trial vessel. For each of the five vessels three retrofit options have been formulated and within task 7.2 each option is assessed.

Each retrofit option will impact the business case of the ship owner. Not only does the economic profile of the vessel change; there might also be an impact on the logistical operation of the vessel. To analyse the impacts of the retrofit options the current operational profile of the vessel is compared with the expected operational profile once a certain retrofit option is implemented. Also the payback period of the investment is considered.

1.2 Technical approach

The effects of each retrofit option are compared with the reference situation which equals the current operating profile of the shipping company concerned. To establish current operating profiles face-to-face interviews with ship owners involved in Move-IT are held and questions related to the vessel operation, financing of the vessel and other vessel related costs are asked.

Three retrofit options were formulated for each of the five shipping companies. In total 15 options were formulating ranging from hull adaptations to new rudder designs. In Move-IT task 7.1 these options are presented in further detail. For each of these options the main economic advantages and drawbacks were identified by the Move-IT WP7 partners jointly with the ship operators concerned, and checked with the technical partners to ensure consistency and reliability.

From task 7.1, cost estimate for the retrofit investment, impacts on maintenance costs and effects on fuel consumption were provided. These estimates are the basis of the analyses made to assess the feasibility of each retrofit option. For each shipping company in total three options are calculated, so the results look similar to:

Table 1.1 Presentation of outcomes feasibility assessment

	Reference situation	Retrofit option 1	Retrofit option 2	Retrofit option 3
NPV				
IRR				
Pay back period				

For each of the three options the change in operating costs are compared to the reference situation is calculated, as well as the payback time of the investment. Other indicators calculated are the internal rate of return (IRR) and the net present value (NPV).

1.3 Results and Achievements

The following table provides an overview of the retrofit options considered for the five vessels in the project. The ship owners indicated that duration of the pay back period is crucial in their decision making process. For each of the options analysed, is determined whether the option is highly feasible from the perspective of the ship owner (payback period between 1-4 years), the option could be considered (payback period between 5-10 years) or the retrofit option is not a viable option (payback period of more than 10 years).

Table 1.2 Summary of the proposed retrofit options

		Very desirable option	Option to be considered	No option
Dunaföldvár	Removal flanking rudders + installation bow thruster	√		
	New engines (6 barge)			√
	New engines (9 nine barge)	√		
Herso 1	Lengthening of the vessel with 20%	√		
	Installation of trapezes		√	
	Installation of Ship Studio Solution		√	
Inflexible	Installation of Ship Studio Solution		√	
	Replacement of rudders.			√
	Removal of struts from nozzle propellers			√
Veerhaven X	Installation of SCR			√
Carpe Diem	2-rudder solution			√
	Shortening of gondola			√

Although many retrofit options are available some seem to be more feasible than others. Especially improvements of the propeller, both pre-swirl and other improvements, turn out to be feasible options. The investment costs are reasonable compared to the estimated fuel reductions, which are considerable. Lengthening of smaller vessels seems to be an option to analyse further. The investment costs are also reasonable and the additional fuel consumption is more than compensated by the possibility of additional cargo. Also the installation of new engines is an option to explore further.

Options that do not seem feasible are rudder improvements. The investment costs are relatively high and the reduction in fuel is often limited. Also changes in the bow thruster gondola seem not to be viable at the moment.

1.4 Exploitation and Implementation

Based on the analysis carried out in task 7.2 the following recommendations can be made:

1. Retrofit options relating to propeller improvements are feasible options and many European vessels will benefit of such improvements. A wider application of these kinds of retrofit options is desirable, as investment costs are reasonable compared to possible fuel reductions.
2. For smaller vessels lengthening seems to be a feasible option as the option increase the cargo carrying capacity of the vessel against an almost negligible increase in fuel consumption. This retrofit option could be applied widely on smaller vessels.
3. The installation of new engines is a feasible option, as fuel consumption can be reduced and in some cases it could enable vessels to transport more cargo. A reduction in fuel consumption will reduce the level of CO_2 emissions. However it should be analysed what the impact the new engines is on the level of other emissions. It might well be that the emissions levels of for instance NOx and PM might increase.
4. Some of the options considered for the five vessels participating in the consortium are not feasible for the analysed vessels; however they might be feasible for less advanced vessels than the ones considered in Move-it! It is desirable to analyse these retrofit options further, as they might be feasible options for other vessels or vessel types.

2 Introduction

2.1 Background

Due to the liberalization of the European continental transport market competition on the transport sector has increased considerably. This applies both the competition between modes (road, rail and IWT) and within the same mode (e.g. between vessel types and / or cargo markets).

On top of that the fuel prices have increased during the last years. All modes mainly use fossil fuels (e.g. diesel, gasoline and gasoil) and the rising fuel prices have led to higher fuel bills. In combination with the sharpened competition as the impacts of the economic crisis from 2009 on, freight rates and transported volumes have decreased. To stay competitive on the market transport companies have to become more efficient. Especially IWT is loosing more and more ground to the other modes like rail and in particular road transport.

In order to cope with the increased competition and cost increases, inland shipping, known as the cleanest and most fuel-efficient transport mode, needs to become more efficient than it already is, as to improve business operations. However inland vessels have a very long life span and remain in the market for a considerable time. The strategy of phasing out of existing inefficient vessels and replace them by new and more efficient ones is not easily done, takes too long, and is way too costly. Therefore it is important to modernize and improve the existing vessel fleet as well. The following table shows the average age per vessel class in Western Europe. On average the Eastern European fleet is older than 40 years.

Table 2.1 Average age of Western European vessels

Tonnage of the vessel	Building year	Classification	Average age
0 – 650 tons	Ca. 1950	CEMT I and II	60 years
650 – 1500t tons	Ca. 1960-1970	CEMT III and IV	45 years
1500 – 3000 tons	Ca. 1995 (110 m ship)	CEMT V	25 years
3000 – 4000 tons	Ca. 2000 (135m)	CEMT VI	15 years
Over 4000 tons	Ca. 2005	>CEMT VI	5 years
Average age of pushing units (barge and pushers) is 20 years			

Currently there is insufficient knowledge about how to modernize the inland waterway fleet efficiently. Goal of the MoVe-IT! project is to obtain the required knowledge. Objectives of the project are:

- Improve the hydrodynamic behaviour of the ships involved (WP2);
- Improving the operational performance (WP3);
- Improve the performance of engines (WP4);
- Improve the construction (also when integrating new structures in existing vessels to meet new requirements) (WP5);
- Finding new trades for exiting vessel by reconstruction of parts of the vessel (WP6).

Within the defined work packages new improvement measures are identified and further investigated. It is crucial to take into account how all these elements interact and how they can properly be integrated with the systems of existing vessels. This is the main goal of Work package 7. WP7 consists of three tasks:

1. Assessing the consequences of the technical integration (7.1);
2. The cost-benefit consequences for the ship (7.2);
3. The impact on the environment (7.3)

2.2 Aim of task 7.2

The aim of this task is to estimate the consequences on the costs and benefits once the vessel is modernized. In the consortium five shipping companies are included and each company has put one vessel at the disposal of the consortium to use as trial vessel. For each of the five vessels three retrofit options have been formulated and within task 7.2 each option is assessed. In total 15 different designs are available which range form hydrodynamic improvements, to improvements in the powering and after treatment technologies.

Each retrofit option will impact the business case of the ship owner. Not only does the economic profile of the vessel change; there might also be an impact on the logistical operation of the vessel. To analyse the impacts of the retrofit options the current operational profile of the vessel is compared with the expected operational profile once a certain retrofit option is implemented. Also the payback period of the investment is considered.

The result of task 7.2 is an overview of the impacts of 15 different retrofit options. It should be noted that the results apply for the five specific vessels and can not be, one on one, transferred to other inland vessels, because the operational profile of inland vessels is highly different and the same retrofit option will not have the same effect for all vessels.

2.3 Structure of the report

In chapter 2 of this report the characteristics of the logistical chain in IWT is described as well as the economic of IWT. The chapter concludes with the methodology used to assess the feasibility of the retrofit options proposed for each shipping companies.

The chapters 3 till 7 each describe on of the participating vessels in the projects. The chapters start with a description of the current operation profile of the vessel, followed by a description of the proposed retrofit options. Each description contains general information on the option, possible impacts of this option on the logistical operations of the vessel, the data used to carry out the feasibility assessment and an overview of specific assumptions made. Each chapter concludes with a comparison of the proposed options and the sensitivity analysis carried out per option.

Chapter 8 provides the overall findings of task 7.2 and provides recommendations. Chapter 9 contains and overview of literature used and in chapter a list of figures and tables can be found as well as a list of abbreviations used. The report also contains two Annexes.

3 Characteristics of logistics and economics in the IWT sector

3.1 Logistics characteristics of IWT

3.1.1 Relevant parties in the IWT logistical chain

In the IWT freight logistical chain many parties play a role. One of the most important parties is the shipper, who is the owner of the cargo and therefore can decide how the transport is organised and which mode(s) is (are) used. The shipper can decide to arrange the transport himself or he can outsource this decision. In case the shipper outsources the decision, a shipping agent or freighter can organize the transport entirely or only partly, on behalf of the shipper.

Almost all cargo enters or leaves Europe through one of the seaports. The seaport forms a nodal point between sea- and hinterland transport. Besides this nodal function, seaports are a location for seaport related activities (e.g. process industry of logistical activities). The sea transport is carried out by maritime shipping companies, which are often large companies. In the seaport the cargo has to be transferred from the sea vessel to the inland vessel or other modes. This activity is organised by the stevedore, who has a contractual relationship with the maritime shipping company. Costs made by the stevedore are charged on the maritime shipping company who on its turn charges the shipping agent or shipper for the costs made.

The inland shipping company or operator is responsible for the inland waterway related transport and he is the owner of the vessel used. Clients of the inland shipping company are very diverse and can be the shipper or shipping agent / freighter, however in container transport it can also be the inland terminal or the maritime shipping company.

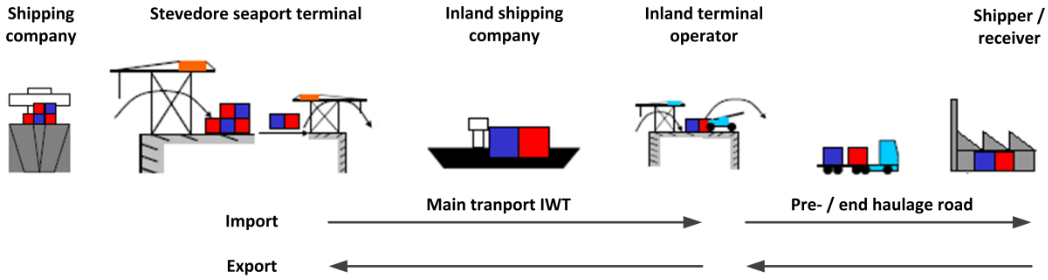
The last important party in the logistical chain is the inland port where the cargo is transferred from an inland vessel to another modality. In this inland port processing industry and logistical activities can place as well. The inland port can be seen as a nodal point and location provider.

Although the parties mentioned always play a role in the logistical chain, their role might differ between different commodity markets. The importance of the parties, the competitive position and growth perspectives might differ. For the Move-it project the logistical chain of the container market is the most relevant one, as two companies often transport containers and the model can be applied to the other three companies as well.

3.1.2 The logistical chain in container transport

In this commodity market international and national transport are strongly separated. Almost all transport has an overseas origin or destination and therefore needs to go through a sea port. Main parties at the maritime side are the large container companies with their deep sea container lines (i.e. carrier haulage) and shipping agents (merchant haulage). These parties organise the coordinate the entre transport chain between seaport, inland port, pre- and end haulage to the user of the cargo. The following figure shows an impression of the logistical chain.

Figure 3.1 The logistical chain in container transport



Source: Basisdocument containervaart, a&s management , DLD en SPB, 2003, edited by authors

The logistical chain is characterised by full competition, especially in the hinterland transport. There are many inland shipping companies who can transport the cargo the inland ports, but also other modalities, e.g. rail and road, are able to transport the cargo. This results in fierce competition. This often results in low transport prices and some inland operators are even sailing under cost price.

3.2 The economics of IWT

Types of markets

The shipping market consists of two submarkets; the spot market and the scheduled liner markets. In the spot market ship owners often have a one voyage contract with a client and they agree to transport the goods from A to B. Once the voyage is finished the ship owner is able to sail on a different route. The vessel capacity is often fully used by one client only, so the whole vessel is hired by the same client. In case the vessel has also barges attached, it is likely that the vessel is hired by one client and the barge by another.

On the other hand vessels can sail on a scheduled plan. An example of a market where scheduled shipping occurs is the container market. A vessel is loaded with containers from (multiple) clients, which all reserve the space they need. The liner services sail between A and B and then return on a fixed frequency (daily, weekly, etc.).

Types of contracts

In inland shipping several contracts exists. Only a few shipping companies in inland waterway transport sail for one company only. In these cases the shipping company is often owned by the shipper, e.g. a steel factory who aims to ensure constant delivery of commodities. To end the transport contract between the shipping and the shipper the shipping company privatized and become an independent company or the shipping company could be sold to another company that would like to have a dedicated shipping company.

More commonly is the usage of long lasting contracts. These contracts are conducted for several weeks, months of even years. In this period the shipping company or particular vessels operate for one client only. Main benefit of this construction is a guarantee that the shipping company will be paid a fixed price for a certain period for time and income is ensured. On the other hand the company has to sail for the agreed transport price and if transport prices rise, is not able to benefit directly from this as the agreed price is leading. If transport prices decrease again the shipping company can benefit of the fixed price.

In inland waterway transport also many shipping companies do not have a contract with a specific shipper. These companies have to ensure cargo every trip they make and operate a looser schedule than companies with fixed contracts. For companies without a contract it is worthwhile to wait in port a few days and wait for cargo instead of operating a fixed schedule with the risk of sailing without any cargo at all.

Handling costs

Once the vessel is in port the cargo needs to be handled. Most inland vessels do not have on board equipment to ensure the handling. Therefore they have to use handling equipment in the port. To use the equipment a fee needs to be paid. Usually the fee is paid by the client and not by the shipping company.

Ship owners may not always directly benefit from the retrofit options, although they have to invest in the retrofit option. Most retrofit options proposed in the Mo-Ve-IT! project will increase the fuel efficiency of the vessels and reduce the fuel consumption. However whether the ship owner will benefit of the increased fuel efficiency depends on who is paying the fuel costs: the operator or the client.

Cost structure

The cost structure of an average shipping company consists of fixed and variable costs. The main fixed costs are capital costs and insurance costs. These costs are independent of the operations of the ship or of the transport revenues, and once the fixed costs can not be paid it is likely that the shipping company goes bankrupt. Main variable costs are labour costs, maintenance costs and fuel costs. The level of these costs can vary considerably over time and for a short term it is possible not to pay variable costs without the fear of going bankrupt.

Fixed costs

Capital costs

Every shipping business starts with buying a vessel, which can be a new built one or an existing vessel. Once the investment is made the company has to depreciate on the vessel and pay interest on the loan taken.

Depreciation is done to include the decreasing value of the vessel in the total costs. Important factors for the depreciation are the depreciation period considered (about 20 years for a new vessel and 5 – 10 years for the engine) and the residual value of both vessel and engine.

A factor to take into account for the depreciation is the residual value of the vessel. Prevailing residual values applied are 5-10% of the new build value. It is assumed that the vessel can still be sold against this residual value (sometimes scrap value).

Also the interest costs are an important part of the capital costs. The two types of interest costs used in inland navigation are the interest costs of borrowed capital and the opportunity cost for the investment of equity.

Insurance costs

Inland vessels often have two types of insurance: the casco or hull & machinery (H&M) insurance and the protection& indemnity (P&I) insurance. The H&M insurance insures the entire vessel and all the on board machinery. The H&M insurance is traded on the commercial insurance market and influencing factors for the height of the insurance could be the vessel type, the insured value, the vessel tonnage, the year of construction, and the state of the engine. Usually all vessels have a H&M insurance.

The P&I insurance insures amongst others the cargo transported, cargo shortage, pollution and damaged caused to other vessels. The P&I insurance is obtained via a P&I club which collects the premiums along the members of the club. If a shortage in insurance money occurs additional premium is required of the members. Not all inland vessels have a P&I insurance. Mainly large vessels or vessels transporting dangerous cargo have a P&I insurance.

Variable costs

Labour costs

Labour costs form an important cost aspect of inland shipping. The costs can be qualified as variable costs. Depending on the business model used the labour costs can differ. Many vessels are operated by the owner (and his family). This group consists of the so-called owner operators. Their wage is the margin that is left once all the fixed and other variable costs are paid.

Some vessels are not operated by the owner operator himself, but are operated by crew which works for a shipping company. All crew members have a labour contract with the shipping company and are paid (fixed) wages.

Maintenance costs

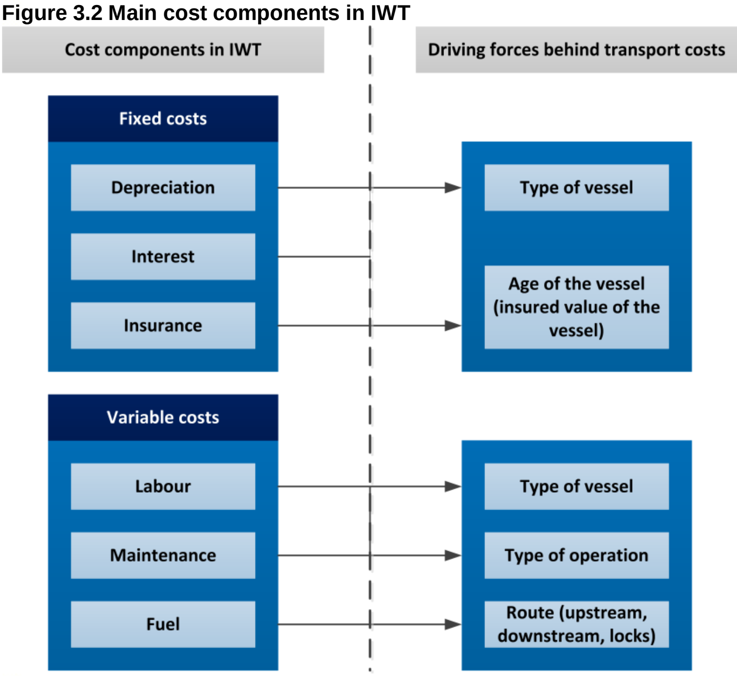
Maintenance costs can be divided into regular maintenance costs and costs associated to emergency repairs. Regular maintenance is often scheduled in time, and during these maintenance periods, many other activities, like certification and large inspections, are done as well. Beforehand a good cost estimate of the maintenance can be made. The second category relates to unexpected maintenance, for which costs can be considerable.

Fuel costs

Fuel costs are a large cost component in inland shipping. Fuel consumption is influenced by many factors. The route sailed is an important factor (downstream versus upstream). The fuel use is also influenced by the cargo transported (loaded or empty) and by water level conditions.

The figure below shows the main cost components for inland shipping. They components can be divided into fixed and variable costs. For each of the main cost components the driving forces behind these costs are indicated.

Figure 3.2 Main cost components in IWT



Source: Nea et. al (2012), edited by authors

3.3 *Description of the analysis methodology*

The aim of task 7.2 is to analyse the operational, logistics and economic effects of the proposed retrofit options on the operator's business. The effects of each retrofit option are compared with the reference situation which equals the current operating profile of the shipping company concerned. To establish current operating profiles face-to-face interviews with ship owners involved in Move-IT are held and questions related to the vessel operation, financing of the vessel and other vessel related costs are asked. An example of the questionnaire used for these interviews can be found in Annex A. The information obtained in those interviews is the starting point of the feasibility analysis.

Three retrofit options were formulated for each of the five shipping companies. In total 15 options were formulating ranging from hull adaptations to new rudder designs. In Move-IT task 7.1 these options are presented in further detail. For each of these options the main economic advantages and drawbacks were identified by the Move-IT WP7 partners jointly with the ship operators concerned, and checked with the technical partners to ensure consistency and reliability.

From task 7.1, cost estimate for the retrofit investment, impacts on maintenance costs and effects on fuel consumption were provided. These estimates are the basis of the analyses made to assess the feasibility of each retrofit option. For each shipping company in total three options are calculated, so the results look similar to:

Table 3.1 Presentation of outcomes feasibility assessment

	Reference situation	Retrofit option 1	Retrofit option 2	Retrofit option 3
NPV				
IRR				
Pay back period				

For each of the three options the change in operating costs compared to the reference situation is calculated, as well as the payback time of the investment. For shipping companies the pay back period is the most relevant indicator. This indicator shows when the ship owner has earned back his initial investment and when he starts to make money. The lower the pay back period is the sooner the ship owner will have earned back his investment.

