MANAGEMENT OF **WEATHER** EVENTS IN THE **TRANSPORT** SYSTEM

SEVENTH FRAMEWORK PROGRAMME

Guidebook for Enhancing Resilience of European Inland Waterway Transport in Extreme Weather Events

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List of Abbreviations

CLIMATE-ADAPT: European Climate Adaptation Platform

CEF: Connecting Europe Facility

FIS: Fairway Information Services

HNWL : Highest Navigable Water Level

ICPDR: International Commission for the Protection of the Danube River

ICT: Information and communication technologies

IPCC: Intergovernmental Panel on Climate Change

ISRBC: International Sava River Basin Commission

IWT: Inland Waterway Transport

LNWL: Low Navigable Water Level

MWL : Mean Water Level

RIS: River Information Services

SEE: South East Europe Transnational Cooperation Programme

TEN-T: Trans-European Transport Networks

UNECE: United Nations Economic Commission for Europe

WFD: Water Framework Directive

The MOWE-IT project: The goal of the MOWE-IT project is to identify existing best practices and to develop methodologies to assist transport operators, authorities and transport system users to mitigate the impact of natural disasters and extreme weather phenomena on transport system performance. The project is funded by the European Commission's 7th RTD framework programme between October 2012 and September 2014. MOWE-IT is co-ordinated by the Technical Research Centre Finland (VTT) and involves 12 European research institutes and companies. For more details please consult our website www.mowe-it.eu.

The main task of this guidebook was to draft policy recommendations and to design a long-term development plan for the implementation of the recommended policy actions, based on the results of comprehensive literature research, in house information and stakeholder interviews. This development plan will assist in the preparation of the inland waterway transport sector for the forthcoming periods, and enable it to maintain or even upgrade its competitiveness as an environmentally friendly, cost efficient and reliable mode of transport.

This guidebook pulls together recent knowledge and good practice cases on the risk changing weather patterns impose on the inland waterway transport sector and how they can be tackled best with short, medium and long-run strategies. Despite concentrating on European case, events and solutions worldwide are monitored to enrich the knowledge basis as far as possible.

It is written mainly for use by policy-makers, public authorities, waterway management authorities and transport professionals like weather data services, port operators as well as logistic service providers.

Executive Summary

Inland waterway transport is expected to stay a reliable and cost-effective transport mode.

Inland waterway transport (IWT) is a cost-efficient and environment-friendly mode of transport. It is associated with a high degree of reliability and safety, as well as the lowest noise emissions being reflected in the lowest external costs related to one ton (t) of cargo transported over one kilometre (km), compared with other modes of transport.

Extreme weather events relevant to inland waterway transport are low-water events (drought), high water events (floods) and ice occurrence. Of less importance are wind gusts and reduced visibility. There is no convincing evidence that low-water events will become significantly severer on the Rhine as well as the Upper Danube in the near future. On the Lower Danube some impact of drought in association with increased summer heat might appear, demanding however dedicated research. Related to high-water events no reliable statement with respect to increase of discharge and frequency of occurrence can be given. However, consideration of floods on inland waterways will remain important also in the future due to reasons related to flood protection.

In the Rhine-Main-Danube corridor no decrease in the performance of inland waterway transport due to extreme weather events is expected until 2050. As a consequence, **inland waterway transport is expected to stay a reliable and cost-effective transport mode.** For the more

distant future (2071-2100), the costs of inland waterway transport are projected to increase more significantly in Danube and Rhine waterways due to adverse impacts of climate change.

Nevertheless the implementation of short-term measures presented in this guidebook will improve the navigation conditions already today. The inland waterway transport sector will benefit from these measures immediately, not only in an uncertain future. Long-term climate change adaption strategies and related measures shall become part of an overall long-term European inland navigation policy. The adaptation needs in particular refer to the year 2050 and beyond when climate change is projected to change the discharge characteristics of the Rhine-Main-Danube corridor more significantly.

Promising Adaptation Strategies

Improving the inland waterway infrastructure by implementation of the respective TEN-T priority projects acknowledged by the European Commission as well as national activities will have a significant positive impact on the reduction of the vulnerability of inland waterway transport to extreme weather events today and in the future. Further measures with high potential comprise the development of customer oriented waterway management as well as River Information Services and new ICT technologies.

Framework Conditions

Climate change is scientifically confirmed worldwide, inter alia, by the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC).

