WP 6 – new scales and services

D6.5: - Adjustment to climate change

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ABSTRACT

While already today the IWT sector faces low water periods on the Rhine and the Danube, analytical work from ECCONET and KLIWAS indicate that major worsening is mainly to be expected in the second half of this century, which is beyond the time horizon of retrofit solutions investigated within MoVe IT!.

Still, also in the current situation, improvements to ships that reduce their draught may contribute to improved performance in low water operating conditions. Especially larger sized ships (larger draught) are susceptible to low water periods, and their operating costs will increase extensively during these periods. Smaller sized ships on the contrary, having a much lower draught are much less vulnerable to water fluctuations, but do face a scale disadvantage against larger-sized vessels. As the current European IWT fleet contains a substantial number of these ships, considerations to increase their performance while maintaining their low water advantages could be worthwhile.

The aim of task 6.5 is to investigate how existing vessels can better cope with low water levels in rivers, which will increase in the (near) future due to the changing climate. For the adaptation of ships to lower water levels, several technical approaches are possible. They are analysed and assessed with regards to their feasibility and practicability, using a business case approach describing the technical and economic feasibility of adjusting specific ships.

A number of technologies has been identified that would contribute to lower draughts of ships. However most of these are very costly and only realistic in the case of implementation on newly built ships. In the context of MoVe IT!, looking at retrofit possibilities for existing ships, two specific options were identified and assessed, making use of climate change scenarios from ECCONET for the period 2021-2050:

- The implementation of an adjustable tunnel on a 110m ship. This application, with an estimated investment of € 350.000, would result in an average lowering of transport costs per ton by 7%. The case was found to be economically feasible, and would have a payback time of 3 years.
- The use of coupled convoy formations for an 85m ship. This application, with an estimated investment of € 0.5 mln, would result in an average lowering of the transport costs per ton by 41%. Such an investment would become feasible at operating levels of around 36,000 tons transported per year; a payback time of 4 years would then be achieved.

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1. Executive Summary

1.1. Problem Definition

While already today the IWT sector faces low water periods on the Rhine and the Danube, analytical work from ECCONET and KLIWAS indicate that major worsening is mainly to be expected in the second half of this century, which is beyond the time horizon of retrofit solutions investigated within MoVe IT!. Adaptation measures investigated in ECCONET and KLIWAS show that negative impacts of climate change can be generally mitigated. In this study two special ships are retrofitted; the economic benefits are assessed.

Still, also in the current situation, improvements to ships that reduce their draught may contribute to improved performance in low water operating conditions. Especially larger sized ships (larger draught) are susceptible to low water periods, and their operating costs will increase extensively. Smaller sized ships on the contrary, having a much lower draught are much less vulnerable to water fluctuations, but do face a scale disadvantage against larger sized ships. As the current European IWT fleet contains a substantial number of these ships, considerations to increase their performance while maintaining their low water advantages could be worthwhile.

1.2. Technical approach

The aim of task 6.5 is to investigate how existing vessels can better cope with the low water levels in the rivers due to the changing climate. For the adaptation of ships to lower water levels, different technical approaches are possible. They are analysed and assessed with regards to their feasibility and practicability, using a business case approach describing the technical and economic feasibility of adjusting the ships.

A three step research approach is followed to investigate the feasibility and practicality of adaptation measures as retrofit options for existing vessels:

1. Indicative assessment based on expected gains, efforts and comparison of cost components for new-build and existing vessels.
2. Technical assessment of two promising measures: the adjustable propeller tunnel for larger and therefore rather low-water sensitive ships;

upgrade to coupled convoys for smaller, less low-water sensitive vessels to improve the transport performance.
3. Economic assessment of the candidate measures applied to existing ships, under consideration of a pessimistic climate/water level scenario.

This task was conducted independent of other tasks within MoVe IT!. However use was made of data gathered for particular ships in the context of Wp7 as well as of economic assessment methods designed under task 6.4 and 7.2.

1.3. Results and Achievements

A number of technologies have been identified that would contribute to lower draughts of ships. However most of these are very costly and only realistic in the case of implementation on newly built ships. In the context of MoVe IT!, looking at retrofit possibilities for existing ships, two specific options were identified and assessed, making use of climate change scenarios from ECCONET for the period 2021-2050:

- The implementation of an adjustable tunnel on the 110m ship Carpe Diem. This application, with an estimated investment of € 350.000, would result in an average lowering of the transport costs by 7%. The case was found to be economically feasible, and would have a payback time of 3 years.
- The use of coupled convoy formations for the 85m ship Herso 1. This application, with an estimated investment of € 0.5 mln, would result in an average lowering of the transport costs by 41%.Such an investment would become feasible at operating levels of around 36,000 tons transported per year; a payback time of 4 years would then be achieved

1.4. Contribution to MoVe IT! objectives

The aim of WP6 was to assess how inland ships can be adapted to changing conditions, and task 6.5 focuses on climate change and the consequences of water levels. Technical solutions were already identified in other projects, but have now been assessed in the context of existing rather than new ships. Since a large part of the current fleet will remain in operation for a substantial amount of years to come, the fact that climate change adaptations for existing ships are found to be feasible is to be considered promising.

1.5. *Exploitation and Implementation*

In this task, an assessment is made particularly for the climate change situation on the Rhine, for two selected vessels. The results can be used directly for existing ships of the same characteristics. Whether or not they can also be applied to other vessel types would require additional investigation.

As regards implementation it is known that the Herso 1 is already operating in coupled convoy composition, thus showing the advantages of the concept. For the Cape Diem, several other retrofit options are also being considered in the context of the WP7 assessment, and no decisions on implementation are as yet known.

2. Introduction

2.1. Background

In the MoVe IT! project, measures to modernise existing vessels are investigated, with the aim to raise their economic or environmental performance, and to contribute to improved competitive performance vis-à-vis other modes of transport.

Whereas other Work Packages of MoVe IT! investigate technical options to retrofit existing inland waterway vessels with the aim to continue serving their current markets, WP6 looks at modifications aiming to allow the ships to serve changing environments. In this context, task 6.5 addresses adaptations to climate change.

2.2. Aim of the task

The aim of task 6.5 is to investigate how existing vessels can better cope with expected low water levels in the rivers due to the changing climate. For the adaptation of ships to lower water levels, different technical approaches are possible. Selected promising approaches will be analysed and assessed with regards to their feasibility and practicability. This will be worked out in business cases describing the technical and economic feasibility of adjusting the ships.

2.3. Structure of the report

In chapter 3, an elaboration of the envisaged problem is presented, i.e. the impacts of climate change on water levels of inland waterways. Use is made of the findings from previous projects on this matter. Chapter 4 then addresses the impacts of these developments on the inland water transport sector. In chapter 5, possible adaptation measures are identified, which are technically assessed in chapter 6. Those measures that are considered technically feasible are then economically assessed in chapter 7. The report closes with conclusions and outlooks in chapter 8.

3. Problem Analysis

3.1. Climate change and influence of low water levels

The effect of climate change on the performance of IWT vessels is a matter of available water depth. The influence of fairway depths on the cost structures of IWT vessels of different sizes was amongst others investigated in *"Technische und wirtschaftliche Konzepte für flussangepasste Binnenschiffe"* by VBD [2004].

Figure 1 shows a typical dependency of the transport costs of three ship sizes in relation to the fairway depth. At large water depths the large-sized vessel has advantages due to its large cargo capacity. The costs are divided by a large amount of cargo resulting in low costs per unit transported. This is called economy of scale. What yields for all ship sizes is that the transport costs increase with decreasing water depths: initially moderate, subsequently disproportional. At low fairway depths, the benefit of the large-sized ship inverses and becomes a disadvantage; the costs at low water depths increase heavily. This effect is called low-water sensitivity. Smaller vessels with moderate draught, however, are less sensitive against decreasing water depths; their unit costs increase less intensively.

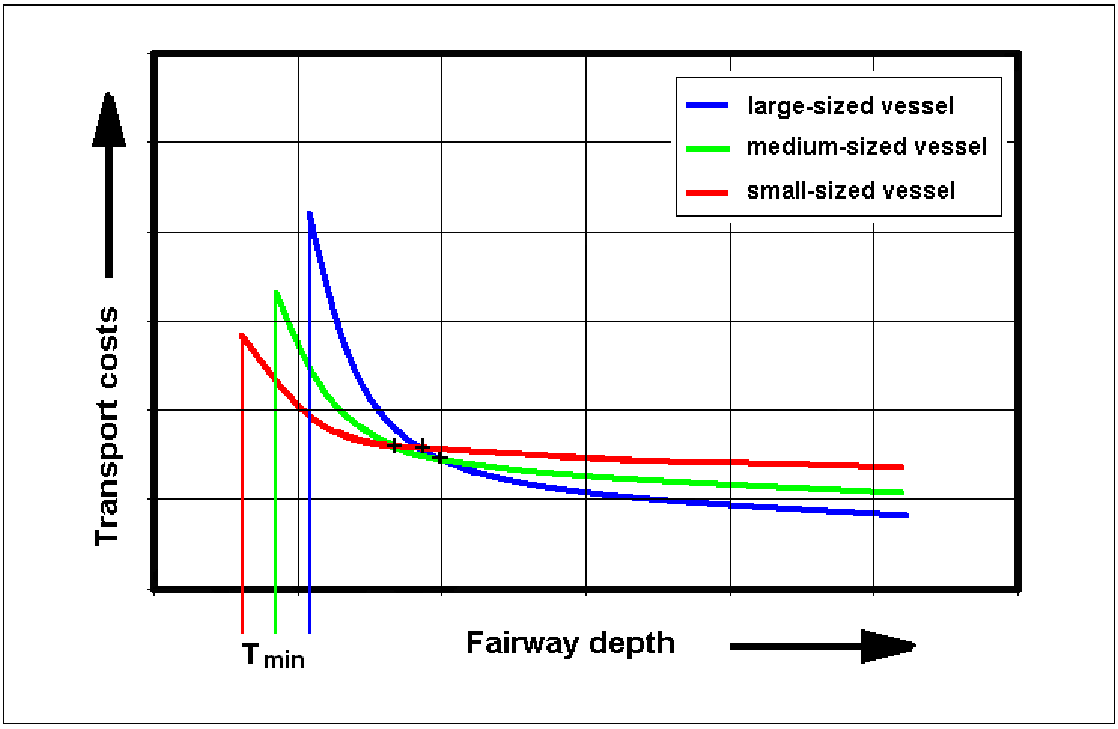

Figure 1– Typical dependency of transport costs in relation to the fair way depth [VBD, 2004].