Another indicator used is the internal rate of return (IRR). This indicator measures and compares the profitability of different options or more specifically the IRR of an investment is the discount rate at which the net present value of costs (negative cash flows) of the investment equals the net present value of the benefits (positive cash flows) of the investment. The higher the IRR is the more profitable it is to invest in a retrofit option.

A last indicator used is the Net present value (NPV). This indicator is often used in policy related decisions and indicates the ‘difference amount’ between the sums of discounted: cash inflows and cash outflows. It compares the present value of money today to the present value of money in the future, taking inflation and returns into account. The higher the value of this indicator the more attractive it is to invest in the retrofit option.

General assumptions

Several general assumptions are made, which apply to all shipping companies and all retrofit options.

The first assumption relates to the time horizon used to calculate the effects. Apart from the investments costs, which occur only once, all other costs components are recurring. Some of them recur every year, e.g. the casco insurance premium and wages of employees, while other cost components only occur every two or three years, e.g. large maintenance costs. The time horizon chosen is 25 years.

The second assumption relates to the discount rate. All future costs or benefits are expressed in their present value, so all effects will be discounted to the year of investment. The year of investment is assumed to be 2016[1]. By discounting the costs and effects, costs and effects later in time count less heavily than costs and effects made earlier in time. The discount rate used in the analysis is 5.5%.

The third assumption relates to the prices used. All effects will be expressed in Euros, and data obtained in other currencies are converted to Euros. The effects will all be expressed in real prices and the price level used is price level 2013.

Main effects – direct effects

- *Investment costs*: One of the most important aspects in the economic evaluation are the investment costs needed to obtain the new retrofit option. For each of the options the technical partners have estimated the investment costs. It is assumed that the investment costs will all fall in one year and can be qualified as one-of costs.
- *Maintenance costs:* Closely related to the investment costs are the additional costs for maintenance. Installing a new engine or place a new rudder arrangement might cause an increase of the maintenance costs. It is assumed that maintenance related to the retrofit installation is needed every couple of years, and assumptions on this are made for each option. This means associated costs are included in the analysis using the assumed frequency (e.g. every 2 years, 3 years, etc.).

Main effects – operational profile

- *Fuel consumption:* Depending on the retrofit option chosen, fuel consumption of the vessel may increase or decrease. Most of the technical improvements suggested in the previous Work packages will result in a decrease of the fuel consumption of the vessel, resulting in a lower fuel bill, assuming that fuel prices remain constant. However some options, e.g. lengthening of the vessel, will increase the fuel consumption and therefore increase the fuel bill. For estimating the fuel prices the CBRB Gas oil circulars for inland shipping are used.
- *Insurance costs:* In inland shipping there two important types of insurances; the casco insurance or the hull and machinery insurance (H&M) and the protection and indemnity insurance (P&I). For the economic evaluation the casco insurance is the

[1] The MoVe-IT project ends in November 2014. It is assumed that companies need 2015 to ensure financing, make arrangements, e.g. reserve yard space and decide on the retrofit options. The first possible year of investment is 2016.

most important one, because the modernisation of the vessel will influence the height of the casco insurance. Insurance costs may increase if a technology is implemented that is much more expensive then the systems in place in the reference situation. On the other hand as it may concern a replacement by a newer and more reliable system, in some cases perhaps premiums can be reduced, because the chance of failure had reduced.

- *Capital costs:* The financial picture of the company can change due to the retrofitting of the vessel. To finance a retrofit option it is assumed that the shipping company has to obtain an additional loan from a bank or from another investor. The interest costs will probably increase and the company faces higher financing costs than before.

Additional effects

- *Cargo volumes:* Cargo carrying capacity can change due to the retrofit modernization of the ship. For most proposed retrofit options this effects will be limited, as cargo capacity or sailing speeds will not change. However in case the vessel is lengthened the ship's capacity will increase allowing larger volumes to be transported, resulting in a revenue increase (assuming sufficient demand). On the other hand some other retrofit options may cause a (slight) reduction of the cargo capacity of the vessel.
- *Labour costs:* labour costs could be affected by the modernisation of the vessel. This could concern the need for hiring additional personnel to comply with current legislation, or the need for additional training, which brings (temporary) additional costs. The first impact may occur when a vessel is lengthened, and if a threshold in manning regulations is passed, additional crew is required. On the other hand the retrofit option can require additional skills of the employees for which and additional training is required.

3.3.1 Assessing different economic scenario's

As assumptions are made which are uncertain, while the base case development may also be uncertain (e.g. how will the IW market develop, what will the level of fuel prices be in future years, etc.), for each ship/retrofit option combination, multiple scenarios will be tested. Generally we assess a baseline scenario (e.g. applying the middle assumptions on costs and impacts), a high, and a low scenario (using the range ends of costs and impacts estimated. These will be presented as sensitivity tests on the baseline scenario.

As the uncertainties on assumptions vary between the ships and retrofit options, no standard scenarios for all ships are developed, but the baseline and alternative scenarios are made for each ship/retrofit option specifically. However general inputs such as interest rates, residual values or fuel prices are applied similar for all ships.

4 Dunaföldvár

4.1 *Current operating profile*

General information of the vessel

The Dunaföldvár is owned and operated by Helogistics and was built in 1989 and is a pusher vessel, that sails with barges on the Danube. Main dimensions of the pusher and the barges are given in the following table.

Table 4.1 Main dimensions vessel and barge

	Dunaföldvár	Barges
Length	37.20 m	76.5 m
Beam	12.54 m	11.54 m
Draught (max)	1.95 m	2.8 m

The Dunaföldvár operates in a six barge system, but Helogistics would like to expand this to a nine barge system to increase its competitive position. Length of a six barge system is 266.7 m and width is 23.08 m.

Figure 4.1 Impressions of the Dunaföldvár

Cargo information

The convoy mainly transports iron ore and grain. The maximum capacity of a single barge is 1,800 tons. On average one barge carries 1,283 tons. The following table provides an overview of the cargo transported.

Table 4.2 Cargo information

	Six barge combination
Total capacity	10,800 tons
Average capacity	7,700 tons
Total capacity transported per year	184,831 tons

Main routes, sailing time and total distances

The convoy operates between Hungary and the Black Sea. Typically, a trip starts in Budapest, Hungary and ends in Izmail, Ukraine. Possible intermediate stop can be in Serbia. The journey downstream (towards Ukraine) lasts 7 days, while the upstream trip (to Hungary) takes 14 days. The vessel performs this trip once a month and per year 12 round trips are performed.

The vessel is normally loaded on 100% of trips, because the vessel does not set sail before cargo is acquired. The company prefers to wait in port for cargo instead of performing empty trips it. The total distance sailed per year is 34,000km.

Engine information

The vessel has three main engines on board, each with a capacity of 515 kW. Brand of the main engines is Skoda S6 27.5 A2L. The vessel also has 3 auxiliary engines on board. Two engines are used as normal auxiliary engines and they have a capacity of 75 kW each. Brand of these auxiliary engines is IFA 6VD. Besides the two normal auxiliary engines the vessel also has one emergency auxiliary engine on board with a capacity of 37.5 kW. Brand of the emergency engine is also IFA 3VD. Total available capacity of all engines together is 1,732.5 kW. The vessel does not have a bow thruster.

The company uses gasoil (ULS EN590) as fuel. Total fuel consumption was 1,597,540 litres in 2010. The main engines used 1,540,600 litres of fuel and the remaining 56,940 litres were used by the auxiliary engines. The vessel consumes around 10 tons of lubricant oil per year. Following table provides an overview of energy capacity and fuel consumption.

Table 4.3 Engine information and fuel consumption

	#	Capacity	Total capacity	Fuel consumption
Main engines	3	515 kW	1,545 kW	1,540,600 litres
Auxiliary engines (normal)	2	75 kW	150 kW	56,940 litres
Auxiliary engine (emergency)	1	37.5 kW	37.5 kW	

Crew information and maintenance

One crew consists of seven crew members. The vessel operates a B schedule which means that the vessel is sailing 24 hours a day. The following functions are presented:

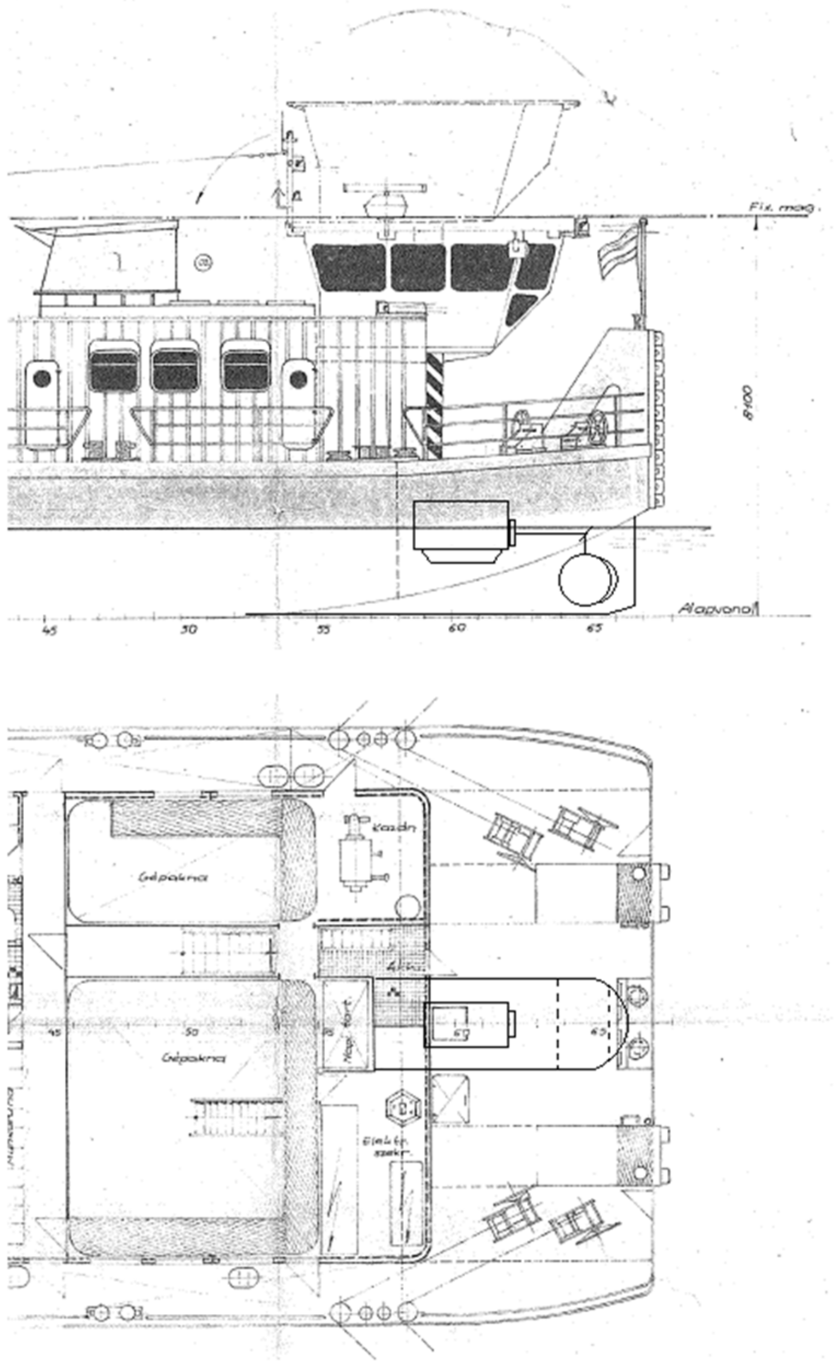
- Captain (2)
- Patent (1)
- Machinist (2)
- Boatman (2)

Every 20,000 running the vessel goes into maintenance and this equals every three to four years. This is an overall large maintenance period. Every 2,000 running hours the vessel undergoes a short service period, in which mainly the oil needs to be changed. This equals every six months. The short maintenance takes a few days and an be done while the vessel is in port waiting for cargo, while the larger maintenance will take 1 or 2 weeks, depending on the maintenance that needs to be done.

4.2 Option I: Remove flanking rudders and instalment of a bow thruster gondola

The first option considered consists of two activities. First the flanking rudders need to be removed. The vessel has five rudders for onwards manoeuvring and four ones for backwards manoeuvring. These flanking rudders are mainly used when the vessel needs to manoeuvre sternwards and this generally only happens in port. During regular sailing the rudders are idle and increase the ship's resistance and therefore influence the fuel consumption. The fuel consumption of the vessel can be lower due to the positive effect of flanking rudders removal. In the previously quoted report of MARIN, Delivery of WP2, an increase of forward thrust of 3% as a minimum can be obtained. According to the experts this can be translated to an average 5-7% reduction of yearly fuel consumption.

Figure 4.2 Thruster arrangement



The second component of this option is to install a bow thruster. Currently the vessel has no bow thruster, but a bow thruster could take over the role of the rudders in manoeuvring backwards and reduce the fuel consumption. Also the bow thruster will probably only be used when manoeuvring in port and coupling work of barges, however many modern techniques are available to reduce resistance of a bow thruster, for instance installing a bow thruster valve that can close the section where the bow thruster is located when the thruster is not used. The resistance of the vessel decreases and the fuel consumption reduces. The installation of a new engine is required. The brand of the new engine will be Scania DC13 and the power of the engine is 364 kW.

Input data for feasibility assessment

Table 4.4 provides an overview of the input data on this retrofit option. The fuel consumption will decrease slightly once a bow thruster is installed and the flanking rudders are removed. This reduction in fuel can be attributed solely to the removal of the flanking rudders. The addition of a bow thruster will increase the fuel consumption slightly; however this increase will be negligible and therefore is not further considered.

Due to the installation of the bow thruster the maintenance costs per year will increase, because the bow thruster requires additional maintenance.

Table 4.4 Overview of input data from WP 7.1

	Remove flanking rudders + installation bow thruster gondola
Investment costs	€ 215,000 - € 265,000
Time at yard	3 weeks
Maintenance costs	€ 1,000 per year
Δ Fuel consumption	5 - 7% reduction
Δ Lubricant consumption	0%
Δ Economic lifetime	0%
Additional ship capacity	0%
Δ Insurance costs	3%

Specific assumptions

1. To implement this option, the vessel needs to go in dry dock for three weeks. On average the vessel makes twelve roundtrips per year and in total 24 single trips. To perform this retrofit option the vessel will miss one roundtrip (2 single trips).

2. It is assumed that the vessel and its barges solely transport coal. The transport price per ton coal is assumed to be € 10,-. The average capacity per barge is assumed to be 1,800 tons. Average cargo carried of the convoy is 7,700 tons.

3. It is assumed that only the fuel consumption of the main engine will decrease. The fuel consumption of the auxiliary engines will remain the same.

4.3 Option II: Installation of new engines

The second option considered for the Dunaföldvár is the installation of new engines. The current engines are not powerful enough to push a nine barge combination. The company would like to use a nine barge combination instead of the current six barge combination, because in case of low water the company would then be able to transport the same amount of cargo as it normally takes with 6 barges. The three additional barges would also allow the company to transport more cargo at once and therefore to increase its competitive position.

In this option the installation of three new main engines is considered. The engines would have a capacity of 750 kW each and this means that each engine has an additional capacity of 235 kW, as the old engines had a capacity of 515 kW each. Total capacity of the main engines will become 2,250 kW.

Figure 4.3 Current Skoda main engine and engine room of Dunaföldvár

4.3.1 Input data for feasibility assessment

The following table provides an overview of the data received of the technical partners in WP7.1 and the ship owner.

Table 4.5 Overview of input data from WP 7.1

	New engines
Investment costs	€ 1,425,000 – 1,700,000
Time at yard	0 weeks
Maintenance costs	€ 21,000 per year
Δ Fuel consumption	15% reduction
Δ Lubricant consumption	0%
Δ Economic lifetime	10 – 15 years
Additional ship capacity	0%
Δ Insurance costs	10% increase

The investment costs include all costs that need to be made to install the new engines. First of all, the old engines need to be removed. It is expected that this will costs € 30,000. -. The installation costs add up to € 200,000 and the price per engine is estimated at € 300,000 each. Also three new screws and nozzles need to be installed, which can work under the increased capacity. Without changing the screws and nozzles the propulsion cannot work efficiently and so the propulsion is needed to be fitted to the increased capacity and operation. The investment costs for the new screws and nozzles add up to € 180,000. The last activity relates to drive train that needs to be modified to ensure proper working of the new engines, screws and nozzles. Costs for drive train related work are estimated to be € 15,000.-

The feasibility analysis undertaken is split into two parts. First only the installation of the new engines is considered, without extending the convoy to nine barge. In the second part the additional benefits realized by shifting to a nine barge combination operation is addressed.

4.3.2 Specific assumptions for new engines only

1. It is assumed that the vessel and its barges solely transport coal. The transport price per ton coal is assumed to be € 10,-. The average capacity per barge is assumed to be 1,800 tons. Average capacity of the convoy is 7,700 tons.

2. It is assumed that only the fuel consumption of the main engine will decrease. The fuel consumption of the auxiliary engines will remain the same.

3. For the input data that are provided as a range, e.g. investment costs, the average is assumed. So for the investment costs, an average of € 1,562,500. - is considered.

4.3.3 Specific assumptions for a nine barge combination

1. It is assumed that savings in fuel consumption will slightly diminish compared to the six-barge system, because the vessel needs additional capacity to push the three additional barges. It is assumed that fuel savings will be 14% instead of 15%.

2. It is assumed that the company already owns the three additional barges and therefore no additional investments need to take place.

3. It is assumed that there is not always cargo available for the three new barges and that the barges only carry cargo for 50% of their sailing time.

4. It is assumed that the three additional barges are not 100% loaded. The average loading capacity of the six original barges is 71%. It is assumed that when the three barges are loaded, their load factor is 71% as well.

4.4 The retrofit options compared

All three retrofit options considered for the Dunaföldvár are economically feasible. The table below shows that Net Present Value, the internal rate of return and the return on investment. All NPVs calculated are positive. Important factor is the return on investment. This indicator shows when the ship owner will have earned back its initial investment.

Table 4.6 Outcome of economic assessment

	Installation bow thruster gondola	New engines 6 barges	New engines 9 barges
NPV (x1,000)	€ 601	€631	€ 5,659
IRR	30%	11%	44%
Pay back period	4 years	12 years	3 years

Main benefit for the owner will be the reduction in fuel consumption. During the interview the ship owner indicated that he is the party paying for the fuel. This means that any fuel savings will directly benefit the ship owner and he is able to earn back his investment through the fuel savings he realizes. Another benefit realized by the ship owner is the additional revenue created by the possibility to transport more cargo. Additional revenue is only a benefit in third retrofit option, where the vessel will sail with nine instead of six barges.

4.4.1 Sensitivity analysis for installation bow thruster gondola

For the first retrofit option two effects are taken into account in the sensitivity analysis; a change in investments costs and a change in fuel prices. Changes in transport costs of coal are not considered as this retrofit option does not change the cargo capacity of the vessel. The vessels needs to go into dry dock, however this will be one-off costs and a change in transport prices will have a limited effect on the outcome.

Table 4.7 Outcome sensitivity analysis installation bow thruster gondola

		Investment costs		Fuel price	
	Base case	-20%	+20%	-10%	+10%
NPV (x1000)	601	641	560	512	689
IRR	30%	37%	25%	26%	34%
Pay back period	4	4	5	5	4

This retrofit option is only slightly sensitive to changes in both investments as well as fuel costs. Only when the investment cost increase or fuel prices decrease the return on investment changes. In both cases the ship owner will earn back its investment in five instead of four years. In case the investment costs decrease or fuel prices increase the return on investment does not change and the ship owner will earn back his investment in four years time.

4.4.2 Sensitivity analysis for new engines (6 barges)

Also for this retrofit option several sensitivity analysis are done. The effects taken into account are the investment costs and fuel price. The transport costs of coal are not considered for this option, as the retrofit option does not influence the cargo capacity of the vessel and only the barge is shortly taken out of operation. The effect of being out of operation for two weeks is negligible.

Table 4.8 Outcome sensitivity analysis new engines (6 barges)

		Investment costs		Fuel price	
	Base case	-20%	+20%	-10%	+10%
NPV (x1000)	631	897	365	411	851
IRR	11%	15%	8%	9%	12%
Pay back period	12	9	17	15	11

The sensitivity analysis shows that this retrofit option is very sensitive to changes in both investment costs and fuel prices. If the investment costs decrease with 20% the earn back period is shortened with three years, from 12 to 9. However if investment costs would be 20% higher than estimated the earn back period will be 17 years instead of 12. The retrofit option is also very sensitive to changes in fuel prices. Especially when fuel prices are lower than expected the earn back period will be 15 years instead of 12. In case the fuel prices are 10% higher than expected the return on investment is 11 years.