At the European level, the most important policy documents on adaptation to climate change for the water sector are the EC White Paper on Adaptation, the EU CIS Guidance No. 247, beside the Guidance on Water and Adaptation to Climate Change, which was developed in the framework of the United Nations Economic Commission for Europe (UNECE). The European Climate Adaptation Platform (CLIMATE-ADAPT) is currently accessible under the domain name http://climate-adapt.eea.europa.eu. A short description of the most important documents is given in Annex, Table 1.

Long-term climate change adaption strategies and related measures shall become part of an overall long-term European inland navigation policy.

Major Impacts to Inland Waterway Transport

Most significant extreme weather events result from high precipitation, droughts, as well as temperatures below zero Celsius degrees.

Climate change is neither a new or discontinuous phenomenon, which is expected to change from one day to another one. Extreme weather events have been occurring in the past and today, and the European transport sector has taken and is taking efforts in order to cope with such events to a greater or lesser extent. In the light of a projected accelerated change of the climate it is often assumed that extreme weather events are going to increase in severity and frequency.

Similarly to other modes of transport, inland waterway transport has to deal with weather events, affecting navigation conditions and the infrastructure on inland waterways.

European Inland Waterways

The most significant European inland waterways are presented in Fig. 1, being located in the North-South Corridor, the Rhine Corridor, the South-East Corridor and the East-West Corridor.