Not only is the ship's cargo capacity affected by the water depth, but also the sailing speed as exemplarily shown in Figure 2: At water depth of 5 m and a draft of 2.50 m (right curve) a sailing speed of about 17 km/h is possible with 800 kW propulsive power, whereas half the water depth (2.50 m) only allows a reduced draft of 2.00 m and due to shallow water effects a reduced sailing speed of 9 km/h. The sailing speed reduces almost with 50%, although the same propulsive power is applied.

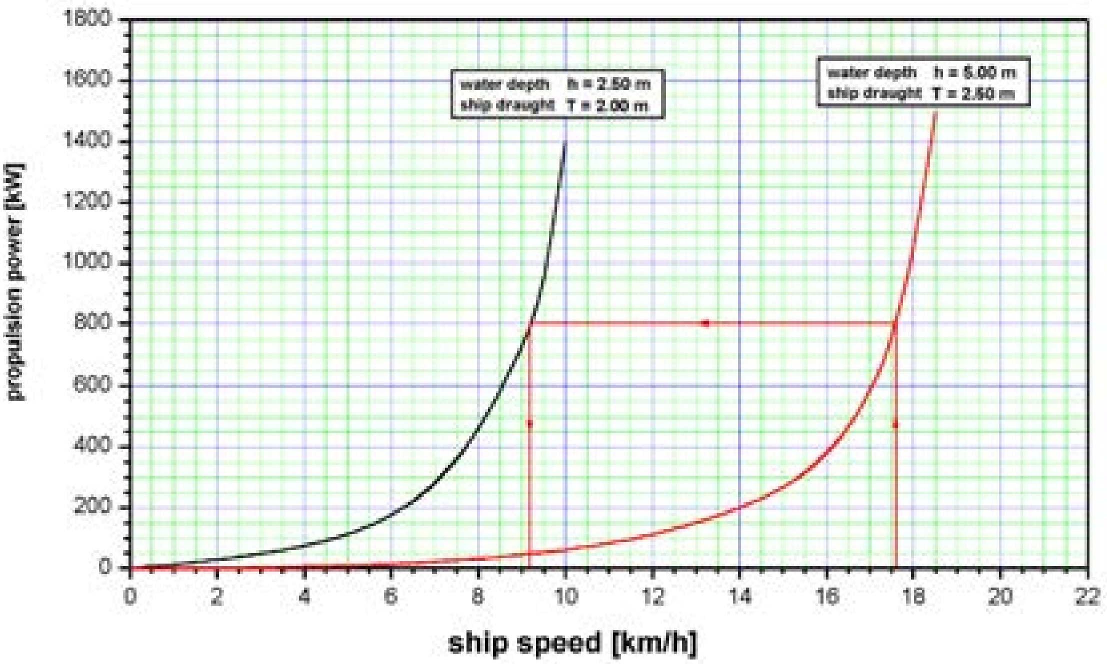

Figure 2 – Power-speed profiles for two water depths [ECCONET D3.3]

As the fixed costs (for investment and labour) are linearly dependent of the sailing time, the low water condition leads to almost a doubling of the fixed costs. Similar considerations yield for the voyage costs, which are mainly determined by the fuel consumption. However, the relations are generally more complex as the propulsive curves shift in horizontal sense if the effect of current e.g. in a free-flowing river is considered.

To which extent the costs of inland waterway transport are affected by the effects of the projected climate change was amongst others investigated in the research projects ECCONET and KLIWAS.

3.2. Findings from other studies

3.2.1. ECCONET

The ECCONET project *"Effects of Climate Change on the inland waterway NETwork"* was a 3-year Coordination and Support Action funded by the European Commission (DG-MOVE) in the context of the 7th Framework Programme. The objective was to assess the navigation conditions in the future taking into account the influence of climate change on the waterway network. Parallel thereto, ECCONET analysed possible adaptation strategies in order to improve the performance of inland waterway transport (IWT) in the light of climate change.

In ECCONET hydrological changes due to climate change affecting the navigation conditions in the catchments of the Rhine and the Danube were investigated for the past (1950-2005), the near future (mid of the 21st century) [1] and the distant future (end of the 21st century). A summary of the general effects of climate change and hydrological changes on navigation conditions is given in Table 1.

Table 1– Summary of climate effects, extracted from [ECCONET D1.5]

Phenomenon	Period	Effects on navigability	
		Rhine	Upper Danube
Low water	1950-2005	Positive	Positive effect
	Mid of 21st century	Unclear	Negative effect
	End of 21st century	Negative effect	Negative effect
High water	1950-2005	No effect	No effect
	Mid of 21st century	Negative effect	No effect
	End of 21st century	Negative effect	Unknown

In the above table, 'positive' implies an improvement from the perspective of the IWT sector (e.g. less ice, higher water levels). From the table it can be seen

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[1] In the context of other studies and policy considerations, this is often considered long term as well, however in the context of climate change trends it is considered 'near'. It is noted that the time horizon of MoVe IT! is shorter as this project deals with already existing ships instead of new ships.

that negative impacts only appear from the mid-21st century, which would be beyond the time horizon of MoVe IT!.

To assess future effects of climate change on transport costs and model split, ECCONET followed a scenario approach. Different climate scenarios (‘dry’ or ‘wet’) led to different consequences with regard to water levels on the Rhine and Danube, and thus on inland navigation. Typically, lower water levels led to increased cost levels because fewer payloads can be transported.

Cost functions were used to determine the relationship between water levels and costs for trips on selected routes, taking into account different cost components such as loading costs, time costs (for capital and labour), and fuel costs, which are different depending on the type of ship and or water levels.

Further, adaptation measures to counteract the negative effects of climate change were identified and assessed. The most promising measures that may compensate climate change effects concerned technical or operational adaptations of the IWT fleet.

3.2.2. KLIWAS

In KLIWAS or *„Impacts of various discharges on transport costs and capacity on Inland Waterway Transport on the Rhine”* (KLIWAS 4.01) the climate change impact projected for the future was captured using different river discharge scenarios generated by the German Federal Institute of Hydrology (Bundesanstalt für Gewässerkunde, BfG), in which available climate projections were taken into consideration and are integrated into a multi-model ensemble [BMVBS, 2009].

The effect of climate change on the performance of inland waterway transport was analysed for six different climate scenarios comprising up to 150 years of daily water depths and flow velocities for 17 segments in which the complete navigable river Rhine is divided. For these scenarios cost analysis simulations were performed for representative ship types sailing on six selected routes.

The differences in unit costs and for both ‘pessimistic’ and ‘optimistic’ scenarios with respect to the reference period were used as indication of the expected effect of climate change on IWT.

3.3. Conclusions from ECCONET and KLIWAS

Both studies on the effect of climate change on IWT came to the conclusion that: climate change will have serious impacts on IWT in terms of significant water level decreases. These negative effects however are expected on long-term horizon as at end of this century (year 2071 to 2100) a distinct trend towards lower water levels and rising unit costs is apparent in both ('pessimistic' and 'optimistic') climate scenarios.

On the mid-term horizon conversely, the effects of climate change can develop in either directions: for middle of this century (year 2021 to 2050) the results show an ambivalent pattern. It is apparent that in the 'optimistic' scenario, average unit costs will fall because of the rising mean water levels, whereas slightly rising average unit costs are associated with the 'pessimistic' scenario. At the time being there is no scientific evidence that one of the scenarios is more likely.

Further, it was concluded that inland waterway transport would need to become less vulnerable to low water levels to remain a reliable and competitive transport mode. Various adaptation measures were developed to make the fleet less low-water sensitive (see below). But, since the real impacts of climate change are expected rather in the second half of the century than in the first half, both studies recommend using the remaining time to subsequently adapt the existing fleet. The process of 'natural' substitution of old units by new ones is considered as a promising approach to adapt the fleet with rather limited additional efforts, this in contrast to MoVe IT!, which aims to modernise existing vessels. Again it is noted that the time horizon for MoVe_IT! is much shorter than was the case for ECCONET or KLIWAS.

3.4. Measures to adapt to climate change

ECCONET and KLIWAS gave a broad overview on adaptation measures with the purpose to counter-act the negative effects of climate change. Several adaptation measures were considered as promising approaches on a general level for the larger and thus more low-water sensitive ship types – for newly built ships that is. For smaller and thus less low-water sensitive vessels, a measure was proposed to upgrade capacity and thus transport performance.

For the larger and therefore rather low-water sensitive ship types like the Large Rhine ship types (GMS-110 and GMS-135), the following measures were investigated in the mentioned studies:

- Lightweight structures
- Multi-propeller propulsion system
- Combined Diesel-Electric drive with multi-propeller
- Adjustable tunnel
- Combined Diesel-Electric drive with adjustable tunnel
- Reduced maximum draught design

For smaller ship types like the Europe-type vessel (Johann Welker, JW), which are less sensitive to climate change due to their lower draught, the formation of a coupled convoy with an un-propelled barge was assessed.

In ECCONET and KLIWAS, the potential benefits of the adaptation measures and their chances for implementation were investigated under the assumption that on the long term the inland waterway fleet will gradually be replaced with new-built, adapted ship types. Therefore, the economic analysis was based on costs structures of new ships. Further explanations on the results are given in chapter 4.

3.5. Applicability to MoVe IT!

As the project MoVe IT! has the focus on modernisation of the existing IWT fleet and a distinct trend in low-water levels is expected rather in the second half of this century, the negative effects of climate change might play a role beyond the economic and technical lifetime of parts of the current fleet.

Nevertheless, as certain adaptation measures not only showed their positive effect on transport costs for the future projections of climate change but also in the present time period, they have a potential to reduce the low-water sensitivity of existing vessels already. A reduction in average transport costs may be achievable for existing vessels.