4.4.3 Sensitivity analysis for new engines (9 barges)

The following table shows the outcome of the sensitivity analysis carried out for the first retrofit option. The effects of changes in the investment costs, the fuel prices and changes in the transport costs of coal are considered. Each of these effects is considered separately and a worst case and best case scenario are presented.

Table 4.9 Outcomes sensitivity analysis new engines (9 barges)

		Investment costs		Fuel price		Transport price	
	Base case	-20%	+20%	-10%	+10%	-25%	+25%
NPV (x1000)	5,658	5,925	5,393	5,453	5,864	4,365	6,952
IRR	44%	57%	36%	42%	46%	36%	52%
Pay back period	3	2	4	3	3	4	3

This retrofit option is not very sensitive to any of the analysed effects. Changes in investment costs, fuel prices or transport costs might have a slight effect on the return on investment, however the effect is minimal.

5 Herso I

5.1 Current operating profile

General information of the vessel

The Herso 1 is owned by Plimsoll from Hungary. The vessel was built in 1961 in Duisburg, Germany. Plimsoll bought the vessel in 2003. The vessel can be qualified as a motor freight vessel. The vessel operates in a coupled convoy pushing the barge SL Leinie. To enable the Herso 1 to push a barge, the vessel was retrofitted once. The vessel used to have a traditional bow and during the retrofitting process the bow was more flattened. Main dimensions of the pusher and the barge can be found in the following table.

Table 5.1 Main dimensions vessel and barge

	Herso 1	Barge
Length	84.95 m	70.75 m
Beam	9.50 m	10.44 m
Draught (max)	2.7 m	2.47 m

If the barge is placed in front of the Herso the entire combination has a length of 155.7 m. The barge is placed in front when the vessel sails upstream (from Hungary to Germany and from Rumania to Hungary) and is connected alongside the vessel when sailing downstream (from Germany to Hungary and from Hungary to Romania). The Herso is allowed to push two barges; however this only happens when sailing between Hungarian ports, because the engine capacity is not sufficient to push two barges for a longer period of time.

Figure 5.1 Impressions of Herso 1

Cargo information

The vessel and barge can transport all kind of dry cargos. Main cargos transported are agricultural products and specialized steel structures. The vessel could also transport containers, however this rarely happens.

The total capacity of the vessel is 1,381 tons. Average loading is 1,000 – 1,100 tons (considering an air draft of 2.3 m). The barge can add a total capacity of 200 tons (considering an air draft of 2.2 m). Per year, the convoy transports 18,000 tons of cargo and this equal 1,000 tons per trip. In 2011, a particularly bad year for navigation on the Danube, the convoy transported only 700 tons per trip. Vessel and barge often sail for different clients and therefore can transport different goods.

Main routes, sailing time and total distances

The main routes originate from Dunaújváros, Hungary and are towards either Regensburg, in Germany, or Constanta, in Romania. The vessel may call at other German ports as intermediate stops. Sailing to Regensburg takes 7 days upstream and 5 days downstream, totalling 12 sailing days for the whole voyage. Loading and discharging take a day each and so total voyage time is 14 days. Sailing to Constanta is longer, with 10 days on the way downstream and the return journey taking 14 days, making the sailing days 24 days. Loading and discharging take two days each and the whole voyage duration is 28 days. In total every year the vessel makes nine return trips to Regensburg and nine to Constanta.

Total distance travelled by the vessel per year is 33,480 km (9 x 1,600 km to the German port and 9 x 2,120 km to the Romanian one). The vessel carries cargo 90% of the time, so the total distance covered with loads on-board is 30,132 km; approximately 10% of the time the vessel sails without any cargo on-board.

Engine information

The vessel has one main engine, with a power of 780 kW. Brand of the main engine is Deutz RBV 8M 545. The vessel also has two auxiliary engines, each with a power of 25 - 30 kW. Brand of the auxiliary engines is Deutz 912. Total available power of all engines together is 830 - 840 kW. Besides the main and auxiliary engines the vessel also has one bow thruster installed, with a power of 212 kW. The bow thruster is mainly used for manoeuvring in ports.

The type of fuel consumed by the vessel is ULS EN590 (10 PPMS), of which the vessel used 370,295 litres in 2012. Approximately 220,000 litres of fuel are used by the auxiliary engines and bow thruster, which equals to around 15% of total consumption. The vessel is also using 1,000 litres of lubricants per year. Following table provides a summary of the engine capacity and fuel consumption.

Table 5.2 Engine information and fuel consumption

	#	Capacity	Total capacity	Fuel consumption
Main engines	1	780 kW	780 kW	314,750 litres
Auxiliary engines	2	25 – 30 kW	60 kW	55,544 litres[2]
Bow thrusters	1	212 kW	212 kW	

Crew information and maintenance

The vessel operates an A-1 schedule which means that the vessel is sailing 14 hours a day. This scheme requires 1 master and 3 engineers / crew members. The following functions are presented:

- Captain (1)
- Second (1)
- Engineer (2)

The vessel operates 340 days per year and has to go into dry dock every 8,000 – 10,000 working hours. This equals every 3 years. Small repairs and maintenance are done while the vessel is loading/unloading in the port. The on-board engineers are responsible for the maintenance.

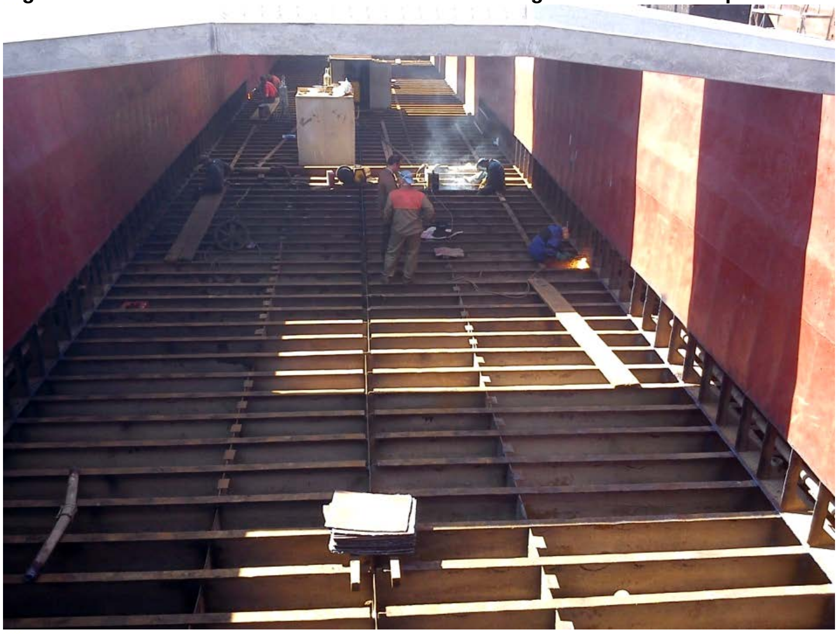
5.2 Option I: Lengthening by 20%

One of the options considered for the Herso 1 is lengthening of the vessel by 20 – 25%. Main advantage of lengthening is that the vessel is able to carry more cargo per trip and could increase its competitive position. The Herso 1 is operating on the Danube, a river with fluctuating water levels. In dry periods water levels become so low that navigating is impossible. By lengthening the vessel, the vessel is able to transport the same amount of cargo as it is doing today, but is able to operate in low water periods, because the draft of the vessel can be decreased. Lengthening enables the company to reduce the number of days on which the vessel is not able to set sail.

The proposed lengthening of the vessel complies with the Germanischer Lloyd (GL) rules. Lengthening of the vessel with 20 – 25% results in a length of the vessel between 101.94 m and 106.19 m. According to GL rules the maximum possible length of a vessel with a draught of 2.9 m is 101.45 m. This means that the vessel is lengthened with 16.5 m and this equals almost 20%.

[2] 15% of the fuel is used by the auxiliary engines, bow thruster and boiler. Due to a lack of measurements it is not possible to further divide the fuel consumption between those engines etc.

Figure 5.2 Structural details of "HERSO 1" in the cargo hold area with opened double bottom



This option might influence the logistical operation of the company. Main aim is to increase the cargo capacity of the vessel. On the one hand this option enables the company to transport the same amount of cargo with a lower depth. The vessel operates on the Danube, a river with fluctuating water levels, and if the vessel is able to sail with a lower draught, the company is able to operate longer than it is nowadays. On the other hand the company can transport more cargo than before and increase its revenue.

5.2.1 Input data for feasibility assessment

Table 5.3 provides an overview of the data used in the feasibility analysis. The data are collected in WP 7.1 and verified with the technical partners responsible for the lengthening option. Due to the lengthening of the vessel the fuel consumption will slightly increase, however it is expected that the increase in fuel consumption is compensated by the possibility to carry more cargo. It should be noted that the additional cargo mentioned in the table is the maximum amount of additional cargo. The vessel is often not fully loaded and therefore the vessel will not carry the maximum additional cargo.

Table 5.3 Overview of input data from WP 7.1

	Lengthening 20%
Investment costs	€ 220,000 – 250,000
Time at yard	4 weeks
Maintenance costs	€ 0,-
∆ Fuel consumption	6% ; 9% increase
∆ Lubricant consumption	0%
∆ Economic lifetime	0%
Additional ship capacity	340 tons
∆ Insurance costs	10% increase

5.2.2 Specific assumptions

1. Since the input data that are provided as a range, e.g. investment costs and fuel consumption, the average is assumed. So for the fuel increase, an increase of 4% is considered.

2. The vessel and barge can transport steel structures and agricultural products. For each of these commodities a transport price per ton of € 10, - is considered.

3. In case of lengthening the fuel consumption will rise. However this concerns the fuel consumption of the main engine. The consumption of the auxiliary engines will not change as a result of the lengthening. Therefore, to calculate the fuel increase only the fuel consumption of the main engine is considered.

4. To lengthen the vessel, the vessel needs to go in dry-dock for 4 weeks. If the vessel is sailing to and from Regensburg the entire trip duration is 14 days (2 weeks in total) and sailing to and from Constanta takes the vessel 28 days (4 weeks in total). It is assumed that the vessel goes into dry dock and misses one round trip to Constanta. This is economically more viable than taking the vessel into dry dock if sailing to and from, Regensburg, because then 2 round trips would be missed.

5. The Herso 1 is often not fully loaded. The maximum capacity of the vessel is 1,381 tons, but on average it carries 1.050 tons. The load factor thus is 76%. It is assumed, that also when the vessel is lengthened, the vessel will not be fully loaded. According the WP7.1 the additional cargo capacity is 340 tons. For the additional capacity it is assumed that 76% will be used, equalling 258 tons (assuming there is sufficient demand).

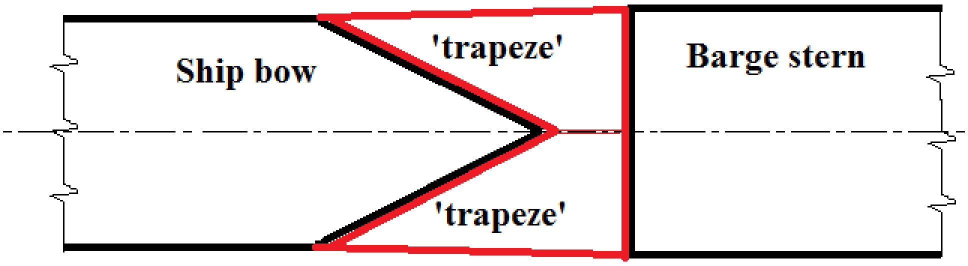
6. It is assumed that the vessel, after lengthening, will still use the barge. In all calculations it is considered that the SL Leinie will carry the same amount of cargo as before the lengthening.

5.3 Option II: Installation of trapezes

A solution proposed for coupled convoys to reduce resistance is the installation of trapezes between the pushing vessel and the barges. The open space between the vessel and the barges creates turbulences, which increase the fuel consumption. This problem can be solved by filling the spaces with (flexible or fixed) trapezes. In case flexible trapezes are installed, the trapezes need to be installed/removed every time the vessel and barge are connected/disconnected. In the case of the Herso the trapezes will be fixed and therefore no installation or removal of the trapezes will take place.

The Herso 1 is sailing almost never without its barge. Only between Hungarian ports the vessel is sailing independently. Because the vessel and barge always sail together it is proposed to install fixed trapezes. The trapezes will be connected to the barge. To install the trapezes the barge needs to go into dry dock for two weeks, but during this period the vessel can still operate.

Figure 5.3 Additional 'trapeze' structure between barge and ship (top view, schematic)



This retrofit option will probably not influence the logistical operations of the vessel. The trapezes will fixed to the barge and therefore no time is lost in coupling or decoupling the trapezes from the barge. Also no storage space is needed as they are connected to the barge.

5.3.1 Input for feasibility assessment

The table below shows that data that are used in the feasibility analysis. The data were discussed with the technical partners involved in task 7.1. The investment cost presented are the maximum costs. Probably investment costs will be lower, between € 75,000- 85,000 euros.

Table 5.4 Overview of input data from WP 7.1

	Trapezes
Investment costs	€ 100,000
Time at yard	0 week for the vessel; 2 weeks for the barge
Maintenance costs	€ 0,-
∆ Fuel consumption	7% - 11% reduction
∆ Lubricant consumption	7% - 11% reduction
∆ Economic lifetime	0%
Additional ship capacity	0%
∆ Insurance costs	0%

5.3.2 Specific assumptions

1. To install the trapezes, only the barge needs to go in dry dock for a period of two weeks. The vessel can stay in operations. A roundtrip Regensburg has a duration of 14 days (2 weeks), while a roundtrip Constanta has duration of 28 days (4 weeks). It is considered that the barge will go into dry dock while the vessel is sailing to Regensburg. The barge will miss 1 round trip.

2. The barge can transport steel structures and agricultural products. For each of these commodities a transport price per ton of € 10, - is considered.

3. Since the input data that are provided as a range, e.g. fuel and lubricant consumption, the average is assumed. So for the fuel decrease, a decrease of 9% is considered.

4. Installation will decrease the fuel and lubricant consumption. It is assumed that only the consumption of the main engine will change, while the consumption of the auxiliary engines remains the same.

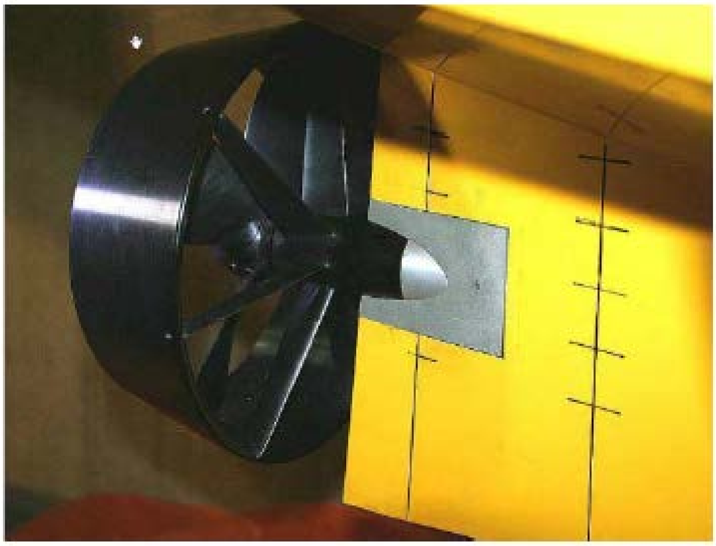
5.4 Option III: Ship Studio Solution

The pre-swirl is a stator-rotor system that will be placed either in front or behind the propeller. It will ensure a more uniform inflow of water into the propeller. With a pre-swirl there is no need for struts and bossing's, meaning the vibrations will be reduced. The use of a pre-swirl is less beneficial in shallow waters since sediments will lead to erosion of the system, and renewal of a swirl is costly. Furthermore a pre-swirl is not able to provide a uniform inflow of water.

To install the pre-swirl the existing nozzle can remain. The stator that will be used consists of two parts. One part contains 4 vanes and the other part contains 3 vanes. The stator is put together by a hub that consists of two parts. The rotor that needs to be installed consists of propeller with four blades.

The Herso 1 has propeller and therefore the system only have to be installed once. In case the vessel had more propellers the ship owner would be advised to install a pre-swirl on all propellers.

Figure 5.4 The Ship Studio Solution for improved propulsion



Source: Knappmann et al, 2013

It is expected that the installation of a pre swirl will not influence the logistical operation of the vessel.

5.4.1 Input for feasibility assessment

The following table provides an overview of the data obtained from task 7.1. The data presented are used in the feasibility analysis. The investment costs consist of the actual investment in the system and the installation costs. Installation costs are € 15,000. - per propeller. The system itself costs € 95,400.-.

Table 5.5 Overview of input data from WP 7.1

	Ship Studio solution (pre-swirl)
Investment costs	€ 110,400
Time at yard	1 week
Maintenance costs	€ 0,-
Δ Fuel consumption	10% - 11% reduction
Δ Lubricant consumption	10% - 11% reduction
Δ Economic lifetime	0%
Additional ship capacity	0%
Δ Insurance costs	0%

5.4.2 Specific assumptions

1. To install the pre-swirl the vessel needs to go into dry dock for one week. It is assumed that the vessel will miss one roundtrip to Regensburg, as the duration of this trip is 14 days. Compared to the roundtrip duration to Constanta of 28 days, it is economically more feasible to miss a trip to Regensburg (only one missed round trip instead of two).

2. It is assumed that the barge will not be used when the vessel goes into dry dock, and therefore also the barge is not generating income.

3. The vessel and barge can transport steel structures and agricultural products. For each of these commodities a transport price per ton of € 10, - is considered.

4. Installation of the pre-swirl will decrease the fuel and lubricant consumption. It is assumed that only the consumption of the main engine will change, while the consumption of the auxiliary engines remains the same.

5.5 The retrofit options compared

All three retrofit options considered for the Herso 1 are economically feasible. The table below shows that Net Present Value, the internal rate of return and the return on investment. All NPVs calculated are positive. Important factor is the return on investment. This indicator shows when the ship owner will have earned back its initial investment. Lengthening of the vessel seems to be the most beneficial one and the ship owner will be able to earn back the required investment in three years. The other solutions will be earned back within five years.

Table 5.6 Outcome of economic assessment

	Lengthening by 20%	Trapezes	Ship Studio Solution
NPV (x1,000)	€ 730	€ 182	€ 200
IRR	44%	27%	24%
Pay back period	3 years	5 years	5 years

Main benefit for the owner will be the reduction in fuel consumption. Especially the installation of trapezes as well as the installation of pre-swirl will result in a reduction in fuel consumption. During the interview the ship owner indicated that he is the party paying for the fuel. This means that any fuel savings will directly benefit the ship owner and he is able to earn back his investment through the fuel savings he realizes.

5.5.1 Sensitivity analysis for lengthening

The following table shows the outcome of the sensitivity analysis carried out for the first retrofit option. The effects of changes in the investment costs, the fuel prices and changes in the transport costs of coal are considered. Each of these effects is considered separately and a worst case and best case scenario are presented.

Table 5.7 Outcome sensitivity analysis lengthening

		Investment costs		Fuel price		Transport price	
	Base case	-20%	+20%	-10%	+10%	-25%	+25%
NPV (x1000)	730	770	690	744	716	445	1,005
IRR	44%	59%	35%	45%	43%	28%	62%
Pay back period	3	2	4	3	3	5	2

This retrofit option is particularly sensitive to changes in transport costs. In the base case scenario the return on investment is three years. In case transport prices drop with 25% (from € 10.- per ton to € 7.50) per ton the return on investment increase to five years. In case the transport price rise with 25% to € 12.50 the return on investment is 2 years. For this option also a change in investment costs is relevant as the return on investment is influenced by it. It seems that this option is hardly influenced by changes in the fuel prices.

5.5.2 Sensitivity analysis for installation of trapezes

Also for this retrofit option several sensitivity analysis are done. The effects taken into account are the investment costs and fuel price. The transport costs of coal are not considered for this option, as the retrofit option does not influence the cargo capacity of the vessel and only the barge is shortly taken out of operation. The effect of being out of operation for two weeks is negligible.

Table 5.8 Outcome sensitivity analysis installation of trapezes

		Investment costs		Fuel price	
	Base case	-20%	+20%	-10%	+10%
NPV (x1000)	182	198	165	155	209
IRR	27%	36%	22%	24%	31%
Pay back period	5	4	6	5	4

The sensitivity analysis shows that the return on investment is mainly influenced by a change in investment costs. In case the investment costs are 20% lower than expected the return on investment decrease with one year from 5 to 4 years. If the investment costs increase with 20% the return on investment will increase with one to 6 years. This option is also sensitive to changes in fuel prices, however these changes are smaller.