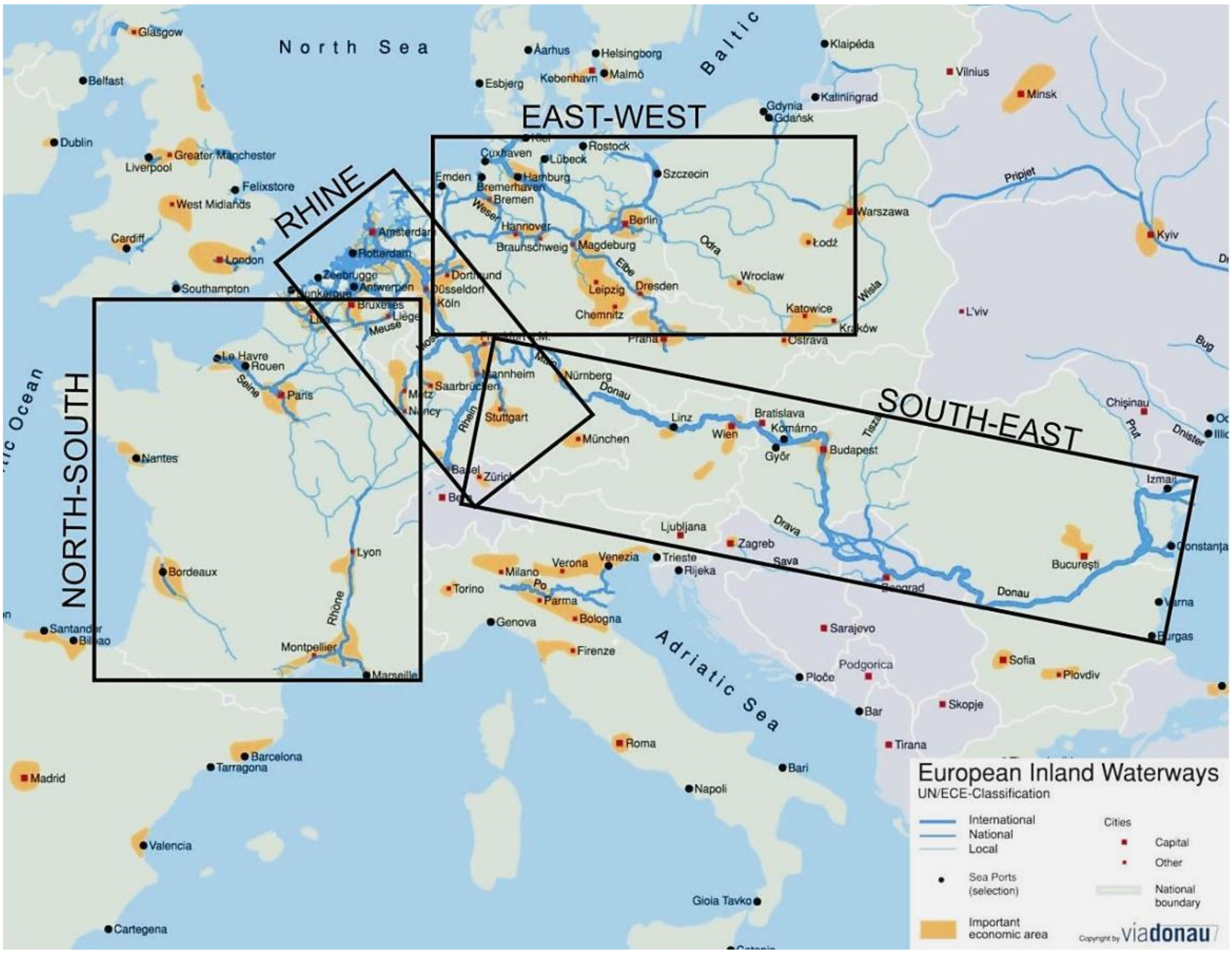

Figure 1: Overview of European inland waterways.

The focus is on the Rhine-Main-Danube Corridor, where highly important inland waterways such as the Rhine, the Main, the Main-Danube-Canal and the Danube are located. In this corridor, a variety of different geographical, meteorological and hydrological domains are present, as well as transporting highest amount of cargo by means of inland waterways in Europe, allowing for a comprehensive consideration of the topic.

For inland waterway transport, it is not possible to give a single general meteorological criterion (e.g. amount of precipitation during a time period) for the evaluation of whether a critical weather situation is affecting the inland waterway transport system adversely. The reason may be traced to the complexity of the transport system and the variety of factors determining whether a weather constellation is becoming critical or not. For instance, discharge, water levels and flow velocities determining the navigation conditions of inland waterways are affected by the intensity and duration of precipitation, the location of its occurrence, melting ice and snow, evaporation and the geometry of the river under consideration. Whether a weather event becomes critical depends on the flow regime of a river, which is seasonally and locally varying.

Critical Weather Phenomena

The weather phenomena symbolised on the map in Figure 2 (see next page) are those identified as the most common extremes with identifiable consequences, i.e. heavy rain, heavy snowfall, extreme winds, extreme heat, drought, and visibility.

Most significant extreme weather events result from high precipitation, droughts as well as temperatures below zero Celsius degrees. Heavy rainfall, in particular in association with snow melt, may lead to floods resulting in suspension of navigation and causing damage to the inland waterway infrastructure as well as the property and health of human beings living in areas exposed to flooding. Navigation on the Moselle, the Saar, and the Neckar, as well as on the German Danube and the Danube from the Austrian-Hungarian border till the Iron Gates is susceptible to the occurrence of high waters. For example, on the Neckar, suspension of navigation due to high water may exceed 30 days a year in severe cases. Navigation on the Middle Rhine and the Main-Danube Canal is not susceptible to the occurrence of high waters.

Long periods of drought may lead to reduced discharge and low water levels limiting the cargo carrying capacity of vessels and increasing the specific costs of transportation. The occurrence of drought in association with heat waves can affect transport on the Rhine through restricted water depths. Other critical waterway sections with respect to low water occurrence and relevance to the cargo-carrying capacity of vessels are the stretch between Straubing and Vilshofen on the German Danube, the free-flowing sections in the Wachau and between Vienna and Bratislava on the Austrian Danube, and the free-flowing sections between Gabcikovo and Budapest as well as Budapest and Mohács on the Hungarian Danube.

Nevertheless, it has to be noted that climate change impacts may have also positive effects e.g. reduced ice occurrence on certain inland waterways. Ice occurrence leading to suspension of navigation is possible on almost the whole Danube, even on the lower part of it. Very high susceptibility of navigation with respect to ice occurrence is present on the Main-Danube Canal, where navigation may be suspended by more than 40 days a year in severe cases. In the Rhine area navigation is not affected by ice occurrence.