3.6. Research approach

A three step research approach is followed to investigate the feasibility and practicality of adaptation measures as retrofit options for existing vessels:

1. Indicative assessment based on expected gains, efforts and comparison of cost components for new-build and existing vessels.
2. Technical assessment of two promising measures: the adjustable propeller tunnel for larger and therefore rather low-water sensitive ships; operation as coupled convoy for smaller, less low-water sensitive vessels to improve the transport performance.
3. Economic assessment of the candidate measures applied to existing ships, under consideration of a pessimistic climate/water level scenario.

4. Indicative assessment of adaptation measures

The indicative assessment of the mentioned adaptation measures as retrofit option is based on interpretation of the available ECCONET results. These results, in terms of transport costs [€/t], give a first indication of the cost effectiveness of the adaptation measures.

It is assumed that the transport costs of existing ships are comparable with those of new-built ships, as they are mainly determined by the three cost components: capital costs, labour costs and fuel costs. In general, the labour costs are dictated by the manning regulations and therefore not influenced by the age of the vessel. The differences in fuel consumption are assumed to be small, as the propulsion characteristics implemented in the KLIWAS simulation model are representative for the current existing Rhine fleet [KLIWAS 2013]. The capital costs are assumed to be in the same range, when the replacement value for an existing ship is assumed to be 50% of the new-build price and its economic lifetime approximately 10 to 15 years, while the depreciation time for new-built ships can be estimated with 25 years [BdB].

4.1. Adaptation measures for large vessels (CEMT class V)

In ECCONET, the mentioned technical adaptation measures for a Large Rhine ship (type GMS-110) were assessed on the relation Rotterdam – Basel in upstream direction, considering the pessimistic discharge scenario. The effect of the adaptation measures on the transport costs in [€/t] is shown in Figure 3.

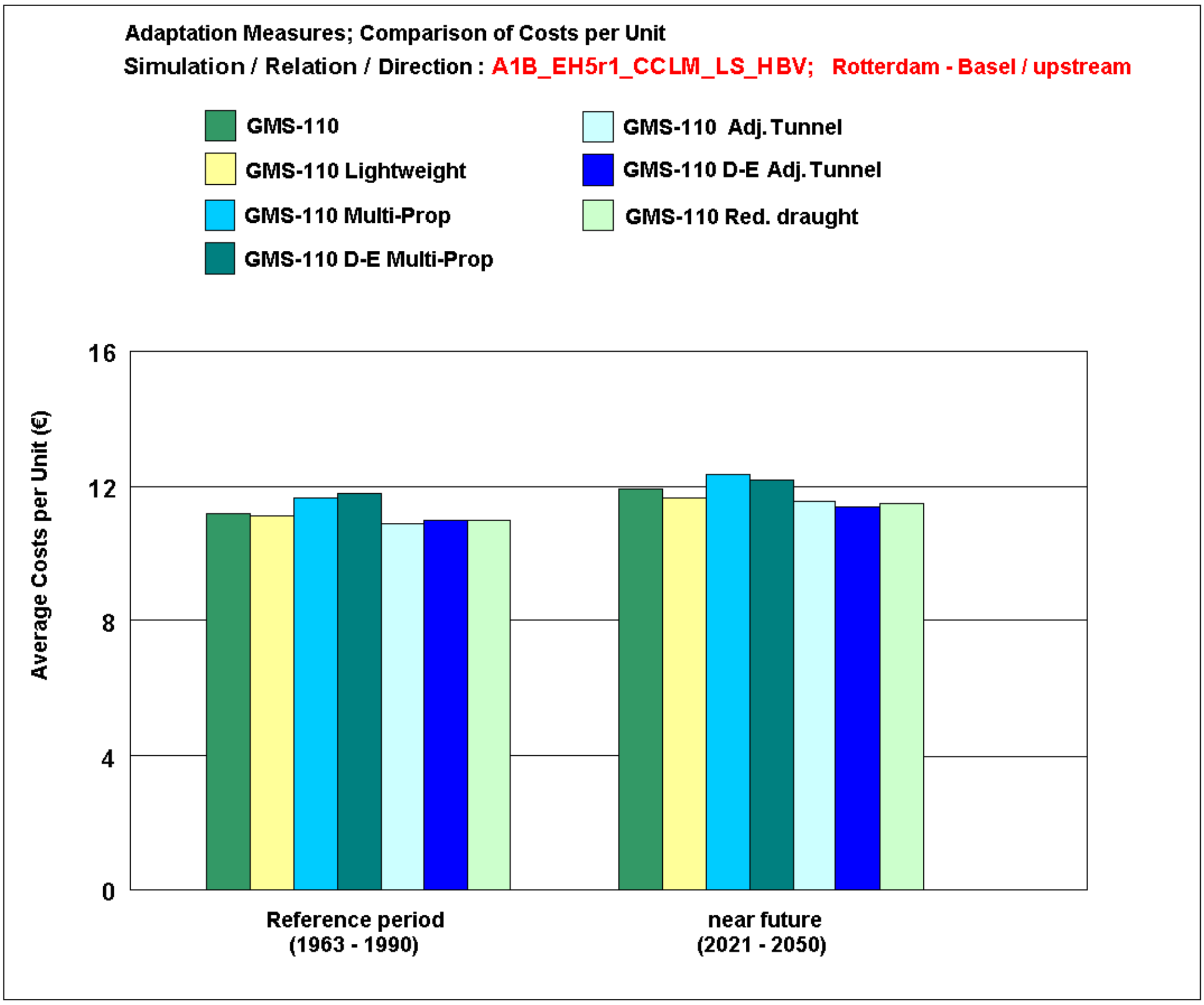

Figure 3 – Comparison of transport costs of the investigated technical adaptation measures [ECCONET D3.4]

The graph shows that the multi-propeller options do not result in lower average costs per unit of cargo transported, but all other measures do – for a new ship. Their applicability for existing ships – as retrofit application – will be assessed below.

4.1.1. Lightweight structure

Reduction of the hull weight can be achieved by the application of light-weight structures, e.g. higher tensile steel instead mild steel or through sandwich panels to the ship structure in the range of the cargo hold.

Gain:

Then the vessel can transport more payload or can operate at lower draught with the same payload, which results in a lower number of non-operational days due to too low water levels. The applicability of lightweight structures to ship hulls is limited, a weight reduction of 100 tons on a 110m large Rhine ship is assumed to be feasible. The gained increase in payload is approximately 3.5% at full draught. In the near future period the adapted ship type is able to operate against 2.2% lower costs compared to the base version of the Large Rhine Vessel.

Effort:

The gain in payload is obtained against a firm price. Due to the application of high-tech materials, an increase of 15% of the investment costs is assumed, in case of a new-built ship.

Conclusion:

This option can be a candidate if the cargo hold is to be replaced anyway or if a hull extension is planned.

4.1.2. Multi-propeller

A multi-propeller arrangement with a smaller propeller diameter enables the ship to sail with a lower minimum draught, without the danger of propeller ventilation. The drawback however is a lower propulsive efficiency due to the smaller propellers.

Gain: Due to the smaller minimum draught a lower number of non-operational days due to too low water levels is achieved. The measure has no effect on the load carrying capacity. Without a successive reduction of the minimum draught, the unit costs will only increase by this measure.

Effort: As the aft ship contour is to be revised and the propulsion arrangement is to be replaced (including shafts, gear boxes and main engines), this retrofit option is to be considered as a replacement of the complete aft section of the ship. As a successive reduction of the minimum draught is to be achieved by hull weight reduction or by a more balanced trim, additional measures are requisite. Therefore, it is likely that the investment costs due to the modification outrun the 8% higher new-building costs.

Conclusion: As high investment costs are expected and increases in transport costs were addressed in ECCONET, this measure is considered as not recommendable as retrofit option.

4.1.3. Diesel-electric drive combined with multi-propeller

A successive reduction of the minimum draught can be achieved by hull weight reduction or by a more balanced trim. Diesel-electric propulsion enables a shift of the heavy diesel engines from the aft ship to the front engine room, which normally only accommodates the bow thruster engine.

Gain: Due to the reduced minimum draught a lower number of non-operational days can be achieved if multiple smaller propellers are applied.

Effort: The aft ship contour is to be revised and the propulsion arrangement is to be replaced (including shafts, gear boxes and main engines). Further, this adaptation measure requires investment in a diesel electric propulsion unit and a complete rearrangement of both engine rooms.

Conclusion: : As high investment costs are expected and increased in transport costs were addressed in ECCONET, this measure is considered as not recommendable as retrofit option.

4.1.4. Adjustable tunnel

Inland vessels are frequently equipped with a fixed tunnel arrangement to prevent non-desirable air suction into the rotating propeller. Even at low water levels this approach enables sufficient water inflow without a considerable loss of propulsion efficiency. However, in case of favourable water levels, the presence of the tunnel causes negative effects on the hydrodynamic performance. With an adjustable tunnel a considerable increase in performance can be achieved. At favourable water depths the tunnel aprons are retracted, which improves the inflow of the propeller. At low water depths the aprons are deployed which leads to the desired tunnel geometry.

Gain: A reduction in fuel consumption of 7% can be achieved, depending on the distribution of water levels and the geometry of the existing vessel. If no propeller tunnel is present, this adaptation measure will not lead to improved hydrodynamic performance, however, a smaller minimum draught can be achieved, which on its part reduces the low-water sensibility of the vessel.

Effort: The extent of the modification activities is depending on the aft ship geometry and the presence of a fixed tunnel. In case of suitable aft ship geometry, the effort of this modification may be moderate and thus the investment costs will also be moderate.

Conclusion: The adjustable tunnel is a promising adaptation measure as it leads to the largest reduction in unit costs for the reference period. As a reduced sensibility to low water levels and an improved hydrodynamic performance can be achieved against moderate investment costs, this adaptation measure is identified as a candidate retrofit option.

The technical feasibility of this adaptation measure will be investigated in Section 5.2 and a detailed economic assessment in Section 6.2.

4.1.5. Diesel-electric combined with adjustable tunnel

A successive reduction of the minimum draught can be achieved by hull weight reduction or by a more balanced trim. Diesel-electric propulsion enables a shift of the heavy diesel engines from the aft ship to the front engine room, which normally only accommodated the bow thruster engine.