5.5.3 Sensitivity analysis for Ship Studio Solution

For the Ship Studio Solution two effects are taken into account in the sensitivity analysis; a change in investments costs and a change in fuel prices. Changes in transport costs of coal are not considered as this retrofit option does not change the cargo capacity of the vessel. The vessels needs to go into dry dock, however this will be one-off costs and a change in transport prices will have a limited effect on the outcome.

Table 5.9 Outcome of sensitivity analysis Ship Studio Solution

		Investment costs		Fuel price	
	Base case	-20%	+20%	-10%	+10%
NPV (x1000)	200	219	181	169	232
IRR	24%	30%	20%	21%	27%
Pay back period	5	4	7	6	5

Also this retrofit option is sensitive to changes in the investment costs. Especially when the costs increase with 20% the return on investment will increase considerably from 5 to 7 years. If the fuel prices decrease the return on investment will also increase and it will take the ship owner 6 years to earn back his initial investment.

6 Inflexible

6.1 Current operating profile

General information of the vessel

The Inflexible is owned by Compagnie Fluviale Transport (CFT) and was built in 2000. The vessel can be qualified as a pusher and pushes two barges maximum. Main dimensions of the pusher and the barges can be found in the following table.

Table 6.1 Main dimensions vessel and barge

	Inflexible	Barges
Length	22.2 m	79 m
Beam	9.45 m	11.40 m
Draught (max)	2.5 m	3.5 m

The Inflexible can only operate in a system of one row containing two barges. It is not possible for the Inflexible to sail in any other formation due to lock restrictions on the route. In this case the total length of the convoy is 180 m and total width is 11.40 m.

Figure 6.1 Impressions of the Inflexible

Cargo information

The vessel is able to transport all types of commodities, but main commodities are coal, containers and cars. Depending on the contracts awarded and the duration of these contracts the commodities can differ. In 2012 the vessel mainly transported containers, while in 2013 the main commodity transported is coal. Each barge has a maximum capacity of 2,500 tons and so the total capacity of the two barges combined is 5,000 tons. The following table provides an overview of the possible capacity transported per commodity.

Table 6.2 Cargo information

	2 barge system
Total capacity	5,000 tons or 373 TEU
Average capacity dry bulk	4,000 – 5,000 tons
Average capacity liquid bulk	4,000 – 4,500 tons
Average capacity containers	280 TEU
Total capacity transported (per year)	250,000 tons

Main routes, sailing time and total distances

The vessel operates on the Seine river. The trips start in Le Havre and destination is the port of Grennevilliers, near Paris. Possible intermediate stop could be at the port of Rouen. The vessel operates a strict schedule. The journey start on Monday morning in Le Havre and the vessel is due to arrive on Wednesday morning in Paris. The same evening the vessel leaves Paris and will arrive on Friday morning in Le Havre. The duration of a single trip is 30 hours. The vessel performs one round trip per week and operates 50 weeks a year.

The loading and unloading will each take six hours. Only in case the vessel is transporting cars the loading/unloading process is shortened, because the vessel does not wait for the cars to be unloaded. In case the vessel is transporting cars, it is possible to perform two roundtrips per week.

The vessel is normally loaded on 60% of journeys. If bulk cargo is transported the vessel is only loaded on way of the journey. In case containers are transported the vessel can be loaded both ways. Very rarely the vessel transports containers one way and bulk cargo the other way. The distance sailed with cargo per year is 24,000km and the total distance travelled is 40,000 km.

Engine information

The vessel has two main engines on board, each with a capacity of 736 kW. The vessel also has one auxiliary engine on board, with a capacity of 360 kW. Brand of both the main and auxiliary engines is Baudoin. Total available capacity of all engines together is 1,832 kW. Besides the main and auxiliary engines the vessel also has a bow thruster installed.

The type of fuel used by the vessel is ULS EN590 (10 PPMS), of which the vessel uses 500,000 litres a year. The company has no information available on the division of fuel consumption between the main and auxiliary engines. Since June 2012 the vessel has equipment on board to measure the fuel consumption of the main and auxiliary engines individually, however the information is not available yet. All engines are always running together. Following table provides a summary of the engine capacity and fuel consumption.

Table 6.3 Engine information and fuel consumption

	#	Capacity	Total capacity	Fuel consumption
Main engines	2	736 kW	1,472 kW	500,000 litres
Auxiliary engines	1	360 kW	360 kW	

Crew information and maintenance

One crew consists of 5 crew members. There is one captain on board and four crew members. The following functions are presented:

- Captain
- Mate
- Sailor
- Engineer

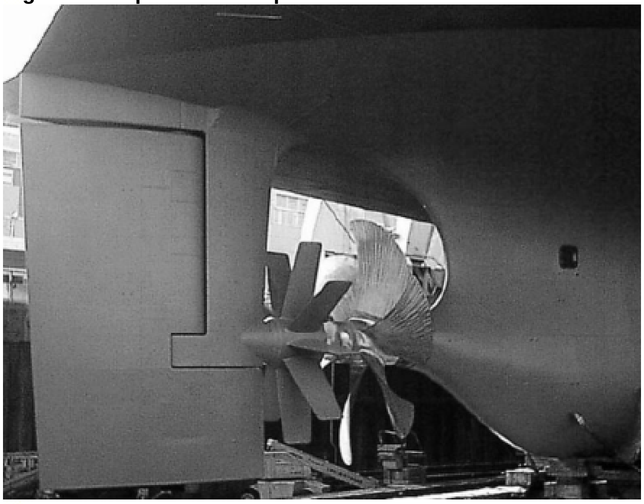
The vessel operates 335 days per year. The maintenance is often unscheduled and happens when some part breaks down. Such a break down occurs once or twice a year and depending on the severity of the breakdown the vessel is out of operation between 2 days or six weeks. A percentage of the turnover is used to pay for the maintenances. The company aims to bring down the number of unscheduled maintenances.

6.2 Option 1: Ship Studio Solution

The pre-swirl is a stator-rotor system that will be placed either in front or behind the propeller. It will ensure a more uniform inflow of water into the propeller. With a pre-swirl there is no need for struts and bossing's, meaning the vibrations will be reduced. The use of a pre-swirl is less beneficial in shallow waters since sediments will lead to erosion of the system, and renewal of a swirl is costly. Furthermore a pre-swirl is not able to provide a uniform inflow of water.

To install the pre-swirl a new nozzle needs to be installed. The stator will consist of two parts. The first part consists of three blades that are used as tube and nozzle structure. The second part consists of a structure of four blades. The pre-swirl does not need a hub, but a rotor needs to be installed. The rotor consists of a propeller with four blades. The Inflexible has two propellers and therefore two pre-swirls need to be installed to ensure increased efficiency.

Figure 6.2 Impression of a pre swirl



It is expected that the installation of a pre swirl will not influence the logistical operation of the vessel.

6.2.1 Input data for feasibility assessment

Table 6.4 provides an overview of the input data received from tasks 7.1. It should be noted that the investments costs of this solution contain both the costs of the actual system as well as the installation costs. Installation costs are estimated to be € 15,000. - per propeller. Total installation costs are € 30,000. - since the vessel has two propellers. The actual system itself costs € 115,400. - per propeller.

Table 6.4 Overview of input data from WP 7.1

	Ship Studio solution (pre-swirl)
Investment costs	€ 260,800
Time at yard	1 week
Maintenance costs	€ 0,-
Δ Fuel consumption	13% - 15% reduction
Δ Lubricant consumption	0%
Δ Economic lifetime	0%
Additional ship capacity	0%
Δ Insurance costs	0%

6.2.2 Specific assumptions

1. To install the pre-swirl the vessel needs to go in dry dock for a week. The vessel operates one round trip between Le Havre and Paris per week and so one round trip will be missed when the vessel is out of operation.

2. The vessel transport different types of commodities. Although the vessel can transport different types of cargo, one commodity is often the main one for a certain period of time. It is assumed that the vessel will transport containers. The average TEU shipped per trip is 280 TEU. It is assumed that the transport price per TEU is € 10,-.

3. The division in fuel consumption by the main and auxiliary engines is unknown. They always run together and no separate measurements are available. In the analysis equal shares are assumed, based on the maximum capacity of the main and auxiliary engines. It is assumed that 80% of the fuel is used by the main engines and 20% by the auxiliary engines.

4. It is expected that only the fuel consumption of the main engine will decrease. The consumption of the auxiliary engines is assumed to remain the same.

6.3 Option II: Replacement of the rudders

The second option considered for the Inflexible is a redesign of rudders. Currently each propeller has one rudder. In this option it is considered to place two rudders at each propeller. Advantage of a 2 rudder system, based on measurements done by MARIN, is the decrease of resistance of the vessel without sacrificing a significant amount of the manoeuvrability of the vessel.

Figure 6.3 Tested rudder configurations by MARIN

It is expected that this retrofit option will not change the logistical operation of the vessel, as the retrofit option only changes the after ship of the vessel and has no impact on the day-to-day business of the vessel.

6.3.1 Input data for feasibility assessment

The following table provides an overview of the input data received from task 7.1. The data presented are used in the feasibility analysis. In the feasibility analysis it is assumed that the entire rudders, including the steering gear are replaced. The more simple, as described in Deliverable 7.1, is not taken into consideration.

Table 6.5 Overview of input data from WP 7.1

	Replacement of rudders
Investment costs	€ 200,000 – 320,00
Time at yard	2 weeks
Maintenance costs	€ 0,-
∆ Fuel consumption	3% - 4% reduction
∆ Lubricant consumption	0%
∆ Economic lifetime	0%
Additional ship capacity	0%
∆ Insurance costs	0%

6.3.2 Specific assumptions

1. The vessel will be four weeks out of operation. As the vessel conducts one round trip per week, the vessel will miss four round trips. It is considered that the vessel will transport containers with a transport price of € 10, - per TEU. The average cargo carried per single trip is assumed to be 280 TEU.

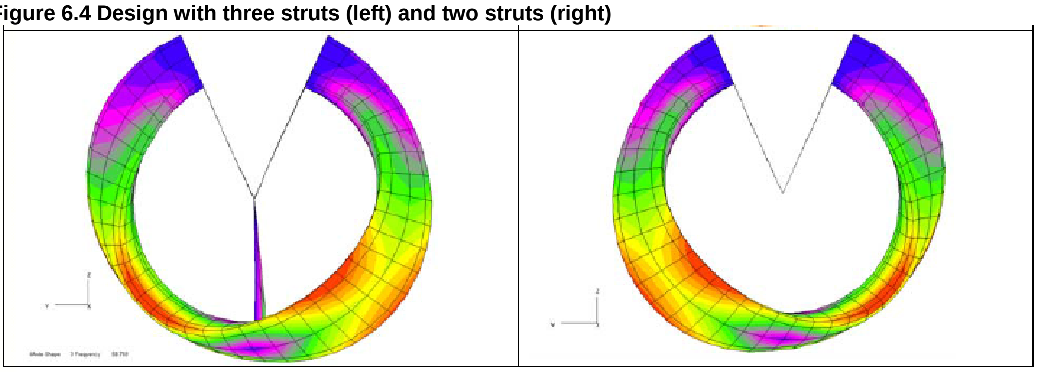
2. For the input data that are provided as a range, e.g. investment costs and fuel consumption, the average is assumed. So for the total investment costs, an price of € 260,000 is considered.

3. It is expected that only the fuel consumption of the main engine will decrease. The consumption of the auxiliary engines is assumed to remain the same.

6.4 Option III: Removal of struts from nozzle propellers

The Inflexible has two propellers, each with a propeller shaft. The shafts are kept in place by three struts each, which are connected with the propeller nozzles. Disadvantages of struts is that they lead to increase drag as well as a disturbance of the propeller inflow. In this retrofit option is analysed what the difference is between a three strut design and a two strut design. In the two strut design the lower strut is removed. Figure 6.4 shows both the design with three struts (left) and two struts (right). In the right picture the lower strut is remove from the propeller shaft.

Figure 6.4 Design with three struts (left) and two struts (right)



This retrofit option will not influence the logistic operation of the company, as the retrofit option only changes the after ship of the vessel and has no impact on the day-to-day business of the vessel.

6.4.1 Input data for feasibility assessment

Table 6.6 provides an overview of the data used in the feasibility assessment. If only the lower strut is removed the investment costs are € 35,000 per propeller. However it is likely that the entire propeller shaft needs to be replaced, which costs € 80,000 euro per propeller. Depending on the work done the investment costs range between € 70,000 and 160,000 euros.

Table 6.6 Overview of input data from WP 7.1

	Removal of strut
Investment costs	€ 70,000 – 160,000
Time at yard	4 weeks
Maintenance costs	€ 0,-
Δ Fuel consumption	5% reduction
Δ Lubricant consumption	0%
Δ Economic lifetime	0%
Additional ship capacity	0%
Δ Insurance costs	0%

6.4.2 Specific assumptions

1. The vessel will be four weeks out of operation. As the vessel conducts one round trip per week, the vessel will miss four round trips. It is considered that the vessel will transport containers with a transport price of € 10, - per TEU. The average cargo carried per single trip is assumed to be 280 TEU.

2. For the input data that are provided as a range, e.g. investment costs and fuel consumption, the average is assumed. So for the total investment costs, an price of € 115,000 is considered.

3. It is expected that only the fuel consumption of the main engine will decrease. The consumption of the auxiliary engines is assumed to remain the same.

6.5 The retrofit options compared

Two of the three options considered for the Inflexible are feasible; the installation of a pre-swirl and the removal of struts are feasibly investments. The table below shows that Net Present Value, the internal rate of return and the return on investment. Important factor is the return on investment. This indicator shows when the ship owner will have earned back its initial investment. If a pre-swirl is installed the ship owner is able to earn back the initial investment in six years and when he chooses to remove the struts he earns back his investment in 11 years. To earn back the replacement of the rudder system will take 25 years.

Table 6.7 Outcome of economic assessment

	Ship Studio Solution	Replacement of rudders	Removal of strut
NPV (x1,000)	€ 330	€ -97	€ 74
IRR	21%	0%	12%
Pay back period	6 years	>25 years	11 years

Main benefit for the owner will be the reduction in fuel consumption. During the interview the ship owner indicated that he is the party paying for the fuel. This means that any fuel savings will directly benefit the ship owner and he is able to earn back his investment through the fuel savings he realizes.

6.5.1 Sensitivity analysis for Ship Studio Solution

For the Ship Studio Solution two effects are taken into account in the sensitivity analysis; a change in investments costs and a change in fuel prices. Changes in transport costs of coal, containers or cars are not considered as this retrofit option does not change the cargo capacity of the vessel. The vessels needs to go into dry dock, however this will be one-off costs and a change in transport prices will have a limited effect on the outcome.

Table 6.8 Outcome sensitivity analysis Ship Studio Solution

		Investment costs		Fuel price	
	Base case	-20%	+20%	-10%	+10%
NPV (x1000)	330	374	285	276	383
IRR	21%	27%	17%	18%	23%
Pay back period	6	5	8	6	5

This retrofit option is sensitive to changes in the investment costs. Especially when the costs increase with 20% the return on investment will increase considerably from 6 to 8 years. If the fuel prices increase the return on investment will decrease and it will take the ship owner 5 years to earn back his initial investment.

6.5.2 Sensitivity analysis for rudder replacement

As the retrofit option not seems to be feasible not all effects possible are taken into account. Only the best case scenarios are considered, because the worst case scenarios will only worsen the feasibility and it is expected that based on the outcomes in the base case, the ship owner will already decide not to pursue the retrofit option.

Therefore only a decrease in investments and an increase influence prices are considered. On top of that it is analysed what the effect on feasibility is when both best case scenarios occur at once, so the situation in which the investment costs are 20% lower than estimated and fuel prices are 10% higher than expected. The results are presented in the following table.

Table 6.9 Outcome sensitivity analysis rudder replacement

		Investment costs	Fuel price	Combined
	Base case	-20%	+10%	
NPV (x1000)	-97	-53	-84	-39
IRR	0%	2%	1%	3%
Pay back period	>25	>25	.25	25

In all cases the return on investment is still more than 25 years. It is expected that the ship owner will not invest in this solution. Even in the scenario where the investment costs are lower than expected and the fuel prices higher than expected the return on investment is more than 25 years.

6.5.3 Sensitivity analysis for strut removal

Also for this retrofit option several sensitivity analysis are done. The effects taken into account are the investment costs and fuel price. The transport costs of coal, container or cars are not considered for this option, as the retrofit option does not influence the cargo capacity of the vessel and only the barge is shortly taken out of operation. The effect of being out of operation for four weeks is negligible.

Table 6.10 Outcome sensitivity analysis strut removal

		Investment costs		Fuel price	
	Base case	**-20%**	**+20%**	**-10%**	**+10%**
NPV (x1000)	74	94	55	55	93
IRR	12%	16%	10%	11%	14%
Pay back period	11	8	13	12	9

The sensitivity analysis shows that this option is sensitive to changes in the investment costs. In case the investment costs decrease by 20% the return on investment changes from 11 years to 8 years. However in case the investment costs increase by 20% the return on investment is extended to 13 years. Also the change in fuel price influence the return on investment, however the changes are smaller.

7 Veerhaven X

7.1 *Current operating profile*

General information of the vessel

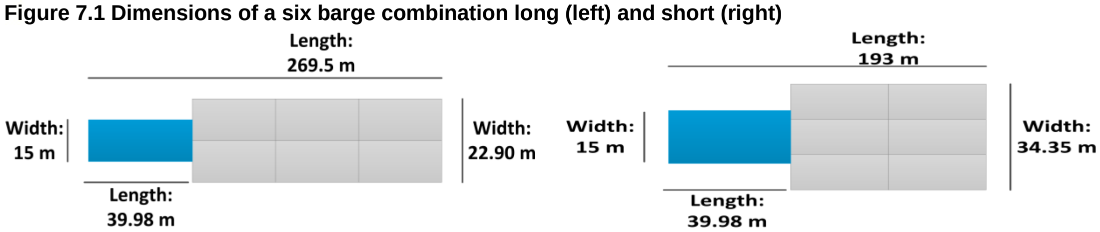
The Veerhaven X is owned by ThyssenKrupp Veerhaven (TKV) and was built in 2007. The vessel can be qualified as a pusher. Main dimensions of the pusher and the barges can be found in the following table.

Table 7.1 Main dimensions vessel and barge

	Veerhaven X	Barges
Length	39.98 m	76.5 m
Beam	15.00 m	11.45 m
Draught (max)	1.90 m	4 m

The Veerhaven X can operate in a four barge or a six barge system. If a four barge system is used the length of the entire combination is 193 m and the width of the system is 22.90 m. If a six barge system is the used the length and width of the entire combination depend on the number of rows. It is possible to sail in two rows of three (short) or in three rows of two (long). Figure 7.1 shows the dimensions of the two six barge combinations.

Figure 7.1 Dimensions of a six barge combination long (left) and short (right)



Since 2013 the company started to sail more in six barge formations, because it enables the company to transport 50% more cargo against limited fuel increases. The short combination is used sailing downstream (towards the Netherlands), while the long combination is used to sail upstream (towards Germany).

Figure 7.2 Impressions of the Veerhaven X

Cargo information

The vessel mainly transports iron ore and coal. Sometimes the vessel transports other supplies; however this happens very rarely and will therefore not be further considered in the feasibility analysis. The maximum capacity of a single barge is 2,800 tons. On average a barge carries 2,300 tons. The following table provides an overview of the cargo transported.

Table 7.2 Cargo information

	Four barge combination	Six barge combination
Total capacity	11,200 tons	16,800 tons
Average capacity	9,200 tons	13,000 tons
Total capacity transported (per year)	2.1 million tons	

Main routes, sailing time and total distances

The majority of trips originate from Rotterdam - this has been estimated at 95% by the company. The remaining 5% of the journeys the vessel departs from Gent, Terneuzen, Vlissingen, Amsterdam or Antwerp. The main destination for the vessel is Schwelgern in Germany, the port of the ThyssenKrupp steel company[3].

The complete voyage of the vessel is about 40-42 hours and the trip can be divided into several segments. The journey from the Netherlands to Germany takes approximately 24 hours. Then decoupling at the German port is scheduled to take two hours. On return from the German location to the Dutch port the journey is approximately 12 hours and decoupling in Rotterdam takes roughly one hour. The vessel performs this trips four times a week.

The vessel is normally loaded on 50% of journeys (upstream). Sailing downstream the vessel is always empty. So 50% of the distance travelled the vessel is transporting cargo this equals 30% of the total sailing time. This means approximately 20% of the fuel is used on empty sailings and 80% when the vessel is loaded. The distance sailed with cargo per year is 50,000 km and the total distance travelled is 100,000 km.