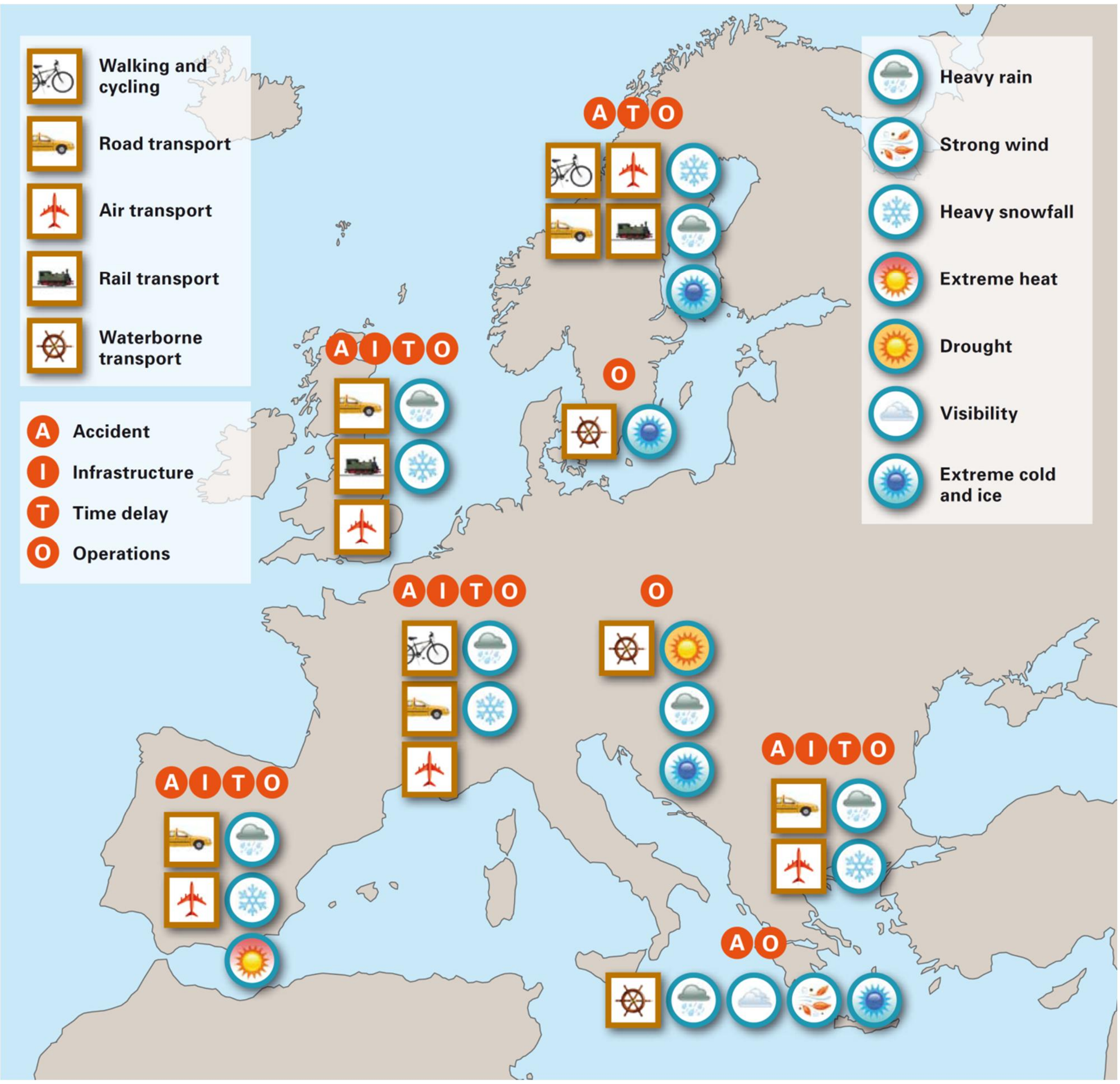

Figure 2: Sum-up of critical weather phenomena, their occurrence by region where effects are the most severe, with the most affected modes of transport and the consequences (FP7 EU project EWENT).

Wind gusts are expected to remain on the same level as today, thereby not decreasing the safety of inland waterway transport. Visibility seems to improve if results for European airports are considered, thereby improving the safety of inland waterway transport as well as operation of inland waterway vessels.

Major impacts to inland waterway transport as well as consequences to infrastructure and operations are given in Annex, Table 2.

Introduction of Adaptation Strategies

Using the knowledge gained with respect to changes in hydrology and navigation conditions, the impact of climate change and extreme weather events on inland waterway transport could be evaluated and assessed.

Considering the European transport system, amongst others, the projects ECCONET, EWENT, WEATHER and Knowledge for Climate have recently been carried out, proposing the following set of policy actions in order to meet above mentioned impacts on inland waterway transport.

The inland waterway transport sector will benefit from proposed adaptation measures immediately, not only in an uncertain future.