Gain: Due to the reduced minimum draught a low number of non-operational days can be achieved if an adjustable tunnel is applied. Further, a reduction of the fuel consumption is expected.

Effort: This adaptation measure requires investment in a diesel electric propulsion unit and a complete rearrangement of both engine rooms. Eventually, modification of the aft ship is required.

Conclusion: In the mid-century period the combination of the adjustable tunnel with a diesel-electric drive-train leads to the lowest unit costs for a 110 meter Large Rhine Vessel. However, because of the high investment costs and substantial shipyard effort, this measure is considered as a solution for new ships rather than a retrofit option.

4.1.6. Reduced maximum draught

The reduced maximum draught solution is based on the principle that a reduction in ship weight can be realized as ship structure is less heavily loaded due to the reduced maximum cargo capacity. The reduction in structural weight on its part would enable some compensation of the load carrying capacity.

Gain: Due to the reduced minimum draught a low number of non-operational days can be achieved. Further, a small reduction of the fuel consumption is expected.

Conclusion: This measure is considered as unfeasible as refit option, as the effectiveness of this adaptation measure is achieved by lower new-building costs compared to the base version of the Large Rhine Vessel. In case of a retrofit, this cost reduction cannot be achieved as a modification of the ship hull is needed. Secondly, a smaller cargo capacity is obtained, which moreover will lead to higher transport costs per unit cargo.

4.2. Adaptation measure for smaller vessel types (CEMT IV)

In ECCONET, a beneficial adaptation measure was applied to a Europe type vessel (Johann Welker or JW): operation as coupled convoy. In Figure 4, the transport costs [€/t] of a Europe-type coupled convoy are compared to those of representative Rhine vessels.

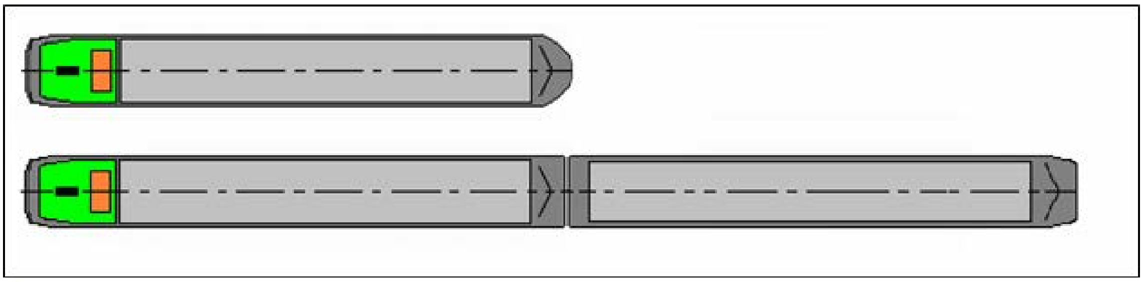

Figure 4 – Europe-type as self-propelled vessel and as dedicated coupled convoy. Source: ECCONET D3.4

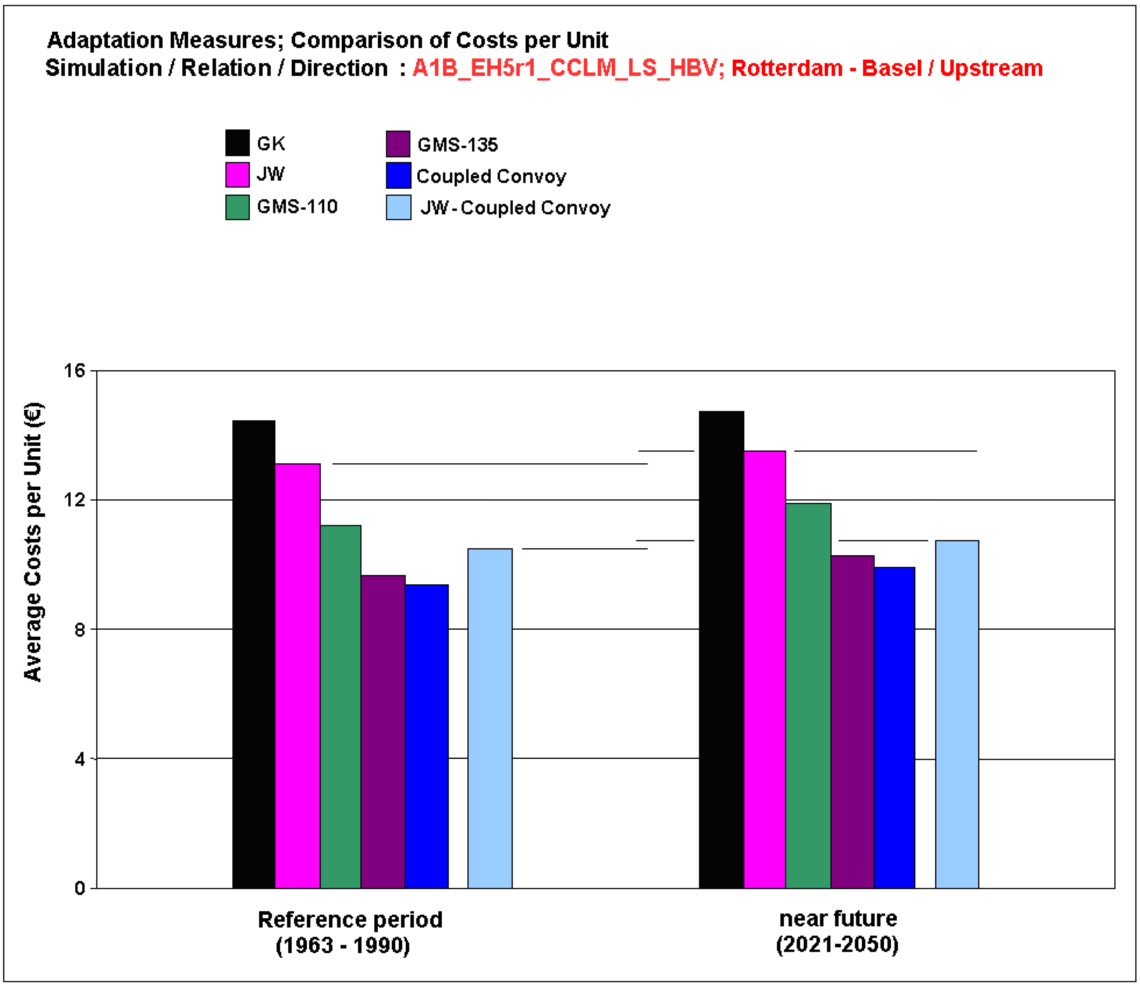

Figure 5 – Comparison of transport costs of a Europe-type coupled convoy and representative Rhine ships.

Gain: The effect in unit costs of sailing an 80 meter long Johann Welker (JW) type vessel as a coupled convoy is substantial as figure 4 points out. Compared to a single-sailing Europe-type motor vessel, a cost reduction of approximately 20% is achieved, also for the existing water level situation. The resulting costs are in the range of 110 and 135 meter Large Rhine Vessels. Moreover, the increase in costs due to climate effects is marginal as the convoy has the same shallow draft of 2.50m as the smaller vessel types (GK and JW).

Effort:

To convert an existing motor cargo vessel into a similar dedicated convoy as the investigated one, several measures are to be taken: acquiring of a dedicated barge, modification of the bow section to obtain a hydro-dynamically optimised transition between barge and vessel, eventually a replacement of the main engine and an upgrade of the crew accommodation. Less cost-intensive alternatives conceive which may however lead to reduced performances. The overall performance is to be assessed technically and economically, e.g. as a case study.

4.3. Conclusions indicative assessment

Four out of six investigated measures for larger and thus rather low-water sensitive Large Rhine Vessel type (GMS-110) lead to marginal, sometimes moderate reductions in transport costs compared to the base-version if a pessimistic climate scenario was considered. Both multi-propeller options lead to increased unit costs and are therefore not considered as refit option. In exceptional cases, the following two measures could be candidate options for retrofit:

- Light-weight solution, if the cargo hold is to be replaced or lengthened.
- Diesel-electric drive in combination with an adjustable tunnel if the complete aft ship is to be replaced for other reasons.

The adjustable tunnel is a promising adaptation measure as it leads to a reduction in unit costs according previous studies. As a reduced sensibility to low water levels and an improved hydrodynamic performance can be achieved against moderate investment costs, this adaptation measure is identified as a candidate retrofit option.

Also upgrade of small vessels to coupled convoys is a promising measure. Multiple configurations exist, varying from very simple to dedicated, hydro-dynamically optimised.

For assessing the applicability of these retrofit options on existing ships, available data from selected ships represented within MoVe_IT! are chosen. These are:

- Larger sized ship; use is made of operational data available for the 110m ship Carpe Diem[2].
- Smaller sized ship; use is made of operational data available for the 85m ship Herso[3].

For the larger sized ship, from the identified potential retrofit options, the adjustable tunnel is deemed relevant, whereas the other two are not applicable to the ship. For the smaller sized ship, the use of coupled convoy operation is considered as promising. These two ship retrofit options will be investigated in the technical assessment of chapter 5 and economic assessment of chapter 6.

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[2] The Carpe Diem is owned by Carpe Diem shipping, based in the Netherlands. Carpe Diem Shipping is one of the MoVe IT! Consortium partners

[3] The Herso 1 is owned by Plimsoll, based in Hungary. Plimsoll if one of the MoVe IT! Consortium partners.

5. Technical feasibility assessment

5.1. Methodology for technical feasibility

The technical feasibility of two promising adaptation measures is assessed as follows: the measures are briefly described as well as the effort that is needed for realizing it if to be applied to existing vessels.

5.2. Adjustable tunnel

5.2.1. General description

As explained in section 3.4, an adjustable tunnel[4] has advantages of fuel efficiency in favourable water conditions as compared to fixed tunnel arrangements, while they still allow navigation in shallow water conditions.