Engine information

The vessel has three main engines on board, each with a capacity of 1,360 kW. Brand of the main engines is MAK 8M20. The vessel also has four auxiliary engines on board, each with a capacity of 300 kW. During sailing only one of the auxiliary engines is running. When manoeuvring the vessel uses all four auxiliary engines. Brand of the auxiliary engines is Scania. Total available capacity of all engines together is 5,280 kW. Besides the main and auxiliary engines the vessel also has two bow thrusters installed, each with a capacity of 400 kW. The bow thrusters are electric and only used for manoeuvring in ports.

3 ThyssenKrupp Veerhaven is a daughter company of ThyssenKrupp. TKV sails exclusively for ThyssenKrupp.

The type of fuel used by the vessel is ULS EN590 (10 PPMS), of which the vessel used 4 million litres in 2011.[4] Approximately 220,000 litres of fuel was used by the auxiliary engines, which equates to around 5% of total consumption. The vessel also using 15,000 litres of lubricants. The bow thrusters do not use any fuel, as they are electric. Following table provides a summary of the engine capacity and fuel consumption.

Table 7.3 Engine information and fuel consumption

	#	Capacity	Total capacity	Fuel consumption (2011)
Main engines	3	1,360 kW	4,080 kW	3,780,000 litre
Auxiliary engines	4	300 kW	1,200 kW	220,000 litre
Bow thrusters	3	400 kW	800 kW	-

Crew information and maintenance

The number of crew members differs between a four barge and a six barge combination. A four barge system requires six crew members and a six barge system requires seven crew members. The vessel operates a B schedule which means that the vessel is sailing 24 hours a day. The following functions are presented:

- Captain (2)
- Mate (1 or 2)
- Sailor (1 or 2)
- Engineer (1)

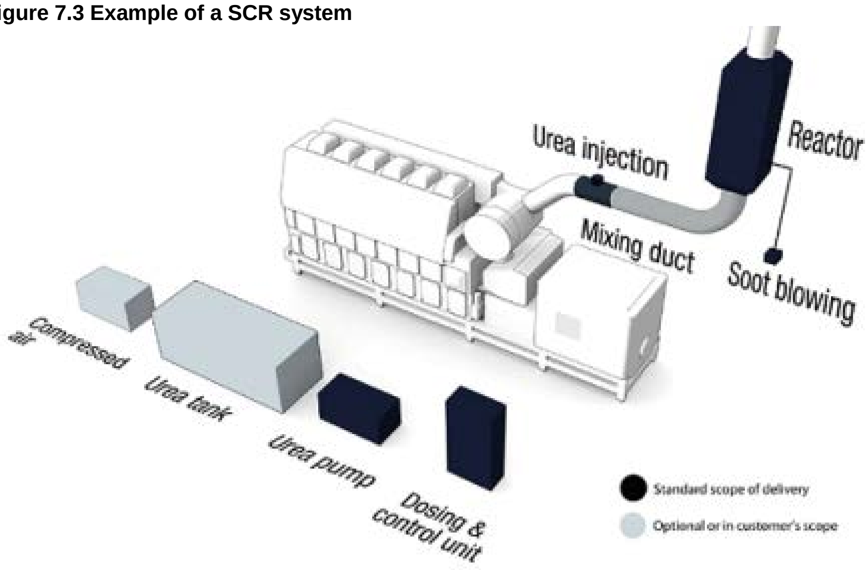
The vessel operates 365 days per year and after 22 months (this equals 15,000/30,000 hours) the vessel goes into maintenance. The maintenance takes two weeks. Than the vessel is in operation for another 22 months.

7.2 Option I: Installation of SCR

Main aim to install a SCR installation is to reduce the NOx emissions. The SCR is placed behind the main engine and the exhaust gas produced by the engine is mixed with urea or ammonia. The NOx in the exhaust gas reacts with the urea or ammonia and after the reaction only water and nitrogen remain. All NOx is removed from the exhaust gas, before it is released into the air.
The temperature of the exhaust gas (and hence also the catalyst) is thereby subject to constraints both on the upper side (in order to avoid oxidation of the reductant) and the lower side (for preventing the formation of undesired by-products such as ammonium sulphates, which may subsequently clog and deactivate the catalyst). The latter is not particularly an issue for inland vessels since they operate with marine gasoil (MGO). (taken from Wp7.1 report)

[4] Since 2011 the fuel consumption of the vessel has decreased to 3,000 – 3,800 m^3 per year due to more efficient sailing.

Figure 7.3 Example of a SCR system



Source: Wärtsilä (2011)

Main difficulty with a SCR installation is the measurements of benefits. For most options proposed in the Move-IT! project the main benefit is the reduction in fuel consumption. However a SCR installation will not change the fuel consumption of the vessel in a positive way and the owner can not reap any benefits from it.

This option might influence the logistical operation of the vessel as the vessel needs to bunker the urea needed to operate the SCR. In the interview held with the ship owner he indicated that preferred option is to take in the urea when sailing. The already takes in fuel and fresh water while sailing and the ship owner expects that the same procedure can be followed for the intake of urea. When this is possible the logistical operation will be influenced a little. In case it is not possible to take in urea when sailing this is disrupt the sailing of the company and the vessel is probably not able to maintain their current sailing schedule.

7.2.1 Input data for feasibility assessment

The following table provides an overview of the inputs received from WP7.1. As the table shows the installation of a SCR system will not have a significant effect on the operational profile of the vessel. The installation of a SCR will not change the fuel consumption of the vessel as was mentioned before. Besides the investment costs the daily operational costs will increase as well, as the company has to pay for the urea used in the SCR and the maintenance cost for this part of the engine room equipment.

Table 7.4 Overview of input data from WP 7.1

	Installation of SCR
Investment costs	€ 300,000 – 380,00
Time at yard	0 weeks
Maintenance costs	€ 0,-
∆ Fuel consumption	0%
∆ Lubricant consumption	0%
∆ Economic lifetime	0%
Additional ship capacity	0%
∆ Insurance costs	0%

In the port of Rotterdam cleaner inland vessels can obtain a discount on port tariffs if they are cleaner than the CCR II emission standards. The Veerhaven X already has a Green Award and therefore receives a discount already. The only way to increase the discount rate is to become 60% more environmental friendly than the current CCR II emission standards. In this case the vessel could get a 30% discount on port tariffs instead of the current 15%. With the installation of a SCR the vessel will achieve a reduction in NOx emissions with 60% easily. However it is unknown if the same reductions will be achieved relating to CO, HC and PM.

It should be noted that port tariffs in Rotterdam are based on tonnage of a total combination. Only the pusher will receive a reduction in port tariffs, the barges are excluded. Benefit of a SCR will be around € 1,500.- a year and so the benefits of the installation a SCR are minimal.

Reason to install a SCR installation is the upcoming regulation in the port of Rotterdam. From 2025 onwards all vessels not compliant with the CCR II emissions standards are no longer allowed to enter the port. Only vessels that do comply with the rules can enter the port. By installing a SCR the vessel surely complies with the rules and ensures continuity of the business. Without taken measures to comply with the company will no longer be admitted to the port and income will be lost.

8 Carpe Diem

8.1 Current operating profile

General information of the vessel

The Carpe Diem is owned by Carpe Diem Shipping. The vessel was built in 1989 and revised in 1996. The vessel can be qualified as a motor freight vessel and never sails as a coupled convoy. Main dimensions of the vessel can be found in the following table.

Table 8.1 Main dimensions vessel

	Carpe Diem
Length	110 m
Beam	11.40 m
Draught (max)	3.35 m

Figure 8.1 Impressions of the Carpe Diem

Cargo information

The vessel only transports containers. The maximum capacity of the vessel is 2,998 tons. This enables the vessel to transport a maximum of 153 TEU. On average the vessel transports 124 TEU per trip. The following table provides an overview of the cargo transported.

Table 8.2 Cargo information

	Carpe Diem
Total capacity	153 TEUs
Average capacity	124 TEU
Total capacity transported (per year)	19,344 TEU

Main routes, sailing time and total distances

The Carpe Diem operates a fixed schedule. The vessel sails between Rotterdam and Groningen with an intermediate stop in Heerenveen. The vessel stops in Heerenveen on both ways of the trip. Between Rotterdam and Heerenveen the vessel transport 3 layers of containers and due to height restrictions of fixed bridges between Heerenveen and Groningen, the vessel sails with 2 layers of containers on this stretch. More empty containers are shipped when sailing to Groningen. Towards Rotterdam the number of empty containers is lower.

The complete voyage of the vessel is about 50-52 hours and the trip can be divided into several segments. The journey from Rotterdam to Heerenveen takes approximately 18 hours. The trip from Heerenveen to Groningen takes around 8 hours. On the way back the division is more or less the same. Each two weeks the vessel carries out three full round trips.

The vessel is normally loaded on 100% of journeys, only within the port of Rotterdam some empty shipping might occur, because the vessel needs to drop containers off on one spot and pick up the new ones at a different spot. The distance sailed per single trip is 309 km. It could be little higher due to additional km sailed between different terminals in the port of Rotterdam. The total distance travelled per year is 50,000 km.

Engine information

The vessel has two main engines on board, each with a capacity of 783 kW. Brand of the main engines is Caterpillar 3508B. The vessel has no auxiliary engines on board. Besides the main engines the vessel has two thrusters installed. There is Scania channel thruster with a capacity of 275 kW and a Caterpillar control grid thruster with a capacity of 405 kW. Total available capacity of all engines together is 1,566 kW and the total capacity including the thrusters is 2,246 kW. The bow thruster is used for manoeuvring in port. However in Groningen strong headwinds can occur and in these cases the bow thruster is used as well.

The type of fuel used by the vessel is ULS EN590 (10 PPMS), of which the vessel uses 364,000 litres each year. Approximately 62,400 litres of fuel is used by the thrusters, which equates to almost 17% of total consumption. Following table provides a summary of the engine capacity and fuel consumption.

Table 8.3 Engine information and fuel consumption

	#	Capacity	Total capacity	Fuel consumption
Main engines	2	783 kW	1,566 kW	301,600 litre
Channel thruster	1	275 kW	275 kW	62,400 litre
Control grid thruster	1	405 kW	405 kW	

Crew information and maintenance

The number of crew members differs between four and six crew members. The following functions are presented:

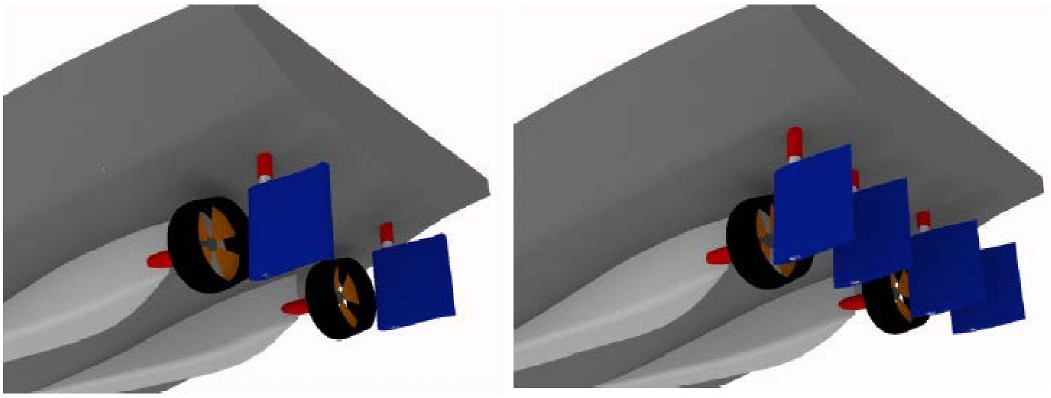
- Captain
- Mate
- Sailor
- Engineer

The vessel operates 350- 365 days per year. Each two years the vessel goes into maintenance for 1 week. Maintenance can be a little longer depending on the work that needs to be done.

8.2 Option I: 2-rudder solution

The first option considered for the Carpe Diem is the installation of a 2 rudder system for each propeller instead of the one rudder system currently used per propeller (impression of the old and new rudder system is indicated in Figure 8.2). Advantage of a 2 rudder system, based on measurements done by MARIN, is the decrease of resistance of the vessel without sacrificing a significant amount of the manoeuvrability of the vessel.

Figure 8.2 Old (left) and new (right) rudder arrangement Carpe Diem



It is expected that this retrofit option will not change the logistical operation of the vessel, as the retrofit option only changes the after ship of the vessel and has no impact on the day-to-day business of the vessel.

Input data for feasibility assessment

The following table provides an overview of the data used in the economic analysis. The data were provided by WP7.1. The investment costs indicate the total costs. The vessel has two propellers and therefor needs two new rudder solutions. The savings in fuel are moderated and are estimated to range between 3 – 4%.

Table 8.4 Overview of input data from WP 7.1

	2-rudder solution
Investment costs	€ 200,000 – 320,000
Time at yard	2 weeks
Maintenance costs	€ 0,-
Δ Fuel consumption	3% -4% reduction
Δ Lubricant consumption	0%
Δ Economic lifetime	0%
Additional ship capacity	0%
Δ Insurance costs	0%

Specific assumptions

1. For the input data that are provided as a range, e.g. investment costs and fuel consumption, the average is assumed. So for the fuel increase, an increase of 3.5% is considered.

2. The transport price per TEU is considered to be € 10,-.

3. The vessel will be two weeks out of operation. Normally the vessel performs three round trips in two weeks, so six single trips are performed. Once the vessel is on dry dock the vessel will miss six single trips. On average the vessel transport 124 TEU per trip.

4. It is expected that only the fuel consumption of the main engine will decrease. The consumption of the bow thrusters is assumed to remain the same.

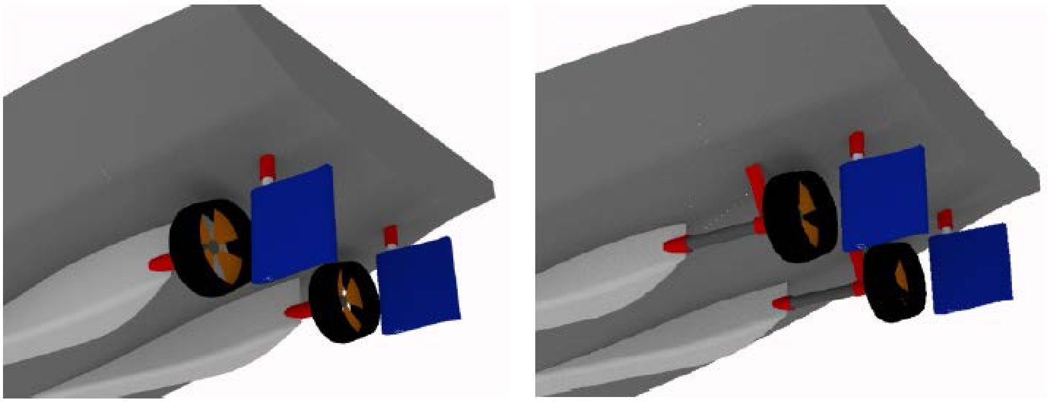
8.3 Option II: Removal or shortening of gondolas

In this retrofit option two options are considered. The first one is the removal of the entire gondolas, while the second option considers the shortening of the existing gondola. The gondolas are placed at the back of the ship and house part of the engines, the gearboxes and the propeller shafts. The gondola leads to an imperfect flow to the propellers, which has a negative effect on fuel consumption. The proposed solutions might solve the problem.

For the Carpe Diem it is not possible to remove the entire gondola, because the engines are located in the gondolas and removing the gondolas means replacing the engines, which is a very expensive activity.

For the Carpe Diem only the shortening of the gondola is considered. It will be ensured that enough space remains available for the engines, so that they do not have to be replaced to another part of the vessel. The gondolas will be shortened as far as possible. Main aim is to reduce the resistance of the vessel and reduce the fuel consumption. The figure below presents the retro fit option. The left picture shows the current arrangement of the gondolas, while the right picture shows the shortening of the gondolas. The connection between the propellers and the gondolas is longer in the right picture than in the left one.

Figure 8.3 Original (left) and new (right) after ship of Carpe Diem



Also for this retrofit option it is expected that the current logistical operation of the vessel will not change to due the retrofitting of the after ship.

8.3.1 Input data for feasibility assessment

Table 8.5 presented the inputs received from WP7.1. The expected fuel reduction of this retrofit option is moderate, between 0-3%. The vessel needs to stay at least 4 weeks at the yard and is not able to generate any income during that period.

Table 8.5 Overview of input data from WP 7.1

	Removal / shortening of gondola
Investment costs	€ 160,000
Time at yard	4 weeks
Maintenance costs	€ 0,-
Δ Fuel consumption	0% - 3% reduction
Δ Lubricant consumption	0%
Δ Economic lifetime	0%
Additional ship capacity	0%
Δ Insurance costs	0%

8.3.2 Specific assumptions

1. The vessel will be out of operation for four weeks. Per two weeks the vessel performs three round trips, so six single trips. If the vessel is at the yard for four weeks the vessel will miss six round trips, and so twelve single trips.

2. On average the vessel transport 124 TEU per trip. A transport price per TEU of € 10, - is assumed.

3. It is expected that only the fuel consumption of the main engine will decrease. The consumption of the bow thrusters is assumed to remain the same.

4. For the input data that are provided as a range, e.g. investment costs and fuel consumption, the average is assumed. So for the fuel increase, an increase of 1.5% is considered.

8.4 The retrofit options compared

The options considered for the Carpe Diem are both not feasible and it will take the company more than 25 years to earn back the investment. It is quite likely that the ship owner will not earn back his investment at all. Of major influence is the fact that the Carpe Diem is considered as a state-of-the-art vessel and the improvements suggested will hardly contributed to any reduction in fuel. Compared to the investment costs that need to be made and the time the vessel has to spend in dry-dock, the options turn out not to be feasible.

The following table shows the outcomes of the economic feasibility study. The table shows for both options the net present value, the internal rate of return and the return on investment.

Table 8.6 Outcome of economic assessment

	2-rudder solution	Removal / shortening of gondola
NPV (x1,000)	€ -127	€ -106
IRR	-2%	-4%
Pay back period	More than 25 years	More than 25 years

It should be noted that the options proposed for the Carpe Diem might not be feasible for this specific vessel, but they might be for less advanced vessels. Especially vessels with a poor rudder arrangement or improperly constructed gondola might benefit of these options. It is expected that investment costs will be more or less the same as for the Carpe Diem, but the possible fuel savings will probably be much higher than for this particular vessel. The higher the fuel reductions possible, the more attractive these options become.

It should also be stressed that the ship owner is not paying for the fuel the vessel uses. The fuel bill is paid by the customers hiring the vessel. Even if the retrofit options would have been more feasibly for the vessel, the ship owner would not have benefited from the reduction in fuel directly. He would not have been able to earn back his investment due to lower fuel bills and to earn back the investment he should try to negotiate higher transport prices. It is questionable if that would be possible in the current market.

8.4.1 Sensitivity analysis for the 2-rudder solutions

As the retrofit option not seems to be feasible not all effects possible are taken into account. Only the best case scenarios are considered, because the worst case scenarios will only worsen the feasibility and it is expected that based on the outcomes in the base case, the ship owner will already decide not to pursue the retrofit option.

Therefore only a decrease in investments and an increase influence prices are considered. On top of that it is analysed what the effect on feasibility is when both best case scenarios occur at once, so the situation in which the investment costs are 20% lower than estimated and fuel prices are 10% higher than expected. The results are presented in the following table.

Table 8.7 Outcome sensitivity analysis 2-rudder solution

	Base case	Investment costs -20%	Fuel price +10%	Combined
NPV (x1000)	-127	-83	-117	-73
IRR	-2%	0%	-1%	1%
Pay back period	>25	>25	>25	>25

In all cases the return on investment is still more than 25 years. It is expected that the ship owner will not invest in this solution. Even in the scenario where the investment costs are lower than expected and the fuel prices higher than expected the return on investment is more than 25 years.

8.4.2 Sensitivity analysis for shortening of the gondolas

The same reasoning as for the previous retrofit option is followed here. Also for the shortening of the gondolas only the best case scenarios are considered and the combination between the two is analysed as well. The following table provides the outcomes of the sensitivity analysis.

Table 8.8 Outcome sensitivity analysis shortening gondolas

	Base case	Investment costs -20%	Fuel price +10%	Combined
NPV (x1000)	-106	-79	-101	-74
IRR	-4%	-3%	-4%	-2%
Pay back period	>25	>25	>25	>25

The ship owner is not able to earn back his investment within 25 years, even when the two best case scenarios are combined. Probably the ship owner will decide not to carry out this retrofit option as well.

9 Overall findings and recommendations

9.1 Feasibility of retrofit options

The following table provides an overview of the retrofit options considered for the five vessels in the project. The ship owners indicated that duration of the pay back period is crucial in their decision making process. According to the ship owners they are willing to invest in a retrofit solution when they are able to earn back their investment within 4 years. Options that can be earned back within these 4 years are considered to be very desirable options and are characterised likewise in the following table.