1. Continuous observation of climate change impacts on IWT and research
2. Support the adaptation and modernization of the IWT fleet
3. Development of adaptation measures for infrastructure maintenance
4. Development of adaptation measures for infrastructure planning
5. Stronger cooperation of waterway administrations
6. Permanent and pro-active cooperation of river commissions
7. Preparation of ports for efficient handling of adapted/modernized vessels
8. Enhanced use of Information and Communication Technology "smart waterways"
9. Improved hydrological predictions
10. Logistic management

Continuous Observation of Climate Change Impacts on IWT and Research

Due to the simplifications of the models used for the evaluation of climate change impacts and unknown exact development of the greenhouse gas emissions, it is clear that there remain many uncertainties with regard to the implications of climate change, and the viability of potential mitigation or adaptation responses. Whilst uncertainty should not be used as an excuse for inaction, there are clearly many areas where research might generate new solutions or improve confidence in others. Further developments in relevant technologies to mitigate the effects of climate change are also urgently needed.

Uncertainty in weather predictions should not be used as an excuse for inaction – there are many areas where research might generate new solutions.

There is a number of areas where ongoing or new research is required to enable the inland waterway sector to further reduce its contribution to global warming, and to improve its ability to adapt to the consequences of climate change. The Government, navigation authorities and other relevant partner organisations as appropriate should therefore support measures that seek to:

- Develop alternative fuels/sources of energy, including bio-fuels, alternative energies, hybrid engines, fuel cell technology, also hull design

- Explore options for improving the resilience of assets and infrastructure including use of (drought tolerant) vegetation in engineering
- Improve innovation in water conservation and identify new water resources and storage opportunities
- Research and promote additional measures to reduce sediment in run-off reaching water bodies
- Better establishing the carrying capacity of natural systems and water-ecology interrelationships
- Investigate alternatives or improvements to avoid or minimise the adverse effects of dredging
- Improve understanding of vectors for transfer of alien species and methods for the management or eradication of alien species
- Explore and exploit ‘win-win’ options for habitat creation or restoration schemes.

Adaptation Strategy: Infrastructure

The quality of infrastructure directly affects cost efficiency and service quality of inland waterway transportation. In particular the conditions of the fairway and existing bottlenecks directly influence the degree of vessel utilisation, load factors and the quality of service such as the delivery speed and time reliability. Therefore, waterway maintenance, and especially the maintenance of the fairway’s guaranteed or recommended depth, is of crucial economic importance.

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Interventions on waterways involve many sectors (transportation, agriculture, water supply, power generation, tourism, etc.). Therefore an integrated approach towards the development of infrastructure adaptation measures requires an adequate funding by the public waterway administrations and has to address the following areas:

- Development of innovative methods for the improvement of river monitoring (shear stress, sediment transport, morphodynamics etc.);
- Development and programming of numerical models (3D hydrodynamics, sediment transport and habitat modelling);
- Development and optimisation of river engineering works in order to improve navigable conditions in line with the minimisation of river bed degradation, the optimisation of flood protection and maximisation of improvements in environmental conditions.

Among the investigated adaption options for reducing the negative impact of climate change on inland waterway transportation, an improved infrastructure management carried out by the waterway administrations must be considered as most relevant and essential for a successful adaption strategy. Despite the relatively modest overall impact of climate change at short and mid-term perspective, the high impact of low-water situations on the efficiency and thus on the competitiveness of inland waterway transportation requires changes in short-term, mid-term and long-term maintenance and engineering strategies. These strategies should include different sets of measures in order to provide adequate responses to different climate change impact scenarios:

- Short-term adaptation measures mainly address continuous waterway maintenance activities and strategy: In case of changing water discharge patterns (e.g. altered seasonality of low water periods) the fairway maintenance cycle (surveying, dredging and provision of information) shall be accordingly adapted on the time axis. This includes an optimal timing of the necessary dredging works during the year which takes into account changing temporal distributions of the river's water discharge. Improved utilisation of the fairway can be achieved by provision and usage of up-to-date comprehensive information on the fairway conditions as well as implementation of concepts like “fairway-in-the-fairway”. For this purpose waterway administrations need to have sufficient and modern surveying equipment (i.e. surveying vessels and software for data processing and analysing). The purchase of such specialized equipment should be co-funded with the help of European funding schemes (e.g. TEN-T and Structural Funds).