From a hydrodynamic point of view an installation of adjustable tunnel aprons seems to be a good solution to overcome losses in propulsion effects in operation of inland vessels at fluctuating water depths [Zoellner, 2009]. Figure 6 shows the principle of the adjustable tunnel: at favourable water depths the tunnel aprons are retracted, which improves the inflow of the propeller (as on left side); at low water depths the aprons are hinged down which leads to the desired tunnel geometry (as on the right side).

Figure 6 – Adjustable tunnel aprons in functional model scale Source: DST

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[4] The adjustable tunnel produced and marketed as Van der Velden® FLEX tunnel

A fuel saving of 7% is reported by ECCONET, but introduction on an existing ship requires a refit of the aft ship at potentially high costs.

5.2.2. Technical prerequisites

For this modification the following pre-conditions must be fulfilled:

1. the existing aft ship is generally suitable for an adjustable tunnel;
2. the steel structure and scantlings (e.g. frames and longitudinals) as well as the shell plating are intact and capable of bearing;
3. the engine room arrangement and ship machinery equipment allow a modification of the hull geometry.

Aft ship geometry:

The removal of the tunnel is supposed to lead to a more beneficial inflow of the propeller: a slender and, more important, a smooth aft form is to be obtained. Two aft ship geometries are shown in Figure 6. The left geometry has a shallow tunnel form with appendage-like tunnel skirts. Even after removal of the tunnel skirts, a smooth aft ship geometry remains. The right figure however shows a pronounced, fully integrated tunnel. In this case, removing the tunnel leads to a discontinuity in the aft shape: a sharp chine or knuckle occurs.

Further, a hinge line is to be determined around which the adjustable tunnel skirts will rotate. Hydrodynamic investigation by model testing or computational fluid mechanics should be considered as the obtained tunnel form should lead to an improved propeller inflow.

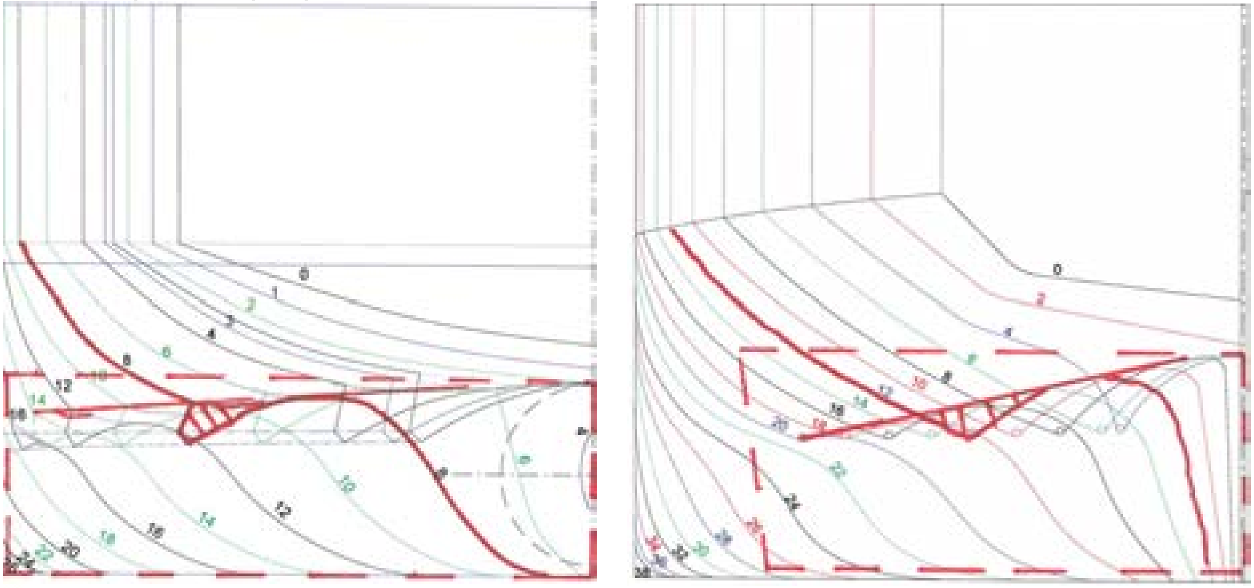

Figure 7 – Aft ship geometries

Ship structure:

Depending on the aft ship form, the remaining ship structure may be strongly affected by removal of the tunnel structure. Figure 7 shows some typical structural details of the aft ship structure around the propeller tunnel.

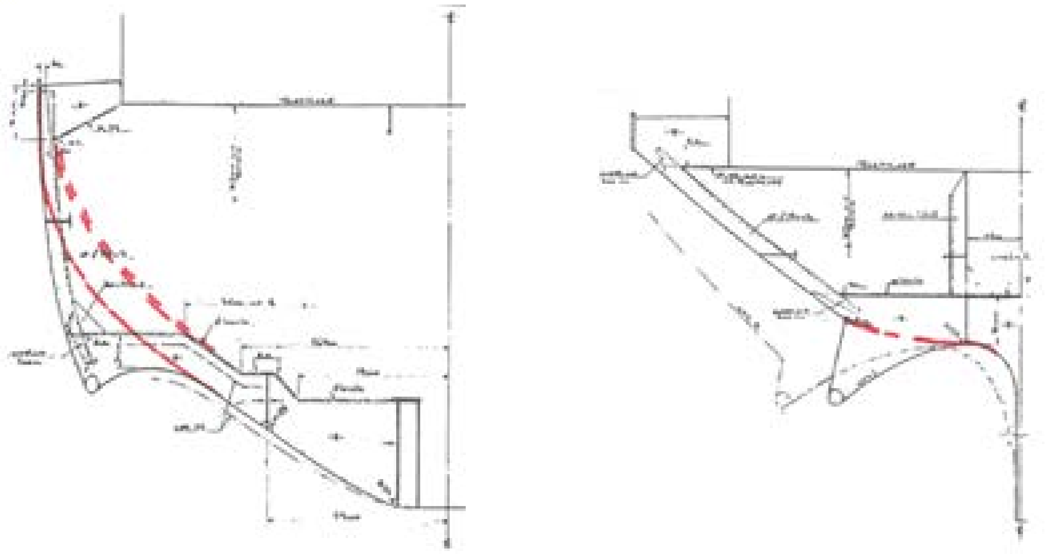

Figure 8 – Structural details of tunnel region

The left figure shows a structural detail of a rather appendage-like tunnel structure. Removal of the tunnel could be achieved by cutting off the skirt and attaching the shell plating. The right figure however shows a structure in which the shell plating has to be stiffened out with a new transversal frame. It is clear that in the second case the required yard activities are extensively. So are the resulting modification costs.

Engine room arrangement:

Not only the ship structure is affected, even the engine room might be. Figure 7 shows that some space in the engine room is to be the sacrificed for the new transversal frame. Besides that, the yard activities themself may require disassembly of ship machinery.

5.2.3. Ship yard activities to be conducted

The necessary activities that have to be conducted at the shipyard to implement the adjustable tunnel can be summarized with:

- Docking of the vessel
- De-installation of components in the aft ship/engine room
- Removal of the existing propeller tunnel
- Modification of the frames
- Positioning, bonding and welding of the apron pockets
- Bonding and welding of shell plating
- Installation of the tunnel flaps, hydraulic and electric components
- Placing into operation and testing
- Undocking of the vessel
- Trials

5.2.4. Conclusion technical feasibility of Adjustable tunnel

This adaptation measure can be applied to existing ships if the existing tunnel is more or less an appendage to the existing ship hull. Pronounced, integrated tunnels are rather unsuitable to be replaced by adjustable ones. Even for appendage-like tunnels the required technical effort is substantial as the hull shape of the aft ship has to be modified: the fixed tunnel structure has to be removed and the complex hull structure has to be modified. This affects also the interior of the aft ship, in case of inland vessels: the engine room at fuel tanks.

This retrofit option will be further investigated in the economic assessment of section 6.2.

5.3. Coupled convoy

5.3.1. General description

ECCONET and KLIWAS showed that upgrading of smaller, less low water sensitive vessels to coupled convoys is an effective adaptation measure against the negative effect of climate change. Further, was shown that the performance of a Europe type motor cargo vessel (Johann Welker or JW-type) can be improved, even in a pessimistic water discharge scenario: A reduction in transport costs of approximately 20% was achieved.

The reduced sensitivity to low water levels of a coupled convoy is because of the ability to distribute the same or even a larger amount of cargo over two vessels, which results in a smaller draught compared to a single vessel.

Complementary, this approach strengthens the flexibility of the transport system: In periods of favourable water conditions this ship type is able to transport almost twice as much cargo as a single vessel, with only limited additional costs. As the number of coupled convoys is continuously increasing since years, this development underlines the high flexibility combined with favourable transport costs this approach offers [ECCONET D2.1.1].

The coupling principle of smaller units can be achieved in multiple ways. Figure 8 shows four examples of coupled convoys: an improvised solution consisting from two units from the same type; a motor vessel pushing an un-motorised barge (eventually a standardised one); a vessel that pushes a dedicated barge equipped with a dove tail connection; and a hydro-dynamically optimised design with a blunt-blunt connection.

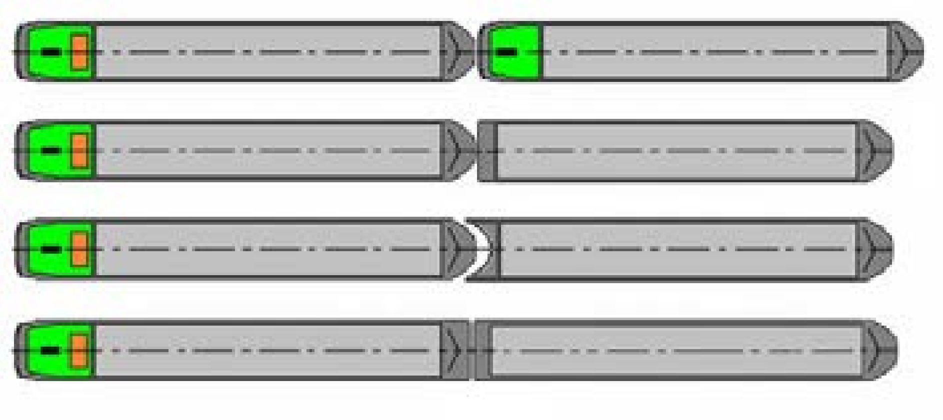

Figure 9 – Four variants of a coupled convoy

5.3.2. Applicability to existing ship types

The applicability of this measure to existing motor cargo vessels is dependent of the actual condition of the existing ship and its technical equipment.