Some options can be earned back in five or six years. These options fall in the second category ‘options to be considered’. Options in this category can be earned back between 5 and 10 years. Options that have a payback period that is more than 10 years should be considered as no viable option and are therefore no option at all.

It should be noted that some of these options might not be feasible for the analysed vessels, however for older or other vessel types these options might still be feasible.

Table 9.1 Summary of the proposed retrofit options

		Very desirable option	Option to be considered	No option
Dunaföldvár	Removal flanking rudders + installation bow thruster	√		
	New engines (6 barge)			√
	New engines (9 nine barge)	√		
Herso 1	Lengthening of the vessel with 20%	√		
	Installation of trapezes		√	
	Installation of Ship Studio Solution		√	
Inflexible	Installation of Ship Studio Solution		√	
	Replacement of rudders.			√
	Removal of struts from nozzle propellers			√
Veerhaven X	Installation of SCR			√
Carpe Diem	2-rudder solution			√
	Shortening of gondola			√

Although many retrofit options are available some seem to be more feasible than others. Especially improvements of the propeller, both pre-swirl and other improvements, turn out to be feasible options. The investment costs are reasonable compared to the estimated fuel reductions, which are considerable. Lengthening of smaller vessels seems to be an option to analyse further. The investment costs are also reasonable and the additional fuel consumption is more than compensated by the possibility of additional cargo. Also the installation of new engines is an option to explore further.

Options that do not seem feasible are rudder improvements. The investment costs are relatively high and the reduction in fuel is often limited. Also changes in the bow thruster gondola seem not to be viable at the moment.

9.2 Recommendations

Based on the analysis carried out in task 7.2 the following recommendations can be made:

1. Retrofit options relating to propeller improvements are feasible options and many European vessels will benefit of such improvements. A wider application of these kinds of retrofit options is desirable, as investment costs are reasonable compared to possible fuel reductions.
2. For smaller vessels lengthening seems to be a feasible option as the option increase the cargo carrying capacity of the vessel against an almost negligible increase in fuel consumption. This retrofit option could be applied widely on smaller vessels.
3. The installation of new engines is a feasible option, as fuel consumption can be reduced and in some cases it could enable vessels to transport more cargo. A reduction in fuel consumption will reduce the level of CO_2 emissions. However it should be analysed what the impact the new engines is on the level of other emissions. It might well be that the emissions levels of for instance NOx and PM might increase.
4. Some of the options considered for the five vessels participating in the consortium are not feasible for the analysed vessels; however they might be feasible for less advanced vessels than the ones considered in Move-it! It is desirable to analyse these retrofit options further, as they might be feasible options for other vessels or vessel types.

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11 Indexes

11.1 Index of Figures

11.2 Index of tables

11.3 List of Abbreviations

CBRB	Centraal Bureau voor de Rijn- en Binnenvaart
CCR	Central Commission for Navigation on the Rhine
CFT	Compagnie Fluviale Transport
CO	Carbon
GL	Germanischer Lloyd
HC	Hydrocarbon
H&M	Hull and machinery
IRR	Internal rate of return
IW	Inland waterway
IWT	Inland waterway transport
kW	Kilo watt
MGO	Marine gasoil
NPV	Net present value
P&I	Protection and indemnity
PM	Particular matter
PPM	Parts per million
SCR	Selective Catalytic Reduction
TEU	Twenty feet equivalent unit
TKV	ThyssenKrupp Veerhaven
ULS	Ultra low sulphur
WP	Work Package

12 Annexes

12.1 Annex A: Questionnaire for ship owners

Purpose of the survey

About the project MoVe IT!

We are collecting data for the five participating vessels in the project which will be used in work package 7.2 and 7.3. This is done by means of this interview. The goal of this interview is to collect data that form the input to the economical and logistical evaluation which is incorporated in task 7.2 and the environmental evaluation which is incorporated in task 7.3.

Your contribution to this interview is highly appreciated. The answer of this interview will be processed anonymously. In case of confidentiality you can indicate this in the answers.

Vessels involved in the project and their owner

Vessel	Company	Country
Veerhaven X	TKV	The Netherlands
Inflexible	CFT	France
Dunaföldvár	Helogistics	Austria
Herso 1	Plimsoll	Hungary
Carpe Diem	Carpe Diem Shipping	The Netherlands

Survey questions

Part I. General questions

1. *Name of the interviewee*

XXX

2. *Name of the company*

XXX

3. *Contact details (Telephone number, Email, Address)*

XXX

4. *Name of the vessel that will be investigated within MOVE-IT*

XXX

Part II. Project related questions

5. What are the technical specifications of the <Name of the vessel>?

Items	Data
o Length of the vessel (cm) o *For each vessel/barge in case of a convoy*	
o Width of the vessel (cm) o *For each vessel/barge in case of a convoy*	
o Maximum draft (cm) o *For each vessel/barge in case of a convoy*	
o Air draft (cm)	
o Loading capacity (tonnes) *For each vessel/barge in case of a convoy*	
o Coupling connection or convoy? o Motor cargo vessel + number of lighters; pusher + number of lighters,	
o Formation of vessels when operated in a convoy (stretchwise) e..g. side-by-side downstream or longitudinal downstream	
o Brand of engines used (main and auxiliary)	
o Capacity (kW/HP) of the main engines *When more than one engine is used please add up the capacity of all engines*	
o Capacity (kW/HP) of all engines (both main and auxiliary engines) *When more than one engine is used please add up the capacity of all engines*	
o In which year was the engine built? o Please give the year of construction for the main engines as well as for the auxiliary engines and the bow thruster engine(s) if the bow thruster engine(s) is not considered as a part of the auxiliary engines	
o When was the latest revision of the engines (main and auxiliary)?? o Check: do any motors change class?	

6. On which waterway corridor does the vessel frequently travel, and what is the performance of the transport services provided on this corridor by this vessel?

Waterway on which the vessel mostly travels	Data
o Origin	
o Destination	
o Possible intermediate stop(s)	
o Total voyage duration, including waiting time	
o Service frequency (# times/week, # times/year) How many times per week/year does a ship sail on this corridor?	

o what is the most economical speed of the vessel o how many days/hours per year on slow steaming o how many days/hours on fast steaming (with maximum speed)	
o Service reliability (% of journeys on time)	
o 'Terminal facilities (e.g., crane, gangways, containerization facilities, bunkering, fresh water, stores) used in ports of loading/unloading	
o Cargo loading and unloading requirements' or 'cargo equipments used in ports of loading/unloading	
o Main route with cargo (Origin-Destination, or Destination-Origin, or both directions)	
o Total number of kilometres sailed, including journeys with empty vessels (km per journey)	
o Number of kilometres sailed with loaded vessel (% of the total sailed kilometres per journey) o % of travel time sailed with empty vessel? o % of fuel use by ballast voyages? o % of fuel use by loaded vessel of total fuel consumption per journey?	
o How the ballast water is treated	
o Average cargo load on the vessel per journey (tonnes per vessel per journey)*	
o Average draught of loaded vessel per journey	
o Draught of empty vessel	
o Total amount of cargo transported by the vessel under consideration per year in tons	
o Total amount of kilometres sailed with cargo per year (do not count kilometres sailed with empty vessel!)	
o Type of fuel used	
o Total fuel consumption used for propulsion of the vessel by main engines (tons per year)	
o Total fuel consumption used by auxiliary engines (litre per year)	
o Total fuel consumption used by bow thruster (litre per year)	
o Is the bow thruster (and its fuel consumption) a part of the auxiliary engines?	
o Is the fuel consumption of the bow thruster already considered in the value: total fuel consumption used for propulsion of the vessel by main engines (see above)	
o Is the bow thruster used for propulsion of the vessels over the majority of time sailed or mainly for manoeuvring tasks?	
o Check of fuel consumption: total fuel consumption of main engines and auxiliary engines (litre per year), including bow thruster	
o Are the main engines equipped with emission reduction devices (e.g. PM filter)?	

o Do the main engines comply with a certain emission standard (e.g. CCNR I or CCNR II)	
o Are the auxiliary engines equipped with emission reduction devices (e.g. PM filter)	
o o Do the auxiliary engines comply with a certain emission standard (e.g. CCNR I or CCNR II)	
o o If the engine(s) for operation of the bow thruster is(are) not a part of the auxiliary engines: Is (are) this (these) engine(s) equipped with emission reduction devices (e.g. PM filter)	
o o Do the bow thruster engines comply with a certain emission standard (e.g. CCNR I or CCNR II)	

Note: * This amount cannot exceed the loading capacity of the vessel provided earlier.

7. *What cargoes are being transported by the vessel? Own transport only.*

Items	Data
Total vessel capacity for containers (max. number of container per vessel)	
Amount of containers shipped (# containers transported per year)	
Average value of the transported containers (EUR per container)	
Total vessel capacity for bulk cargoes (max. M3)	
Amount of bulk shipped (Tonnes transported per year)	
Value of transported bulk (EUR per commodity)	
Total vessel capacity for general cargoes (Total cargo capacity per vessel)	-
Amount of general cargo shipped (Tonnes transported per year)	-
Value of transported general cargo (EUR per commodity)	-

8. *What are the costs of the vessel?*

Category	Items	Data	Data confidential (Y/N)
(1) Operation costs			
Crew	Average number of crew members working on the vessel (#)		
	What ranks?		
	Total manning cost (salary) per year(EUR per year)		
	Vittles cost		
	Repatriation cost		
	Training cost		

Financial / Administrative data	Depreciation rate of ship and equipment (%)	
	Depreciation period of ship and equipment (# years)	
	Interest rate of financing(%)	
	Insurance costs (EUR per year), Please split between the casco insurance and cargo/P&I insurance.	
	Total port cost (including navigation dues), tolls, pilotage fees and other payments to be made for port and waterway use (EUR per year)	
Fuel	Total fuel consumption (tonnes per year)	
	Total lubricant consumption (tonnes per year)	
Operational data	Days of operating under way (Days per year)	
	Days in ports	
	Days waiting to get into ports	
	Days waiting for cargo	
	Number of operational days (Days per year) (days of maintenance should be deducted)	
	Total distance travelled (Km per year)	
Cargo handling costs	Cargo handling costs (EUR per year) and who pays this	
(2) Capital costs		
	o Remaining economic lifetime of the ship and the equipment on board (# years)	
	o Costs of new vessel and/or new equipment (EUR per replacement)	

9. *In which way does the various obstacles affect the operations of the vessel on a typical voyage?*

Items	Data
How long is the route available during the year	
How many days per year does low water-level occur that affect your vessel operation? (#/year)	
What is the duration of low water-level? (E.g. do they last a week or for months?)	
How does low water-level affect your operation (e.g. # vessels have to wait, # vessels had to terminate the operation)	

What kind of measures has been taken to deal with low water-levels? (E.g. reduce cargo load, if so how many kg?)	
Besides low water-level, what are the other obstacles that also significantly affect your vessel operation? (for example locks, time restrictions, sandbanks, etc)	(1) ___________________ (2) ___________________ (3) ___________________ …
How often do these obstacles occur? (#/year)	(1) ___________________ (2) ___________________ (3) ___________________ …
What kind of measures being taken to deal with these obstacles?	(1) ___________________ (2) ___________________ (3) ___________________ …

Part III. Remaining questions

10. *Do the shippers pay you separately for the fuel used?*

a) Always
b) Mostly (50%-80%)
c) Sometimes (less than 50%)
d) Never. As the owner of vessels I pay the fuel myself.

11. *Are you planning to have your vessels retrofitted in the near future? Why or why not?*

12. *In your opinion, is it necessary to have Vessel-A retrofitted in the near future to deal more effectively with the obstacles mentioned above? Why or why not?*

12.2 Annex B: Logistics Analysis

This annex was drafted by Move-IT partner University of Plymouth, who made a detailed assessment of the logistics process of the IWT sector. A summary is included in section 2.1 of the main report.

Definition of IWT logistics

The Council of Logistics Management (CLM) defines logistics as “a part of supply chain process that plans, implements, and controls the efficient, effective flow and storage of goods, services, and related information from the point of origin to the point of consumption in order to meet customer’s requirements" (Ballou, 2004:, p.4). In a more practical sense, logistics refers to the systematic management of various activities required to move goods from their point of production to the customer.

Inland waterways logistics includes elements of loading and unloading at seaports and inland ports, transhipment, storage and warehousing, floating stock and most importantly delivery to customers (ATRC Services 2012; Menist, 2010). Inland waterways transport is not the only inland transport mode but it competes and cooperates with other land modes rail and road (see table below for EU data on the modal split for 2009). Inland waterway transport today is mainly used for the carriage of liquid and dry bulk cargoes including ores, coals and coke, biomass, cereals, gasoline, oil, methanol or ammonia, other miscellaneous bulk cargoes. Container transport is also one of the main items in inland water transport. In addition, inland shipping also serves specialised markets such as the carriage of waste and oversized or heavy goods, roll on/roll off transportation of cars and lift on/lift off traffic with containers (Platz, 2008).

	2008			2009		
	Rail	Inland waterways	Road	Rail	Inland waterways	Road
EU-27	**17.8**	**5.9**	**76.3**	**16.6**	**5.9**	**77.5**
Belgium	15.9	15.6	68.5	12.8	14.3	72.9
Bulgaria	20.5	12.6	66.9	11.9	20.7	67.4
Czech Republic	23.3	0.0	76.7	22.1	0.1	77.8
Denmark	8.7	0.0	91.3	9.2	0.0	90.8
Germany	22.2	12.3	65.5	20.9	12.1	67.0
Estonia	44.7	0.0	55.3	52.7	0.0	47.3
Ireland	0.6	0.0	99.4	0.7	0.0	99.3
Greece	2.7	0.0	97.3	1.9	0.0	98.1
Spain	4.1	0.0	95.9	3.4	0.0	96.6
France	15.8	3.5	80.7	15.0	4.0	81.0
Italy	11.7	0.0	88.3	9.6	0.0	90.4
Cyprus	0.0	0.0	100.0	0.0	0.0	100.0
Latvia	61.3	0.0	38.7	69.8	0.0	30.2
Lithuania	41.9	0.0	58.1	40.1	0.0	59.9
Luxembourg	2.8	3.7	93.5	2.3	3.1	94.6
Hungary	20.6	4.7	74.7	17.1	4.1	78.8
Netherlands	5.4	34.7	59.9	4.9	31.3	63.8
Austria	37.4	4.0	58.6	36.4	4.1	59.5
Poland	24.0	0.1	75.9	19.4	0.1	80.5
Portugal	6.1	0.0	93.9	5.7	0.0	94.3
Romania	19.0	10.8	70.2	19.4	20.6	60.0
Slovenia	17.8	0.0	82.2	16.0	0.0	84.0
Slovakia	23.4	2.8	73.8	19.6	2.5	77.9
Finland	25.7	0.2	74.1	24.1	0.2	75.7
Sweden	35.1	0.0	64.9	36.8	0.0	63.2
United Kingdom	11.6	0.1	88.3	12.1	0.1	87.8
Norway	15.0	0.0	85.0	16.0	0.0	84.0
Switzerland	46.9	0.0	53.1	44.5	0.0	55.5
Croatia	21.8	5.5	72.7	20.6	5.7	73.7

Source:
http://epp.eurostat.ec.europa.eu/statistics_explained/index.php?title=File:Modal_Split_of_transport_performance_of_inland_modes_in_2008_and_2009,_%25_(based_on_declarations_from_the_EU_legal_acts).PNG&filetimestamp=2012033013494

The logistics chain described

The IWT logistics chain is similar to that of other modes of transport in the most essential of its elements. These elements generally fall within three areas/aspects of shipping operations: physical and operational aspects, economic and financial aspects, and information and communication aspects.

Physical and operational aspect:
The main physical element in the IWT logistics chain is the vessel. The types of vessels employed in IWT are of many varieties, mainly including motorised freight vessels and tankers, push boats, tugs, towing barges, passenger vessels, freight push barges, tanker push barges, and towing vessels. This project does not analyse passenger transport, therefore only cargo vessels will be discussed. Carrying capacity of these vessels varies significantly; ranging from spits type vessels of 350t, which is about 14 times the carrying capacity of a lorry, to push convoys carrying 11,000t, which is about 440 times larger than a lorry (Dutch Inland Shipping Information Agency, 2009). The exact specifications of the particular vessels investigated with regards to their logistical abilities and operating profiles within the 'MoVE IT' project will be further analysed in Section 2-5.

The other crucial part of the physical infrastructure are the terminals. Their efficiency, accessibility and facilities, together with the level of traffic, all affect the level and quality of operations of individual companies (Douma, et. al., 2011). However, most of their activities are outside of the inland shipping operator's direct control (Liu, 2010).

A large share of IWT flows begins at a sea port, where sea-going vessels load-unload and where goods may be transferred using other means of transport such as railways or roads. An intermediate stage can include storage and warehousing, including additional, specialist supply chain services at the transhipment stage (Konings, 2006). Once the goods are loaded onto the inland vessels there are various ways of progressing the cargo through the network, with the goal of delivering it to the final recipient. Several types of network exist, with the 'hub-and-spoke' model argued as one of the most cost-efficient and allowing a better control of the cargo and ensuring effective, on-time delivery (Konings, et al, 2013), a model applicable to cargo that is easily transferred between modes, e.g. containers. Other types of networks include the direct link, corridor, connected hubs, static routes, and dynamic routes (Woxenius, 2007).

The flow of goods may begin at the other end of the chain described, however this does not have a major impact on the organisation of the logistical flows, apart from reversing the order of certain operations; therefore, it does not need to be discussed in detail.

Economics and financial aspects:
IWT is a cost-effective mode of transport for almost any kind of cargo, from containers, through bulk to liquid cargo, as large quantities can be easily transferred with the possibility to avoid any necessity to store the cargo within the terminal, depending on the facilities at each port (Notteboom, 2007).

Information and communication aspect:
In parallel to the physical flows of goods, information flows play an equally important role, with exchange of data being the key factor to the Inland Waterway Supply Chain Performance and ensuring on-time deliveries are made without experiencing any unwanted disruptions (Song and Panayides, 2008). Many information systems are used by individual companies; however one particular scheme - the River Information System (RIS) has become one of the main portals and integrators of European-wide information and has the potential to become the standard for inland shipping (RIS, 2013).

Information and communication play a vital role in integrating this fragmented industry and strengthen its position in the wider transportation industry. The use of technology previously adopted in other sectors has now become widespread (GPS/3G technology; Platz, 2009), enhancing the potential to achieve the desired level of communication between IWT partners.
All the aspects mentioned above are interlinked and play equally important parts in the logistical chain of the Inland Waterway Transport and are analysed for the various ships selected within Move/IT in detail in sections 2-5.

Description of the analysis methodology

The research on the impacts of the modernisation solutions on IWT logistics operations is qualitative which is believed to be appropriate for achieving the aims and objectives of this part of the research task within the context of the 'MoVE IT' project.

During a preliminary discussion with the shipping companies involved in the project, the companies commented that the impact of modernisation solutions on logistics operations in Inland Water Transport may vary significantly between different companies, different ships, different shipping routes and even different parts of a route. In view of this, qualitative approach is believed to be more appropriate and advantageous than quantitative research as it could bring insights into the details of different scenarios and provide solutions that are more appropriate for each company and their respective vessel type.

Qualitative research stems from interpretive philosophy and allows developing in-depth understanding based on meanings and relationships between participants' behaviour (Denzin and Lincoln, 2005 in Saunders, et. al., 2012). Adopting qualitative approach was felt appropriate, because of the difficulty to generalise findings from any quantitative data that could have been potentially gathered due to the small size of the sample. The qualitative approach is a more valid and reliable method in such instances and provides rich, complex and elastic data, that can be better interpreted to get a greater understanding of the complexity of the situations analysed and to gain a background for the reasons as to why certain processes occur (Saunders, 2012). Additionally, qualitative research derives meanings from words, as opposed to the quantitative approach that uses principally numbers, which would have been difficult to obtain for this task to be successfully undertaken. Thus, faced with a relatively low potential to create extensive collection of valuable data sets, qualitative analysis was thought to be better suited to provide meaningful results.

In addition to that, considering that this research task includes analyses of both logistics and economic implications and assessment of the modernisation solutions for inland water transport, taking a quantitative approach to economic evaluations of the modernisation solutions, the two aspects of the research should allow triangulation of results using both the qualitative and quantitative elements, to provide meaningful and insightful recommendations and conclusions that can address current problems within Inland Waterway Transport.