- Another important climate change adaptation measure for waterway administrations should be the continuous and differentiated monitoring and analysis of the development of the river’s water discharge regime. The currently used statistical water level reference indicators (LNWL – Low Navigable Water Level, MWL – Mean Water Level, HNWL – Highest Navigable Water Level) represent statistical values based on a long-term (30 years) time series. In order to better evaluate and recognise potential climate change effects shorter statistical time series should be additionally taken into account (e.g. 10 years) which would allow better to monitor potential (mid-term) alterations of the water discharge regime. Furthermore, waterway administrations could develop additional indicators for alterations in the water discharge regime. Such indicators could include long-term seasonal analysis of the water discharge regime, as well as a dynamic analysis of low water conditions: e.g. the lowest water levels within a series of consecutive days (e.g. 3, 5, 7, 10, 21 days).

- Medium and long-term measures include structural modifications of river engineering works as an adequate response to more severe climatic changes. The adaptation of the waterway infrastructure via river engineering works (e.g. groynes and training walls) should be undertaken on the basis of a continuous monitoring of the effectiveness of these elements, whereby the monitoring intervals have to be adjusted to the changes in the discharge regime as well as the river morphology (as the frequency of changes increases, monitoring intervals should become shorter). This means that the life-time of river engineering works will most probably not be up to 100 years (as calculated in the past), but significantly shorter. In case of such a changing framework, these river engineering works will have to be adapted accordingly e.g. by lengthening/shortening and/or heightening/lowering of such structural elements. In order to respond to these new requirements, waterway administrations need to foresee respective budgets. These budgets must be planned and allocated in addition to the conventional budget for maintenance measures like surveying and dredging.

Adaptation Strategy: Sustainable Waterway Planning

Apart from the maintenance of the fairway of inland waterways for the purpose of meeting the recommended fairway parameters, infrastructure work on waterways may also include the improvement or extension of the existing inland waterway network. The improvement of a waterway pertains to the upgrade of its UNECE waterway class or to the removal of so-called "infrastructural bottlenecks". The extension of the network can be the construction of new waterways which in some cases, according to the AGN, may be described as "missing links".

A truly integrative waterway management system will succeed in balancing the needs of inland waterway transport infrastructure and the natural or ecological functions of the rivers.

The maintenance, improvement and extension of inland waterways should always be accomplished by taking the following two main aspects of inland waterway infrastructure development into account:

- Economics of inland navigation, i.e. the connection between the existing waterway infrastructure and the efficiency of transport
- Ecological effects of infrastructure works, i.e. balancing environmental needs and the objectives of inland navigation (integrated planning)

Environmentally sustainable Danube navigation

Large river systems such as the Danube are highly complex, multi-dimensional, dynamic ecosystems and thus require comprehensive observation and management within their catchment area. Such a holistic approach is also required by the Water Framework Directive (WFD) of the European Union (European Commission 2000). For international river basin district entities such as the Danube the WFD requires the coordination of international river basin management plans which also involve non-EU member states wherever possible. In the Danube river basin district, the International Commission for the Protection of the Danube River (ICPDR) is the platform for the coordination of the implementation of the WFD on the basin-wide scale between the Danube countries.

In 2008, the ICPDR, the Danube Commission and the International Sava River Basin Commission (ISRBC) endorsed a Joint Statement on Guiding Principles for the Development of Inland Navigation and Environmental Protection in the Danube River Basin (ICPDR, 2008). The statement provides guiding principles and criteria for the planning and implementation of waterway projects that bring together the sometimes conflicting interests of navigation and the environment. It opts for an interdisciplinary planning approach and the establishment of a "common language" across all disciplines involved in the process.In order to facilitate and ensure the application of the Joint Statement, a Manual on Good Practices in Sustainable Waterway Planning has been developed by the ICPDR and relevant stakeholders in the Danube region within the framework of the EU project PLATINA in 2010 (ICPDR, 2010). The basic philosophy is to integrate environmental objectives into the project design, thus preventing legal environmental barriers and significantly reducing the amount of potential compensation measures.

The Manual proposes the following essential features for integrated planning:

- Identification of integrated project objectives incorporating inland navigation aims, environmental needs and the objectives of other uses of the river reach such as nature protection, flood management and fisheries
- Integration of relevant stakeholders in the initial scoping phase of a project
- Implementation of an integrated planning process to translate inland navigation and environmental objectives into concrete project measures thereby creating win-win results
- Conduct of comprehensive environmental monitoring prior, during and after project works, thereby enabling an adaptive implementation of the project when necessary

Adaptation Strategy: Information and Communication Technology

The usage of ICT would contribute considerably to managing navigability by providing amongst others up-to-date on-line information on water depths and estimated time of arrival.