The following aspects are of concern:

- Pushing and coupling equipment
- Propulsive power
- Availability of crew accommodation

The applicability of this measure is assessed as a business case study on an existing vessel: the 85 meter motor cargo vessel Herso-1. A cost-effective solution is envisaged which is based on the lowest investment approach: a rather improvised coupled convoy is achieved by acquiring e.g. a second-hand vessel that will be pushed by the motor cargo vessel like the upper variant in Figure 8 The other variants require more shipyard activities and thus higher investment costs.

Pushing and coupling equipment:

To push another barge, the pushing vessel is to be fitted with a pushing device. Different solutions are available, depending on what type of barge is to be pushed, if quick coupling and decoupling is intended and if a hinged connection may be desirable. Anyway, the ship structure should be able to bear the additional forces due to pushing and manoeuvring. Further, coupling winches are to be applied to the bow region of the motor vessel.

In the business case the motor vessel is equipped as in Figure 9: with pushing-shoulders at the bow and the pushed vessel is fitted with a saddle structure.

Figure 10 – Example of pushing-shoulders and saddle structure

Due to the connection of the pushing vessel and the barge, a hydro-dynamically un-beneficial coupled convoy has been derived, resulting in a lower sailing speed. Compared to the single motor vessel, an additional power demand of 80% has been taken into account.

Propulsive power:
In the business case, the propulsion equipment is assumed to be suitable for pushing a barge as the motor vessel is equipped with a 920 kW main engine. However, attention is to be paid to the powering of the motor vessel. The applied propeller may be designed or chosen for single-sailing mainly and can therefore be rather unsuitable for delivering more thrust at lower speed, resulting in an undesired lower propulsive efficiency[5].

Crew accommodation:
The accommodation should be large enough to allow for an extended crew, which is required for coupled convoys [CCR-ZKR]. For continuous operation, a further extension of the crew is required.
In this particular case, an extension of accommodation to allow for an extended crew is not needed, as the one on the pushed vessel is left available. Moreover, the convoy is assumed to operate in the same 14h mode.

5.3.3 Ship yard activities to be conducted

The following activities are to be conducted to the barge:

- Docking of the barge
- Removal of obsolete propeller and rudders
- Removal of machinery (optional)
- Application of saddle structure and coupling devices
- Undocking of the barge

To the pushing vessel the following activities are to be conducted:

- Application of pushing shoulders and coupling winches
- Reinforcement of the ship structure
- Replacement of the propeller (optional)
- Upgrade of the crew accommodation (optional)

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[5] This issue is investigated amongst others in MoVe IT! Deliverable 7.1.

5.3.4. Conclusion technical feasibility of Coupled convoys

Conversion of smaller inland vessels to coupled convoys in general is technically feasible, depending on existing conditions. Various configurations exist from an improvised solution consisting of two units from the same type to hydro-dynamically optimised versions with a blunt-blunt connection. Prerequisites are pushing and coupling equipment, sufficient propulsive power to reach required speed and available accommodation for an extended crew.

This adaptation measure is defined based on the configurations of the Herso-1, and assuming the simplest form of implementation at the lowest costs. The resulting convoy configuration is considered as technically feasible.

This retrofit option will be further investigated in the economic assessment of section 6.3.

6. Economic assessment

6.1. Methodology

The economic feasibility of the most promising adaptation measures is assessed as follows:

- A pessimistic climate scenario and associated water level variations are taken from KLIWAS.
- Application of the DST Cost-model for adapted vessel and not-adapted vessel, resulting in an estimate of the difference in performance and thereto related transport costs in [€/t]. This is done for the two selected ship types (110m and 85m).
- Estimated investment costs and amortisation time of the refit/adaptation measure.
- Aggregated results as input for the Economic assessment, for which the methodology as developed in MoVe IT! Tasks 6.4 and 7.2 is applied.

A scenario approach has been used to investigate the economic feasibility of the selected adaptation measures to the effect of climate change. The effects of climate change have been considered by application of a pessimistic discharge scenario.

Cost analysis simulations have been performed on two business cases: a 110m Large Rhine Vessel to which two adjustable tunnels are applied; and an 85m CEMT IV Europa-type vessel that will be upgraded to a low-investment coupled convoy.

For the analysis it is assumed that both representative ship types sail on the Rhine relation Rotterdam-Karlsruhe in upstream direction, transporting dry bulk cargo. The ship type are analysed in two conditions: as base-version and as adapted vessel.

The cost simulation runs comprise daily departures of a vessel over the complete time span 1963 to 2050 of the discharge scenario, based on daily water levels and stream flow velocities on 17 segments of the river Rhine[6].

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[6] The adaptation measures may even better perform on the Danube than on the Rhine as some Danube sections are characterized by pronounced low water regimes. However, at the time proper discharge scenarios based on daily water levels were not available for the Danube

The results of the simulations, expressed in unit costs of transport in [€/t], are analysed for a thirty-year period: the 'mid-century', from 2021 to 2050. A comparison between base-version and the adapted vessels expresses the economic potential of the adaptation measures.

Cost model

The cost of IWT can be aggregated to three main components:

- investment and insurance costs,
- labour costs,
- fuel and lubrication costs.

Hereby, a distinction can be made between fixed and variable costs: Investment, insurance and labour costs are costs components which can be addressed to time charter, so fixed costs. Fuel and lubrication costs are cost components due to sailing with the purpose of transporting cargo, so variable ones. Important is that the costs of IWT among others depend on the available water depth and ship size.

Economic feasibility assessment

Main inputs for the economic feasibility assessment are:

- cost estimates for the retrofit investment
- impacts on maintenance costs
- effects on overall operating costs

These are then inserted in a cash flow model which takes into account the current operating structures of the vessels as well as a number of general assumptions that are presented below. Output of the assessment then consists of:

- Net Present Value: all future costs and benefits are discounted to their value today.
- Internal Rate of Return: the profitability ratio of the investment

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[ECCONET 3.3]. For that reason the assessment has been carried out using the example of the river Rhine with a pessimistic discharge scenario.

- Payback period: the duration (in years) until a positive cumulative cash flow is reached.

General assumptions

Several general assumptions are made, which apply to all ships 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 and benefit 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[7]. 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-off costs.
- *Maintenance costs:* Closely related to the investment costs are the additional costs for maintenance. The retrofit installation added to the

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[7] 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.

ship may 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

Operating costs per ton: by using the Cost model of DST, for each retrofit option, the impacts on operating costs, which could relate to fuel consumption, cargo carrying capacity or crew needs, are all translated into operating costs per ton of cargo carried. It is understood that things like insurance or capital costs are also included in this assessment.

Sensitivity tests

As assumptions are made which are uncertain, the robustness of the analysis will be tested. E.g. will the retrofit option be economically feasible under alternative conditions (e.g. how will the IW market develop, what will the level of fuel prices be in future years, etc.). Therefore, for the general part we assess a baseline scenario (e.g. applying the middle assumptions on costs and impacts), and vary with the inputs by taking high or low estimates of the investment costs and operating impacts to show how they affect the feasibility.

6.2. Business case GMS-110m ship with adjustable tunnel

In this business case the adjustable tunnel is applied to a 110m Large Rhine Vessel (drawings of the “Carpe Diem” taken as an example). Main dimensions of the vessel can be found in the following table.

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

Figure 11 – Impressions of the Carpe Diem

Modification:

The pram-type aft ship of the 110m ship "Carpe Diem" is well-suitable to apply adjustable tunnels (see figure below). The two existing, fixed tunnels are rather appendage-like than fully integrated in the aft ship contour. The geometry of the tunnel is rather wide to avoid additional resistance at favourable water levels. Therefore the depth of the skirts is moderate.

Figure 12 – Rear view on the existing fixed tunnels

Envisaged gain:

The adjustable tunnel enables a minimum draught of 1.30m, instead of 1.75m with the fixed tunnels, as the adjustable tunnels are more pronounced than the original ones[8]. The tunnel skirts are tightly fitted to the propeller nozzle to avoid air suction, providing the propeller sufficient water even at small draughts. The figure below gives a draft of the tunnel contours.

The second effect is that the removal of the original propeller tunnels will lead to a less disturbed inflow of the propellers at favourable water depths. An improvement of the propulsive efficiency of 7% is assumed to be achievable. At low water levels the hydrodynamic performance is assumed to increase with the same percentage.

Figure 13 – Aft ship with contours of a fixed and an adjustable tunnel

Effect on cost components due to modification:

- Investment costs are estimated with €350,000.
- Labour costs remain the same as the mode of operation is unchanged.

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[8] The geometry of a fixed propeller tunnel is a compromised one that is suitable for all water levels.

- Due to the improved propulsive efficiency, a 7% reduction in propulsive power is assumed to achieve the same sailing speed. The resulting total fuel consumption might be different as a lower number of non-operational days are envisaged (and expected) due to the lower minimum draught.

Due to the higher investment costs, reduced fuel consumption and a lower number of non-operational days the complete cost structure might be influenced by the modification.

Simulation results

The application of adjustable tunnels to a Large Rhine Vessel (110m) similar to the "Carpe Diem" as a refit option leads to a less low-water sensitive ship type. The average number of non-operational days reduces from 17 to 1 in the reference period and from 31 to 4 in the mid-century period, when a pessimistic water level scenario is considered (see Figure 4).