The initial stage of the project involved comprehensive literature review and the main strands of analysis concerned the design of the vessels and the impact of technical changes on logistical operations, by looking at the main current issues of IWT in Europe. During this stage we looked at a selection of academic papers published by the leading journals such as Transportation Research (Parts A-E) or the Journal of Transport Geography, as well as a range of public bodies' reports (Eurostat, European Commission, IWT bodies). Apart from that professional and governmental reports, such as the European Commission's Eurostat reports were used as data sources to support the argument. The literature search gave a wide view of the situation in European IWT, to inform the discussion and provide a background for analysis of the specific companies during the interviews which were carried out later in the project.

Following the literature review, the five inland water shipping companies involved in the research project were interviewed with regards to their individual logistical operations and the characteristics of particular vessels. (Sections 2-5 of this annex examine the practical aspects of the logistical operations of the companies taking part in the project.) The survey questionnaire administered was designed for both the economical and logistical analysis, in cooperation with Ecorys. The main sections of the questionnaire were designed to probe the areas of technical specifications of the ships, then looking at the main waterway corridors that the vessels frequently travel, as well as looking at the performance of the transport services provided on the corresponding corridors, finally focusing on the types of cargoes carried and analysing any obstacles affecting the operations. (See annex A for the questionnaire used)

The interviews were conducted using face-to-face, semi-structured questionnaires. These were provided to the IWT companies beforehand, in order to allow them additional time to familiarise themselves with the design and order of the questions and to give them an opportunity to prepare the answers that could otherwise pose difficulty due to the requirement for technical and detailed information regarding operational aspects, something that very often requires access to internal databases and cooperation with other departments and co-workers within the organisations. There was ample opportunity for the companies to clarify all parts of the interview and provide additional details, if necessary.

The main advantage of semi-structured, interviewer administered questionnaires is the ability to provide a rich picture, with sufficient detail to conduct a detailed, meaningful qualitative analysis, based on unbiased, objective information. The use of non-definite and open-ended questions provided the shippers with an opportunity to provide additional details, which may have otherwise not become known in case of closed or multiple choice questions, when using structured interviews. The danger with semi-structured interviews is the fact that they may take an unknown and unexpected direction, therefore the interviewers must maintain the focus and ensure the answers recorded precisely address the questions asked and any irrelevant information that may be mentioned is not included and used in the analysis. This was achieved by taking notes by the two interviewers involved, who subsequently compared their records to arrive at a mutually agreed version that reflected the conversations that took place most closely, reducing the risk of any bias and inaccuracy.

This research approach, as outlined above, was believed to be able to provide the maximum detail of each particular participant company's operations in order to develop a wide range of well-informed recommendations in Section 6.

Herso 1

Current operating profile

Dimensions of the vessel

The vessel measures 84.95m in length and is 2.7m wide, however together with the barge, which is 80m long, the total length increases to approximately 165m. The whole combination is 9.5m wide and the maximum draught is 2.7m for the vessel itself, with 4.8m of air draught.

Loading capacity, average load carried and the total tonnage shipped per year
The vessel can carry containers, bulk and general cargoes on-board. The total capacity for container loads is 54 TEUs and 23 FEUs. However, the total number of containers shipped per annum is unknown. In terms of bulk or oil cargoes the vessel's capacity is 2,100m3. Given the routes sailed and their frequency (see below), this equals to approximately 10,000 tons of bulk transported per year and its value is estimated at €340,000. For general cargo, these figures amount to 1,500 tons of capacity, with approximately 5,000 tons shipped each year, adding to the total value of €280,000. The barges have a capacity of 1977.5m3 or 1,381 tons. The vessel has an average capacity of 1.000-1.100 tons (considering an average draft of 2.3 m). The barge can add an additional capacity of 200 tons (considering draft of 2.2 m). Despite that, in 2011 the vessel only transported 700 tons per trip, due to low water levels. This was around 60% of capacity.

Vessel loading capacity and annual cargo loads

ITEM:	QUANTITY:
Loading capacity	54 TEU or 23 FEU
Bulk cargo capacity (m3)	2,100
Average capacity in tonnes	1,000-1,100
Extended capacity in tonnes (at 2.2m draft)	1,200-1,300
Average load in 2011 in tonnes (% of capacity)	700 (60%)
Bulk cargo transported per annum in tonnes	10,000
Value of bulk and oil cargo transported per annum in €	340,000
General cargo transported per annum in tonnes	5,000
Value of general cargo transported per annum in €	280,000

The coupling connection is made of steel wires and the formation of the convoy depends on the direction of the route. There are two principal directions, upstream from Hungary to Germany and downstream to Romania. The upstream direction requires the boat to push the barge from behind and on the downstream route the barge is alongside the vessel.

The vessel does not have any crane facilities on-board and requires onshore loading and discharging facilities. Fresh water can be taken in during anchorage, but also during sailing. Bunkering is often done in the port, but it is possible to bunker during sailing. The vessel only uses ballast water when empty and whilst the barge is loaded. The ballast tank on board the vessel takes 200 tons of ballast water for that purpose. The ballast water is directly discharged into the river once it is no longer needed.

Main routes, total sailing times, total distances sailed
The main routes originate from Dunaújváros, Hungary, and are towards either Regensburg, in Germany or Constanza, in Romania. The vessel may call at other German intermediate stops. The sailings to Regensburg take 7 days upstream and 5 days downstream, totalling 12 days for the whole voyage. The sailing to Constanza is longer, with 10 days on the way downstream and with the return journey taking 14 days, making the whole voyage 24 days. In total every year the vessel makes nine return trips to Regensburg and nine to Constanza, which adds up to a total of 33,480 km (9 x 800km one way to the German port and 9 x 1,060km one way to the Romanian one,

both multiplied by 2 – return trips). The vessel carries cargo 90% of the time, so the total distance covered with loads on-board is 30,132, km; approximately 5% of the time the vessel sails without any cargo on-board.

The vessel operates 340 days each year, approximately 200 of which it is under way, which adds up to 4,800 hours. It spends two days loading and a further two days unloading on average each time it is in port. The loading can however be delayed, due to bad weather conditions. The atmospheric conditions, such as rain can halt the loading process for sensitive cargoes such as agricultural products.

The vessel does not normally spend any time waiting to get into ports, however it may have to wait for cargo in ports, which is the company's preferred option, rather than allowing it to sail back empty. It can take between three to four days for cargoes to become available, however this ensures the vessel does not return empty.

In terms of low water and the way it affects the operations of the company, in 2011 there were 151 days when water level was too low, this equated to 41% of the operational time. This situation caused a 16% loss of income for the company as it had to reduce the amount of cargo carried by approximately 50-70%. Occasionally, the company is also affected by high water, ice and maintenance work on locks on its routes, however these events do not occur very frequently with approximately five instances of high water, and one for the remaining two categories per year, therefore they do not pose a serious danger to the company's operations.

Main and auxiliary engines

The vessel uses a Deutz RBV 8M 545 engine, which was built in 1961 and is a slow-mover. The engine does not have any classification and to replace it, the cost would be approximately €300,000. Currently, the engine provides 1060 HP (760kW) and the vessel also has two Deutz 912 auxiliary engines, with a capacity of approximately 25-30kW, which add to a total of 830-840kW. The vessel was built in 1961, so the engine is now 52 years old and it was last revised in August 2011. The vessel went in dry-dock for 10 days in the port of Komarno. The engine did not change class after the revision.

Fuel and lubricant oil consumption

The vessel uses Diesel EN590 fuel and in 2012 370,295 litres of fuel were bought. 85% of this amount was used by the main engine (314,750 litres). The remaining 15% (55,544 litres) is used by the two auxiliary engines, the bow thruster and the boiler. The bow thruster engine was built in 1989. The capacity is 212 kW and the brand is DAF 1160. The bow thruster is used for manoeuvring, sailing in ports and near locks. There are no emission reduction devices installed on the vessel and it does not comply with any of the current emissions standards such as CCR II. The total lubricant consumption is 1,000 litres per year.

Vessel maintenance duration and costs and staffing levels

The last dry-dock of the vessel was in August 2011. The vessel went into dry-dock for 10 days and it cost €25,000. This was a large maintenance operation where the engine was also revised. The vessel has to go in dry-dock every 8.000-10.000 working hours (on average every 3 years). Small repairs and maintenance are done while the vessel is loading/unloading in the port. The on-board engineers are responsible for the maintenance.

Consequences of retrofit options for logistics

The vessel was built in 1961 in Duisburg, Germany. Plimsoll bought the vessel in 2003. The vessel has only been retrofitted once. The vessel was built with a traditional round bow. Since the retrofitting the bow of the vessel is flatter to enable the vessel to push a barge. No other retrofit measures have been taken so far.

Within Move-IT three retrofit options are proposed. Their potential impacts on logistics are elaborated in the main report under sections 4.2, 4.3 and 4.4. The below analysis touches upon some other retrofit considerations.

The vessel's engine optimum revolution speed is 320-340 RPM. At this speed the vessel is using 70-80% of its power and the consumption of the engine is 130 litres/hours (90% of power). This gives an average speed of 9 km per hour (kph), assuming the vessel is loaded with 2,000 tons (ship + barge) and there is no flow. However, the suggested revolution of the main engine and propeller is 380 RPM or 1000 HP. The consumption is 180-190 litres/hour and the average speed is 10-11kph. On the other hand, the maximum speed of the engine is 410 RPM and the consumption raises to 260 litres/hours, which allows the average speed to increase to 13kph. This mode is called 'overspeed' and cannot be maintained for longer than 30 minutes at a time. Overspeed is only used when sailing between Hungary and Regensburg in a few selected places (Austrian – Slovakian border DEVEN, near Vienna Airport, Schönbühel an der Donau near Melk , Isar - junction between Danube and Isar).

As the owner of the vessel covers the cost of the fuel, the decisions made regarding the appropriate speed are of paramount importance. The overspeed mode is reserved for the parts of the route where it is necessary, as it is of limited use and generates significantly higher fuel usage profile. The speed does not increase significantly and the reductions in sailing times would not be sufficient to justify the extra expense. Also, due to the length of voyages, it is not recommended to sail at speeds lower than the optimum revolution speed indicated (320-340 RPM), which already generates speeds of only 9kph and halve the consumption as compared against the overspeed mode. It would be beneficial to employ economic planner software to calculate the most economic engine speeds and include information such as lock and terminal availability to allow for the best sailing speed considering all the external factors.

The vessel is allowed to push more than one barge, however this happens very rarely. The only occasion when the vessel pushes 2 barges is between Hungarian ports. The vessel does not have enough capacity to push more than one barge for a longer time. Fuel consumption is unknown for this type of operation, however as this is not undertaken frequently, it is of no concern to general operations of the company.

As the barge does not have a bow thruster and is therefore not allowed to sail further than Regensburg. For operating between the ARA ports and Regensburg barges need to be equipped with a bow thruster. It would be beneficial to consider installation of such a device to allow the vessel to sail beyond Regensburg, as it may be financially viable for the company. This would need to be appropriately assessed financially and from the technical point of view.

Often the vessel is sailing for two customers at the time. The vessel is used for one customer and the barge for another customer. Very rarely both vessel and barge sail for the same client. This calls for appropriate coordination of cargo supply. Alternatively there may be delays to the vessel's schedule. It is assumed that the company uses planning software to tackle this problem, however if this is not implemented, it should be considered as a feasible solution to minimise delays and other unplanned events and to address any changes to schedules dynamically, without the need to involve individuals in taking these decisions and allowing for potential mistakes.

As outlined in section 2.1 low water levels can affect the carrying capacity of the vessel significantly. This issue must be investigated properly and contingency plans put in place, as it leads to significant losses of income (2011 - 16% drop). The company pays a surcharge of 10% for cargo 'lost' due to low water conditions. This is usually 10% of the freight per every 10 cm lost. Low water is particularly difficult to handle and prepare for; as the river becomes inaccessible for the vessel below a certain threshold and very little can be done to prevent it. The situation is difficult to forecast, because apart from the tides that can be predicted with more accuracy, any draughts and periods of hot weather affect the level of water in the rivers and have a direct impact on the company's operations. The company uses other modes of transport, however the shipping company is not entirely content with this, therefore it may be difficult to fulfil its obligations if this option becomes unavailable.

The company indicates that there are plans to have the vessel retrofitted in the near future, this is due to consumption and to increase its capacity, however no further details are available.

Summary of recommendations for Inflexible:
From a logistics point of view, Plymouth University recommends:

1. The use of the overspeed mode is limited already to parts of the voyage where it is absolutely necessary and required, however maintaining the speed above the minimum level of 9kph is key, as there is no savings below this speed. The company may also wish to invest in Economic Planner (see point 3) software to ensure the sailing speeds are optimised for lock and port terminal availability as this will further reduce the fuel costs and ensure timely arrival of the vessel to its destinations.
2. Consider installation of a bow thruster to allow the barge to sail beyond Regensburg, as it may be financially viable for the company. This would need to be appropriately assessed financially and from the technical point of view.
3. The company does not use any planning software, it could be considered as a feasible solution to minimise delays and other unplanned events and to address any changes to schedules dynamically, without the need to involve individuals in taking these decisions and allowing for potential mistakes.
4. Due to low water levels effect on carrying capacity of the vessel a proper investigation is recommended and contingency plans to be developed and put in place, as it leads to significant losses of income. Also an investigation into the possibility of not being able to rent smaller vessels and using other modes of transport should be initiated as the shipping company is not content with using other modes at present. Alternatively, rent smaller vessels or use another form of transport during times of extremely low water.

Inflexible

Current operating profile
Dimensions of the vessel
The 'Inflexible' push boat is 22.2 meters long and 9.45m wide, the length of a barge is 79 meters, its width measures 11.40m. These can also be combined in a row combination of two, as opposed to joining them side-by-side. The convoy measures 180 meters in total, together with the push boat, reaching 11.40m in width due to the size of the barges. The maximum draught of the combination of these vessels is 3.5m when the barges are fully loaded; the air draught is 5.4m.

Loading capacity, average load carried and the total tonnage shipped per year
The total capacity of the convoy is 5,000 tons, which equals 2,500 tons per barge in a two-barge convoy. When containers are carried, the average load on the vessels equals approximately 75% of the space available (352 TEU) and given its operating area, it can ship 280 TEUs per week, each way. In case of dry bulk cargo the loads oscillate between 4,000 and 5,000 tons, compared with 4,000-4,500 tons for liquid cargoes. The total amount of cargo transported by the vessel is approximately 250,000 tons per annum, which is calculated on the basis of operating for 50 weeks per year at 5,000 tons per week.

Vessel loading capacity and annual cargo loads

ITEM:	QUANTITY:
Loading capacity	5,000 tons (2,500 per barge)
Average load (TEU)	280
Average load (% of capacity)	75% (100% - 352 TEU)
Average load (bulk tonnes)	4,000-5,000
Average load (liquid)	4,000-4,500
Total cargo transported per annum in tonnes	250,000

Main routes, total sailing times, total distances sailed
The vessel is based at Le Havre and only operates on the Seine River, where five lock complexes are located. The destination for each voyage is Gennevilliers, near Paris, with a potential intermediate stop at Rouen. The total voyage duration, including any waiting times is 30 hours, one way. On average one round trip per week takes place, with the vessel leaving on Monday evening, arriving in Paris on Wednesday morning and leaving by the evening on the same day, to arrive back in Le Havre on Friday in the morning. The loading and unloading processes take six hours each. The average distance covered by the vessel per annum is approximately 40,000km. Cargo is carried in both directions and the return trip is approximately 600 to 700km, with an average of 130km travelled per day throughout the year. In case of container cargo, the vessel is loaded both ways, however if bulk cargo is transported the vessel is loaded only 50% of the time, with the possibility to transport containers on one leg of the voyage and bulk on the return leg, or the other way around, however this is not practised frequently. Therefore, on average the vessel carries cargoes approximately 60% of the time spent travelling, which equals to 24,000km. The vessel operates five days each week, between Monday and Friday and it spends on average one day in ports per voyage. Fresh water, fuel and other supplies are taken while the vessel is loading or unloading.

In terms of handling equipment the vessel has no special equipment on board for handling the dry bulk. Also for cars and containers no handling equipment is on-board the vessel. Liquid bulk loading does not require a pump, but instead gravity is used. Large hydraulic pumps attached to the barges are used for unloading the cargo. Bunkers are replenished whilst the vessel is loaded or discharged by a tanker car. The vessel is operative for 335 days per year.

Main and auxiliary engines
The vessel utilises the Baudoin engines, both as the main and auxiliary engine. There are two main engines on board, each with 900 HP (736kW). The total capacity of main and auxiliary engines is 2,600 HP, giving the vessel an additional 800 HP (360kW) from the auxiliary source of power. There is only one auxiliary engine on the vessel. These engines were built in 2008, but they do not comply with the CCR II standard, as the manufacturer was unable to supply them to this specification, therefore they conform to CCR I. The engines were last revised at 15,000 hours of operations, which was done in June 2012.

Fuel and lubricant oil consumption
The type of fuel the vessel uses is 10 PPM Diesel, however there is no detailed information available on the division between the consumption of the main and the auxiliary engine. Since June 2012 the vessel has had a flow meter (installed by Move-IT partner Marin). The total consumption of fuel equals approximately 500,000 litres and this includes the auxiliary engine, as the main and auxiliary engines run together at all times. The auxiliary engine fuel consumption includes the bow thruster, which is used for manoeuvring only. There are no emission reduction devices installed on any of the engines.

Vessel maintenance duration and costs and staffing levels
Maintenance is very often unscheduled. Unscheduled maintenance happens once or twice a year and can last between 2 days or 6 weeks, depending on the severity of the break down. The costs of maintenance are unknown or cannot be established due to the uncertainty and lack of repeatability of particular instances of break-downs.

The vessel crew consists of 5 member. Two of these members are on duty for 6 hours while two other are resting/sleeping. The fifth member can be called on deck if necessary. The crew work 24/7 for 7 days in a row. Then the crew will have 7 days of and is replaced by another crew with 5 members. There is no crew covering the Christmas period. The crew training is performed on the job and only the crew working with dangerous cargo receive additional training, such as fire-related courses.

Consequences of retrofit options for logistics
Within Move-IT three retrofit options are proposed. Their potential impacts on logistics are elaborated in the main report under sections 5.2, 5.3 and 5.4. The below analysis touches upon some other retrofit considerations.

The vessels travels most economically at about 1,400 RPM (Revolutions per minute) of the engine, which equates to approximately 12 km/h. The split of speeds between fast steaming, where the power of the engine used is 100% and slow steaming, with a lower power setting, is 5% and 15% of the time, respectively. This means that the vessel is only utilising its full power on 5% of the time, around 80% of the time it sails at around 12 km/h and the remaining 15% are sailed at a lower speed, in order to make the journey more economical. According to the owner of the vessel, 100% of journeys are made on time, indicating a very high reliability of the vessel's operation. Perhaps a larger proportion of slow-steaming voyages could be made to further reduce the costs and the environmental impact of the vessel, but the commercial interests, together with the economic side of operations must be accounted for before committing to this option.

The route that the vessel frequents is available throughout the year and the tides do not affect it, therefore the water levels do not prevent the vessel from sailing. The water depth at Le Havre is approximately 10m and near Paris it reaches 4.5-5m, which is about 1m above the draught of the vessel at full cargo. This means the company operations should not be impacted upon by the changing levels of water. The company is not utilising 'Economy Planner' software, however it would be highly beneficial if it could manage the speed of the vessel according to the availability of the locks and terminals. This is part of Work Package 3. However, a better implementation of RIS application may be necessary to avoid waiting time at the lock and to allow for further fuel savings .

However, as described in section 3.1, the potential enlarged barge convoy of 180m is restricted by the infrastructural build of the route, meaning that this is the maximum length that can enter the river. This is due to the size of the locks on the route and therefore cannot be avoided. This obstacle is of permanent nature and therefore prevents the company from expanding the convoy beyond the current configuration and hence bigger convoys are not an option if the company wishes to transport more cargo.

Any potential modernisation solutions will need to take the dimensions of the current convoy into account, as modifying the vessels dimensions may make it unsuitable to pass through the locks. On the other hand, at present the vessel is slightly smaller than the barges, therefore minimal increases to its size should not have a dramatic impact on the company's operations. If the modernisation leads to power increases or more efficient sailing, this may reduce the voyage times and have a positive impact on the company's operations, both financially and logistically.

The cost of the fuel may have an adverse impact on the company's operations as it covers this expense itself, rather than by charging the customers. If prices go up the obvious reaction will be to increase the charges for the services offered to customers, however this will have a negative impact on the competitiveness of the services offered. To combat this, the company plans to have the vessels retrofitted in the near future, which is viewed as a fuel consumption saving method.