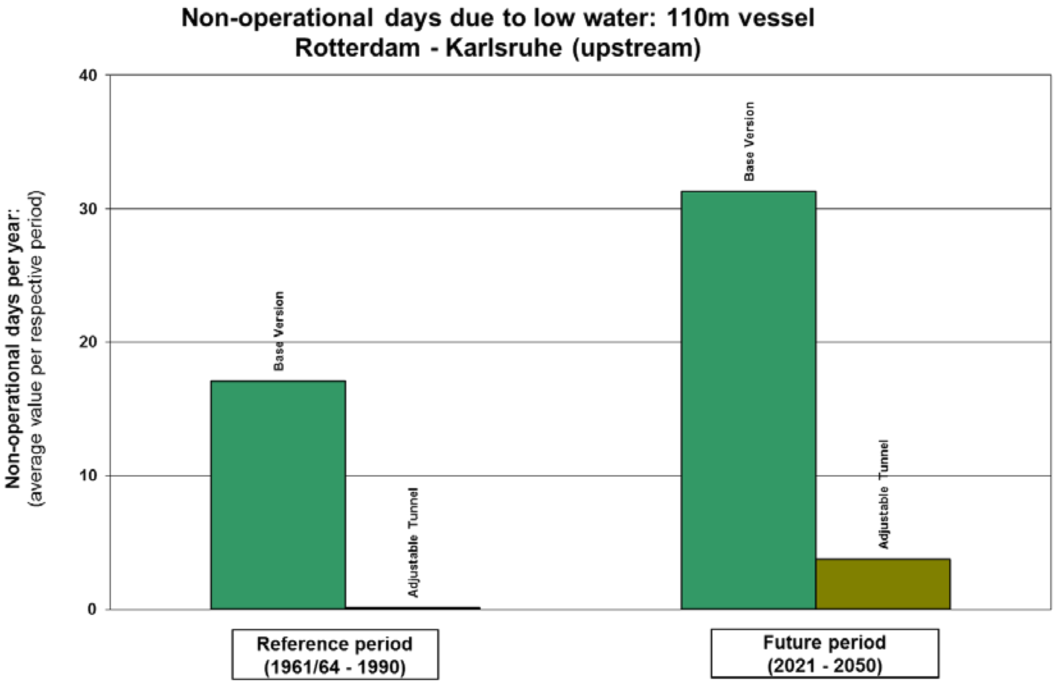

Figure 14 – Comparison of non-operational days due to low water for a 110m vessel without and with adjustable tunnel

Figure 14 shows the averaged transport costs [€/t] for the relation Rotterdam to Karlsruhe in upstream direction, considering a pessimistic water level scenario. In the reference period, a reduction of the averaged unit transport costs with 8%

is achieved with the adjustable tunnel. For the mid-century period even larger reductions are predicted.

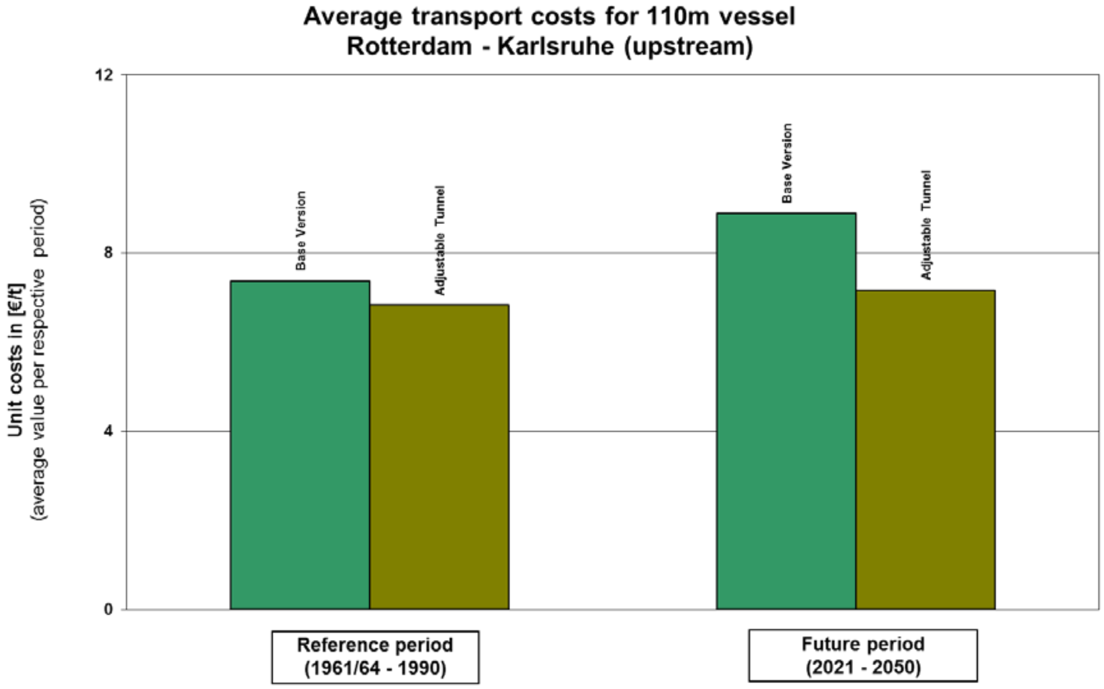

Figure 15 – Comparison of average transport costs for a 110m vessel without and with adjustable tunnel

Analysis results

The results for a modified Carpe Diem to install an adjustable tunnel, are as follows:

- Estimated investment costs: € 350.000. This is an expert estimate.
- Resulting operating cost (using the Cost model presented above) of € 6,83 EUR/ton with adjustable tunnel as compared to € 7,37 EUR/ton in the without situation, in the reference period
- Estimated off-service time to implement the modification: 6 weeks. This is an expert estimate.

For operational data use was made of information gathered on the Carpe Diem as part of MoVe_IT! task 7.2, noting however that the real Carpe Diem operates on canals in the Netherlands rather than on the Rhine. For the analysis undertaken here however this does not matter.

When applying these results into the economic feasibility scheme, the following results are found:

Table 2 – Economic feasibility of installation of an adjustable tunnel on a 110m ship

	Base case	Higher investment cost	Lower efficiency gains
Investment costs assumed	€ 350.000	€ 450.000	€ 350.000
Operating cost saving	7%	7%	6%
NPV € (x1,000)	1.136	1.050	872
IRR	48%	34%	36%
Earn back period	3	4	4

NPV = Net Present value; IRR = Internal rate of return

From the above it is concluded that installing an adjustable tunnel on a 110 ship operating on the Rhine proves economically attractive with a high positive NPV and IRR, and a reasonable earn back period of 3 years. The results are however sensitive to the investment costs as well as to the projected efficiency gain. This the latter drops below 5% earn back period would rapidly rise.

6.3. Business case “85m ship” as coupled convoy

The advantages of a coupled convoy are assessed using an 85m ship as the example ship. Operational data is taken from the Herso-1, owned by Plimsoll and operated on the Danube in a coupled convoy pushing the barge SL Leinie. Main dimensions of such a convoy can be found in the following table.

	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
Average cargo load	1050 t	200 t

If the barge is placed in front of the ship the entire combination has a length of 155.7 m. The barge can be placed in front, e.g. when sailing upstream, or alongside, when sailing downstream.

Figure 16 – Impressions of Herso 1

Modification:

To allow a normal 85m ship (like the Herso) to operate in coupled convoy formation, the motor vessel needs to be equipped with pushing-shoulders at the bow and the pushed vessel is fitted with a saddle structure. Due to the discontinuous connection between the pushing vessel and the barge, a hydro-dynamically suboptimal coupled convoy has been derived, resulting in an additional power demand of 80 % is assumed to obtain the same speed of the motor vessel. As the installed engine power remains the same, coupled convoy will sail at a lower speed, however, carrying more cargo. An extension of accommodation to allow for an extended crew was not needed, as the one on the pushed vessel is left available. Moreover, the convoy is assumed to operate in the same 14h mode: the crew is to be extended with only one crew member.

Effect on cost components due to modification:

- Investment costs are estimated with €0.5mln due to the acquisition of a second-hand vessel and the modifications that have to be conducted on the ship yard and installation of the coupling winches.
- Labour costs increase with €20,000 per year due to the crew extension.
- Fuel consumption per hour remains the same, as the propulsive power is unchanged (This yields also for lubrication). The sailing time will however increase.

Due to the lowering of the sailing speed, the complete cost structure will change, as fixed costs as well as voyage related costs are influenced.

Simulation results

The modification of an 85m ship to a coupled convoy leads to the following results when operated on the Rhine. Compared to the single-sailing version, the average number of non-operational days remains the same (= zero in reference period and 0.5 in the future period) .

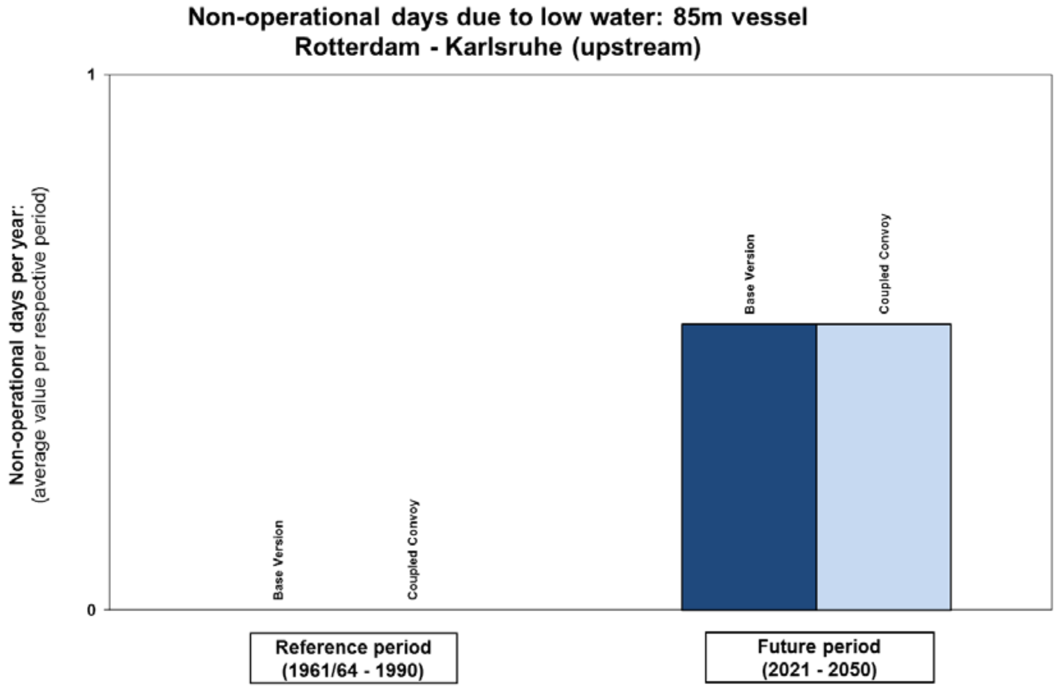

Figure 17 – Comparison of non-operational days due to low water for an 85m vessel and coupled convoy

However, due to the increased amount of transported cargo, the transport costs per unit cargo reduce considerably, even when a pessimistic water level scenario is considered.

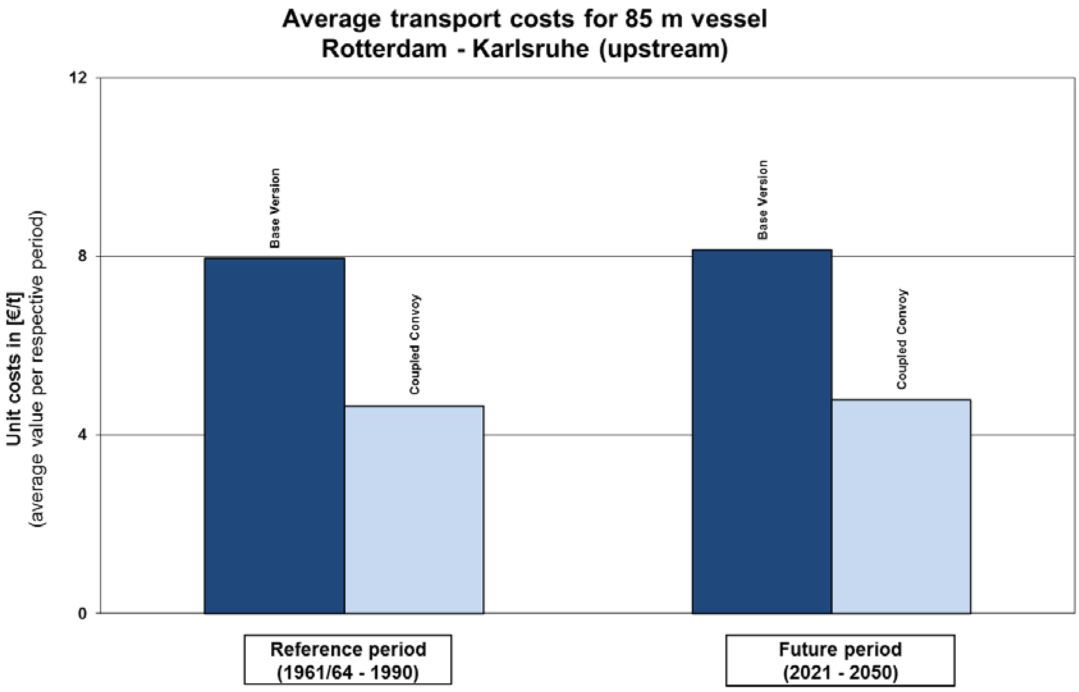

Figure 18 – Comparison of average transport costs for an 85m vessel and coupled convoy

Analysis results

At the maximum draught of 2.50m the cargo capacity has been approximately doubled: from 1.250 t to 2.400 t.

The results for a modified 85 m vessel to apply a coupled convoy model are as follows:

- Estimated investment costs: € 0.5 mln (incl. purchase of the barge). This is an expert estimate.
- Resulting operating cost (using the Cost model presented above) of € 4,66 EUR/ton as coupled convoy compared to € 7,95 EUR/ton in the without situation in the reference period
- Estimated off-service time to implement the modification: 2 weeks. This is an expert estimate.

For operational data use was made of information gathered on the Herso-1 as part of MoVe IT! task 7.2, noting however that the real Herso-1 already operates as a coupled convoy but on the Danube rather than the Rhine. For the analysis undertaken here however this does not matter.

When applying these results into the economic feasibility scheme, the following results are found:

Table Economic feasibility of an 85m ship operated in coupled convoy

	Base case	Lower investment cost	Higher efficiency gain
Investment cost	€ 0.5 mln	€ 0.25 mln	€ 0.5 mln
Operating cost gain	41%	41%	50%
NPV (x1,000)	€ 267	€ 474	€ 415
IRR	12%	27%	15%
Earn back period (years)	9	5	9

NPV = Net Present value; IRR = Internal rate of return

The results show that while the operational gain is very high with 41% lower operating costs per ton, due to the relatively high investment costs compared to the overall ship's capacity, the earn back time is still quite long with about 9 years. It is not likely that even higher efficiency gains would be realised, and even with a 50% reduction of costs per ton transported the case remains commercially unattractive. The main reason of this is twofold:

- The relatively high investment costs. If these could be lowered, notably through the purchase of a cheaper barge (or if the company concerned already has these available), earn back period can be reduced substantially.
- The relatively low transported volume reported for the Herso-1. This of course relates to the fact that the ship operates on the Danube rather than the Rhine. If a doubling of the volume would be achieved (from 18.000 to 36.000 tons per year) or if a larger barge occupancy would be achieved, earn back time would reduce to 4 years, which is considered a feasible option.

7. Conclusion / outlook to next steps

7.1. Conclusions

While already today the IWT sector faces low water periods on the Rhine and the Danube, analytical work from ECCONET and KLIWAS indicate that major worsening is only to be expected in the second half of this century, which is beyond the time horizon of retrofit solutions investigated within MoVe IT!.

Still, also in the current situation, improvements to ships that reduce their draught may contribute to improved performance in low water operating conditions. Especially larger sized ships (larger draught) are susceptible to low water periods, and their operating costs will increase extensively. Smaller sized ships on the contrary, having a much lower draught are much less vulnerable to water fluctuations, but do face a scale disadvantage against larger-sized ships. As the current EU IW fleet contains a substantial number of these ships, considerations to increase their performance while maintaining their low water advantages could be worthwhile.

A number of technologies have been identified that would contribute to lower draughts of ships. However most of these are very costly and only realistic in the case of implementation on newly built ships. In the context of MoVe IT!, looking at retrofit possibilities for existing ships, two specific options were identified and assessed, making use of climate change scenarios from ECCONET for the period 2021-2050:

- The implementation of an adjustable tunnel on a 110m ship. This application, with an estimated investment of € 350.000, would result in an average lowering of the transport costs by 7%. The case was found to be economically feasible, and would have a payback time of 3 years.
- The use of coupled convoy formations for an 85m ship. This application, with an estimated investment of € 0.5 mln, would result in an average lowering of the transport costs by 41%. Such an investment would become feasible at operating levels of around 36,000 tons transported per year; a payback time of 4 years would then be achieved.

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7.2. Recommendations

The analysis of task 6.5 has shown that climate change will on the long term (after 2050) result in substantially longer periods of low water causing capacity and operating costs impacts for the IWT sector. For the first half of the 21st century however, the time horizon for retrofit options as assessed in MoVe_IT!, impacts from various climate scenarios are fairly limited.

Still, as low water is also a problem for vessels today especially on rivers like the Rhine and Danube, retrofit options to better cope with this are worthwhile to investigate.

From the results of the task 6.5 analysis, it is recommended to:

- Assess the need for installation of adjustable tunnels on 110m ships operating on the Rhine
- Explore the availability of second-hand barges that would suit coupled convoy operations. This could be beneficial not only in shallow water periods but raise the competitive position of small ships in general as well
- Put more effort in investigating climate change impacts for the Danube river, as already done in projects like KLIWAS and ECCONET for the Rhine.

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9. Indexes

9.1. Index of Figures

9.2. List of Abbreviations

CCR-ZKR	Central Commission for Navigation on the Rhine
ECCONET	Effects of Climate Change on the inland waterway NETwork
GMS	Large Rhine Ship
IRR	Internal Rate of Return
IWT	Inland Waterways Transport
JW	Johan Welker
KLIWAS	Impacts of various discharges on transport costs and capacity on Inland Waterway Transport on the Rhine
NPV	Net Present Value

WP	Work Package

10. Annexes

10.1. Public summary (mandatory - for each deliverable)

While already today the IWT sector faces low water periods on the Rhine and the Danube, analytical work from ECCONET and KLIWAS indicate that major worsening is only to be expected in the second half of this century, which is beyond the time horizon of retrofit solutions investigated within MoVe IT!.

Still, also in the current situation, improvements to ships that reduce their draught may contribute to improved performance in low water operating conditions. Especially larger sized ships (larger draught) are susceptible to low water periods, and their operating costs will increase extensively. Smaller sized ships on the contrary, having a much lower draught are much less vulnerable to water fluctuations, but do face a scale disadvantage against larger sized ships. As the current EU IW fleet contains a substantial number of these ships, considerations to increase their performance while maintaining their low water advantages could be worthwhile.

A number of technologies have been identified that would contribute to lower draughts of ships. However most of these are very costly and only realistic in the case of implementation on newly built ships. In the context of MoVe IT!, looking at retrofit possibilities for existing ships, two specific options were identified and assessed, making use of climate change scenarios from ECCONET for the period 2021–2050:

- The implementation of an adjustable tunnel on a 110m ship.
- The use of coupled convoy formations for an 85m ship.

The analysis of task 6.5 has shown that climate change will on the long term (after 2050) result in substantially longer periods of low water causing capacity and operating costs impacts for the IWT sector. For the first half of the 21st century however, the time horizon for retrofit options as assessed in MoVe IT!, impacts from various climate scenarios are fairly limited.

Still, as low water is also a problem for vessels today especially on rivers like the Rhine and Danube, retrofit options to better cope with this are worthwhile to investigate.

From the results of the task 6.5 analysis, it is recommended to:

- Assess the need for installation of adjustable tunnels on 110m ships operating on the Rhine
- Explore the availability of second-hand barges that would suit coupled convoy operations. This could be beneficial not only in shallow water periods but raise the competitive position of small ships in general as well
- Put more effort in investigating climate change impacts for the Danube river, as already done in projects like KLIWAS and ECCONET for the Rhine.

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10.2. User Manual

Not applicable

10.3. Training Material

Not applicable

10.4. Other Annexes

Not applicable