The company currently does not service the vessel as part of a maintenance plan. To ensure the vessel's availability and long-term life is taken care of, planned maintenance must be in place, not only to minimise costs and prevent unplanned break downs, but to improve the relationships with current and prospective customers. This causes fewer disruptions to the flow of goods and may result in better contacts with potential customers. It may appear initially that planned maintenance is not the ideal option, especially in the face of few occurrences of severe previous trouble with the vessel, however as it ages it may become increasingly more necessary to service the vessel and if no plans are in place the cost of such operations may increase significantly.

Finally, the company aims to have many similar pushers, so that the fleet becomes more flexible and the same type of vessel can be used on different waterways. This is certainly a good decision, which may reduce the need to service the vessels as frequently and allow them the company to have a fleet to fall back on in case of any unplanned break-downs.

Also, although the engines were revised as recently as June 2012, it could be beneficial to revise them to ensure certification to CCR II standard is obtained at the next revision.

Summary of recommendations for Inflexible:
From a logistics point of view, Plymouth University recommends:

1. Increase the proportion of slow-steaming voyages to further reduce the costs and the environmental impact of the vessel. Consider the commercial side of operations before committing to this option.
2. Consider existing infrastructural and size limitations of the route before committing to any proposed technical modernisation solutions to ensure the upgraded vessel is capable of negotiating the navigable route successfully and safely.
3. Consider potential improvements to the power system and fuel-efficiency improvements to allow for savings in fuel and reductions in voyage times (e.g. improve the implementation of the RIS application); consider including the price of fuel in the price charged to customer to pass the increases in the cost of fuel onto the customers if at all possible.
4. Implement a planned maintenance programme for the vessel to minimise costs and prevent unplanned break downs, improving the reliability of the fleet. The company's decision to increase the amount of pushers may be part of this, however an aging vessel will require further investment if its state is neglected by poor management of its maintenance.
5. Consider potential engine revision to CCR II if deemed necessary and beneficial for the company

Veerhaven X

Current operating profile
Dimensions of the vessel
The Veerhaven X is 39.98m long and 15m wide, however these are the dimensions of the push boat only. Adding a number of barges, each of which is 76.5m long and 11.45m wide makes the combinations considerably larger. The company combines the barges in a variety of configurations, joining either four or six of these barges together. The length of a four-barge combination is 193m and a six-barge convoy measures 269.5m. These combinations can be either two or three-barge widths, which would make the convoy made up of two rows 22.9m wide or one with three rows - 34.35m wide. The maximum draught of the push boat is 1.9m, however the maximum depth for the convoy reaches 4m (barges loaded). On average this is 3.2m (1.7m when the vessel is empty). However, when the water level is low, 10cm less than the available water level considered. In terms of the air draught - it equals 9m.

Loading capacity, average load carried and the total tonnage shipped per year
The loading capacity is 2,800 tons per barge, meaning that the maximum total loading capacity per combination is 11,200 tons (average load is 9,200 tons) for a four-barge combination and 16,800 tons for a six-barge combination (average load 13,000 tons). The coupling connections are achieved by using steel wires and the formation of the vessels depends on the conditions and requirement for transport. The combination used most frequently is a four-barge combination, however if a six-barge combination is used, this will be formed of three rows of two barges in the German direction and two rows of three on the way back to the Netherlands. The total amount of cargo shipped in bulk is 2.1 million tons for the vessel, which is almost 10% of the cargo transported by the company (23 million tons).

Vessel loading capacity and annual cargo loads

ITEM:	QUANTITY:
Total loading capacity per barge (combination)	2,800 (11,200 for 4 or 16,800 for 6 barges)
Average load in tons (number of barges)	9,200 (4) or 13,000 (6)
Total cargo transported per annum in tonnes with this ship/convoy	2,100,000
Total cargo as % of total company's transport	10%
Total cargo carried by company in tonnes	23,000,000

The vessel hardly ever uses ballast water. The only time ballast water is used, is on the way to Amsterdam, while higher water levels occur on this route, which is not a very frequent phenomenon. The vessel needs the ballast water to be able to sail under the bridges on the route because of its air draught.

Main routes, total sailing times, total distances sailed
The majority of trips originate from Rotterdam - this has been estimated at 95% by the company. The remaining 5% of the journeys the vessel departs from Gent, Terneuzen, Vlissingen, Amsterdam or Antwerp. The main destination for the vessel is Schwelgern in Germany, the port of the ThyssenKrupp steel company. There are no intermediate stops for the vessels and the total one way voyage duration, including any waiting time varies between 24 and 28 hours. The complete return voyage of the vessel is about 40-42 hours and the trip can be divided into several segments. The journey from the Netherlands to Germany takes approximately 24 hours. Then decoupling at the German port is scheduled to take two hours. On return from the German location to the Dutch port the journey is approximately 12 hours and decoupling in a Dutch port takes roughly one hour. Occasionally the vessel needs to wait to enter the ports, however this happens very seldom. At times the barges are loaded in advance, especially as official holidays are approaching.

The vessel is normally loaded on 50% of journeys (one way – upstream) and during 30% of journeys the vessel is completely empty. This means approximately 20% of the fuel is used on empty sailings and 80% when the vessel is loaded. The total distance sailed with cargo per year is 50,000km.

Main and auxiliary engines
The main engine is a MAK 8M20 of which there are three on board of the Veerhaven X. There are four Scania auxiliary engines. The reason for using different manufacturers

for these two types of engines is the fact that MAK does not produce small engines. The company is planning to switch to Wärtsilä engines, because they are more advanced and less expensive. The total engine capacity is 4080 kW, each engine having 1360kW. Additional capacity of 1200 kW is available for generators and bow thrusters from the auxiliary engines. The capacity of each auxiliary engines individually is 300 kW each. Therefore, the total available capacity is 5280 kW. All engines were built in 2007 and are CCR I compliant, because the vessel was commissioned before July and CCR II became the standard after that date. Despite this, the level of emissions complies with the CCR II standard and this has been recognised when the vessel received the Green Award. The vessel also has two bow thrusters, which are only used when manoeuvring and these are both electric.

Fuel and lubricant oil consumption
The type of fuel used by the vessel is ULS EN590 (10 PPMS), of which the vessel uses 4 million litres each year; it also uses 15,000 litres of lubricants. Approximately 220,000 litres of fuel is used by the auxiliary engines, which equates to around 5% of total consumption. The bow thrusters do not use any fuel, as they are electric and are only occasionally used. There are no emission reduction devices installed on-board.

Vessel maintenance duration and costs and staffing levels
The vessel operates 365 days per year and after 22 months it goes into maintenance. The maintenance takes two weeks. Then the vessel is in operation for another 22 months. Every 15,000/30,000 hours the ship goes into maintenance. TKV decides when a vessel goes in maintenance and tries to do this before problems arise. During peak times all vessels are available. The four-barge combination has six members of crew, when using six barges it requires seven members. This is made of 2 captains, 1 or 2 mates, 1 or 2 sailors and 1 engineer. The vessel makes approximately 8,000 crew hours per year. This is due to the fact that on average four trips per week are undertaken and the ship makes approximately 200 travels per year, each of the barges on average travels 80 per annum. Overall 12,000-15,000 sailing hours are made by the vessels, each journey is approximately 500km long. The total distance covered by the vessel each year is approximately 100,000km.

Consequences of retrofit options for logistics
Within Move-IT one retrofit option is proposed for the Veerhaven X (installation of an SCR). This is not expected to have any major impact on logistics (see section 6.2). The below analysis touches upon some other retrofit considerations.

The route that the vessel sails is available all year round, with an estimated draught of 3.3 meters. It is rather difficult to establish how often the low water affects the vessel operation and this information would need to be confirmed with the Dutch waterway authorities for a specific voyage before setting sail. However, in case the water levels are too low for the vessel to sail fully-loaded, an additional vessel needs to be rented, which increases the costs of operations for the company. The parent company still requires the same volume of cargo to be delivered, therefore there are not many other solutions that can tackle low water levels. An option to use rail has been previously considered, however it does not offer sufficient capacity and therefore it is not appropriate.

Among other obstacles the main inhibitor is the waiting time, as the ports that the company uses are regularly crowded. This occurs especially when the water levels are low, because than more vessels are needed to transport all the cargo. As mentioned previously, the factory always needs vast amounts of stock (buffer capacity is 10 days) therefore TKV has no choice, but deliver it by any means available. High costs are incurred if this is not achieved. In the event that TKV's vessels are unable to carry as much cargo as possible and required, due to water level conditions, additional vessels must be hired to bridge the gap between the demand and supply.

A potential solution to this problem could be investing in better planning, including upgrades of the electronic software to ensure the information about potential delays is shared with other industry members and mitigating plans put in place. Alternatively the company could consider sailing at either lower or higher speeds, depending on the requirement, e.g. if the company knew the water level was going to drop significantly it could increase the speeds, to ensure the vessel reaches the port before it cannot sail any longer. Similarly, if there was high likelihood of high water, additional ballast water could be taken or the speeds either reduced to slow down fuel consumption in case of non-urgent transports or return legs of the voyage, or the speeds could be increased to meet tight deadlines, before the change of the water levels. These decisions are very dynamic and need to be based on specific requirement at the time of making the decision, hence why it is extremely difficult to generalise in this matter, however owning specialist software can enhance the abilities of even the most experienced company management in making appropriate decisions.

At present 70% of the transport is done with vessels owned by TKV; the remaining 30% of the transport is met by rented vessels. In case of low water levels, more additional vessels are rented and the percentages change slightly. TKV uses both a four-barge combination and a six-barge combination. Since the start of 2013 the six-barge combination is more often used than the four-barge combination, which was more common previously. The main advantage of the six-barge system is the fact that it can carry 50% more cargo per trip. The trip will only take an additional four hours and consumption of fuel increases slightly, offering a clear benefit for the company.

Water, fuel and supplies are taken in during sailing. Also the crew changes occur during sailing, so the vessel spends limited amount of time in ports (mainly to couple and decouple the barges). No additional material is needed, so port facilities are not as important for TKV. This ensures that the time spent sailing is used efficiently and that any potential delays are not generated. The service reliability according to the vessel owner is approximately 99%.

Although the impact of water levels is currently minimal, the company could put appropriate contingency plans in case this becomes more frequent and severe. Adequate planning software can ensure that decisions can be taken quickly in case of urgent changes to schedules, minimising unwanted losses and potential delays.

Any potential modernisation solutions need to address the limited opportunity for maintenance that the vessel receives every 22 months. The potential modernisation would have to be very well planned and may necessitate for a longer than the standard period scheduled to be only two weeks almost every two years.

Summary of recommendations for Veerhaven X:
From a logistics point of view, Plymouth University recommends:

1. Consider investing in better planning, including upgrades of the electronic software to ensure the information about potential delays is shared with other industry members and mitigating plans put in place
2. Consider sailing at either lower or higher speeds to combat challenges imposed by changing water levels. Establish a schedule depending on the factory requirement - decisions are very dynamic and need to be based on specific requirement at the time of making the decision.
3. Utilise the six-barge combination as frequently as possible when cargo is available to minimise cost and improve the throughput of the operation
4. Consider only modernisations that will fit in line with the scarce opportunity to refit, i.e. once every 22 months. Plan and prepare for a longer out-of-service period if modernisations take longer than usual maintenance – scheduled maintenance only 2 weeks.

Carpe Diem

Current operating profile
Dimensions of the vessel
The vessel is 110 meters long and 11.4m wide. Its maximum draught equals 3.35m, although when empty the draught is about 0.75m. The air draught is also approximately 0.75m on average. The Carpe Diem is a motor freight vessel. When sailing to Rotterdam, the maximum possible draught is 2.75m, however on average the draught is 2.30m for this type of voyage. On the other hand, when sailing to Groningen the maximum possible draught is 3.2m, with an average draught of 1.80m, as the containers transported to Groningen contain less cargo and hence are lighter.

Loading capacity, average load carried and the total tonnage shipped per year
The maximum loading capacity of the vessel is 2,998 tons. It can fit 153 TEUs, however the occupancy rate is 81-82%, so on average the vessel transports 124 TEU per trip, approximately 156 one way trips are made each year, so the average cargo transported is 19,344 TEU. The value of freight transported is not known. The vessel has no cargo crane on board, so needs to use cranes onshore to load and unload the vessel.

Vessel loading capacity and annual cargo loads

ITEM:	QUANTITY:
Total loading capacity (tonnes)	2,998
Total loading capacity (TEU)	153
Average loading capacity (TEU)	124
Average cargo transported per annum (TEU)	19,344

In ports the vessel needs fresh water which is supplied by supply vessels. Additional services are taken in while bunkering. The vessel does not use ballast water.

Main routes, total sailing times, total distances sailed
The main route that the vessel sails is from Rotterdam, with a potential intermediate stop at Heerenveen, terminating at Groningen and return from Groningen via

Heerenveen, to Rotterdam. The trip from Rotterdam to Heerenveen last 18 hours and from Heerenveen to Groningen 8 hours. The fortnightly service frequency involves three full round-trips. The typical schedule for the vessel is: leaving Rotterdam on Monday, arriving in Groningen on Wednesday and returning to Rotterdam on Friday and arriving in Groningen the next Monday.

The length of the voyage is 309 km per leg. The company estimates it may be a bit more, due to additional distances travelled within the port of Rotterdam, however this can be generally discarded and the total distances travelled per round trip can be assumed to be no greater than 618km. The annual total distance travelled would therefore equal approximately 50,058 km.

Main and auxiliary engines
The vessel's main engine is a Caterpillar 3508B. There are two main engines on board the vessel. The vessel also has one channel thruster, a Scania (375 HP 275 kW), and a control grid thruster, Caterpillar (550 HP ≈ 405 kW). The capacity of each main engine is 783 kW, so the total capacity of the two engines is 1,566 kW. The bow thrusters have a combined capacity of 925 HP. Total capacity is 2246 kW.

The vessel was built in 1989 and revised in 1996. One main engine was built in 2001 (CCR 0) and the second was built in 2004 (CCR I). The last engine revision was two years ago. The oldest engine was revised, but did not change class.

Fuel and lubricant oil consumption
The vessel uses ULS EN590 fuel. The weekly consumption of the main engines oscillates around 5,800 litres of fuel. Each week the auxiliary engines and bow thruster consume a total of 1,200 litres of fuel, making the total consumption for the vessel in the range of 7,000 litres per week, equalling 364,000 per annum.

The majority of time the bow thruster is used for manoeuvring in port. However when there are strong headwinds in Groningen the bow thruster is used together with the main engine.

The vessel does not have any emission reduction devices installed, however the canal thruster is CCR II certified. The cover grid thruster is certified to CCR I.

Vessel maintenance duration and costs and staffing levels
The vessel remains operational for approximately 350-365 days each year. The last engine revision was two years ago. The oldest engine was revised, but did not change class. Maintenance is scheduled to take one week every two years. The duration of maintenance can be extended if more extensive checks and repairs are deemed necessary. The cost of maintenance varies according to the work done.

The crew varies between four and six members, among who there will be a captain, a sailor, a mate and an engineer. The total manning cost per year is €120,000. No further information has been made available.

Consequences of retrofit options for logistics

Within Move-IT three retrofit options are proposed. Their potential impacts on logistics are elaborated in the main report under sections 7.2, 7.3 and 7.4. The below analysis touches upon some other retrofit considerations.

According to the company, 99% of journeys are made on time. The service operates five days per week. The vessel spends 18 hours in Rotterdam and less time in Groningen and Heerenveen. Therefore, each trip lasts between one and one and a half day in total and the vessel does not normally spend any significant periods of time waiting to enter ports.

Lower bridges in Groningen and in Friesland are among the only significant obstacles that affect the operations of the ship. In order to tackle this problem, less cargo is carried on-board the ship. This might, however, be better tackled if ballast water was used, to reduce the air draught of the vessel and use its full capacity. It is unknown if this would gain sufficient height at all, and if so why the vessel does not use any ballast water, however it is suggested that the company investigates this option.

The proportion of empty shipping trips is relatively low (only a few km in the port of Rotterdam), however the vessel is normally 81-82% full, which means almost 1/5 of the space is available on most voyages and this could be capitalised on. Spare capacity is a valuable resource and efforts need to be made to sell it, even if there is no immediate inflow of extra revenue, initial contacts with other cargo owners may result in increased business and should therefore be treated seriously.

It is unknown whether the company plans to retrofit its vessel, but any modernisation solutions would need to ensure that the draught of the vessel does not increase significantly, as there is not currently much tolerance at present and any changes leading the increases in the total vessel draught.

In terms of the speeds that the vessel maintains it is very difficult to establish the most appropriate speed, as the vessel is only allowed to sail at 8 km/h and this is rather slow. In Groningen and Friesland a speed limit applies and on other segments of the voyage it may be possible to use higher speeds. This slows the transport of goods and results in unwanted costs, however the justification for the limit is unknown and therefore the company may not be able to do anything about it.

Summary of recommendations for Carpe Diem:

From a logistics point of view, Plymouth University recommends:

1. Use ballast water to reduce the air draught of the vessel and use its full capacity where bridges are obstacles
2. Increase the percentage of full-capacity voyages to improve efficiency (approx.. 20% of space available
3. Avoid modernisation solutions that increase the draft of the vessel as at present there is very little tolerance
4. Investigate the possibility to increase the sailing speeds in areas other than Groningen and Friesland to reduce the waiting times – if possible.

Overall findings and recommendations

While the retrofit options designed within Move-IT are evaluated in the main report, Plymouth University has formulated a number of overall findings and recommendations on the basis of the interviews held with the ship operators involved in Move-IT.

Overall findings related to logistics
The main finding from this study is that the generally vessel capacity of the ships assessed is underused. Owners of the vessels should ensure space is filled to avoid fuel waste and increase their earning potential. This is obviously easier said, than done, however by investing their efforts into generating new business, they will ensure continuous service can be maintained, should any of their existing customers withdraw their interest.

For some of the ship owners, maintenance is patchy and mostly unplanned. This aspect can be very costly and appropriate maintenance planning should be part of each company's operations, if they wish to ensure the longevity of their vessels and minimise the costs to the business. Reducing the number of days of unplanned maintenance helps in maximising the utilisation of the vessel and any modernisation that comes as a result of the 'MoVE IT' project should be programmed into the schedule maintenance of the vessels, to minimise the time spent out of service.

It has also transpired through the interviews with the owners of the vessels, that the fuel economy is not always a priority for the ship owners. This, however, is justifiable by the company's requirement to adopt the vessels' speeds to the current needs of the customer, the atmospheric and tidal conditions and general planning schedules. However, if any potential fuel saving devices are included within the 'MoVE IT' modernisations, it can bring potential benefits for most vessels, as fuel consumption reductions are always a positive sign.

Some vessels' air draught and vessel size may be a limiting factor on certain rivers and canals that they use. These is very little that can be done in terms of bridges and locks, as their permanent character would not allow for any modification. The solutions presented by the 'MoVE IT' project must consider the limitations of each route and take account of the potential difficulties when implementing any modernisations that can cause potential delays and reduce the usability of the vessels.

Finally, low water can be a serious problem for any type of vessel, regardless of the modernisations proposed. The lack of measures to address this means that investment in planning and potentially other modes of transport may always be required. On the other hand high water is not such a concern, especially for vessels with relatively small air draught - they can continue to pass the bridges, however larger or taller vessels struggle to negotiate narrow locks and low bridges.
Summarising, the main concern for the ship owners with regards to implementing any external amendments to their ships should come from the increased dimensions of the ship once these changes have been applied. The changes to the engines and internal structure of the ships do not raise such concerns, however in this instance the owners should ensure that the newly equipped vessels are either more economical or

environmentally-friendly and also can undertake the same or more tasks with the same level of reliability.

Recommendations
Separate from the retrofit options proposed in WP7.1 and assessed in the main report of WP7.2, Plymouth University has reviewed the logistics from a more general perspective and formulated a number of suggestions.

Modernisation solutions must improve efficiency of operations, speed of the vessels or its capacity and handling equipment. They should reduce the use of fuel, to ensure the amount of emissions is reduced as much as possible, and reduce any discharges made into the rivers.

Reduce the air draught of some vessels to enable easier crossing of some bridges and ensure the lock sizes are taken account of. This may not be an easy measure or even impossible in some instances, however any modification implemented as a result of this project should consider air draught and the physical limitations of each route.

The vessels will certainly benefit from more planned maintenance and this could be encouraged. Relying on reactive maintenance is bad practice and leads to higher costs in the long-term.
The companies should also consider to increase their attempts to carry more cargo - this can be generated via more robust planning, coordination of all business activities, collaboration with other industry parties and experts and information exchange, by being part of various organisations or (international) consortia.

The final measure to improve the voyage economy is to reduce the speed where possible. Some vessels operate in areas where speed limits operate, therefore this would not apply there, although they may be able to implement this practice elsewhere. Other companies can certainly benefit from reducing the speed where speed is not the main factor or part of the service key performance indicator, as established with the customer.