The use of ICT systems and the use of ICT in the waterway (Smart Waterways) for inland navigation is one of the most feasible measures on a short term.

ICT can lead to a better exchange of traffic and cargo information. The systems which are developed from now until approximately 5 years are River Information Services (RIS), barge planning and a management information system for inland container shipping.

ICT is increasingly used to improve the efficiency of the logistics chain and the lead time of the transportation of cargo. Besides, ICT is used for safe and efficient navigation on the waterways by providing the skipper traffic information amongst others about: waiting times at locks or bridges, waterway conditions and the most efficient route of navigation, in order to save fuel and thus to navigate more environmentally friendly.

Navigability can be improved by providing up-to-date on-line information on current and expected water depths in the shipping route, expected bed topography, as well as real-time draught and trim of the vessel.

Use of ICT in inland navigation would contribute considerably to managing navigability (increase in depth). Both public and private parties are heavily investing in the development of ICT systems for exchanging traffic and cargo information that has so far resulted in a number of operational systems. It is not clear which system will be the future standard. Yet, the success of these systems is largely determined by the number and variety of stakeholders (Government, Port Authorities, barge operators, shippers) that use the system.

- A major challenge is to link the relevant information and systems, to provide all the parties concerned the necessary information that needs to be shared. Therefore it is important to either create generally accepted ICT-systems or to make existing systems compatible. This cooperation can be at governmental level, like the development of River Information Services (RIS), but also by the cooperation of private organisations.

  RIS are modern traffic management systems that provide swift electronic data transfer public and private parties participating in inland waterborne transport: entrepreneurs, captains, waterway authorities and other public institutes. The information is shared on the basis of information and communication standards.

The general objectives of RIS are:

- o Enhancement of inland navigation safety in ports and rivers
- o Optimise the resource management of the waterborne transport chain by enabling information exchange between vessels, lock and bridges, terminals and ports
- o Better use of the inland waterways by providing information on the status of fairways
- o Environmental protection by providing traffic and transport information for an efficient calamity abatement process
- o As regards the status of fairways, the Fairway Information Service portal (FIS, being part of RIS) is a single window for all infrastructure information. It supports the exchange of information on waterway conditions and circumstances that influence navigation (floods, droughts, obstructions etc.)

- Smart Waterways would aim at collecting, recording, visualizing and sharing information on water depths. Gains are expected in efficient sailing in times of low water levels from the reporting of up-to-the-minute water depths, water depth forecasts for the coming days and shipments of goods. The navigability monitoring and forecasting system will be based on the echo sounders that are normally mounted on ships plying the river, a data acquisition and processing system, a hydrological low-water forecast model, a morphological bed-topography forecast model and data-assimilation techniques to use measured data for updating real-time navigability forecasts.

- Therefore the use of these systems asks for strong promotion. Support is needed for the extension of functions and the integration of these systems. A bottleneck to enlarge usage and usability is the lack of budget and/or cooperation among (market) parties.

Support to the Adaptation and Modernization of the IWT fleet

Public support to the adaptation and modernization of various segments of inland waterway transportat is most commonly materialized through:

- Research and innovation activities as part of national and European RTD activities
- Adequate legislation and creation of an efficient and harmonized regulatory framework
- State-aid schemes which stimulate the transition to innovative, adapted, efficient and more environmentally friendly vessels

Any modernization measure to be taken has to be technically as well as economically feasible.

The research activities carried out as part of national and European research and innovation programs will have to improve the reliabilty and the economic performance of inland waterway transport in the case of the occurrence of extreme weather events, in order to remain competitive. The measures to be taken can be subdivided in measures with direct impact on the ship performance at the extreme weather event e.g. reduced ship draught by lengthening of a vessel, and measures with a positive impact on the economic performance of a vessel in general, and in particular, at occurrence of an extreme weather event, e.g. reduction in fuel consumption by improved propulsion devices. The research activities will have to address the following topics in general:

- New power system configurations
- Retrofitting techniques for existing engines
- Ship structural materials
- Improved hull configurations and propulsion
- Assistance systems for energy- and cost-efficient sailing with ships adapted to altered navigational conditions due to negative effects of climate change
- Education- and training standards, facilities and – classes for energy-efficient navigation

The general research activities can be divided in numerous selected sub-topics which are described in detail in Annex Table 3, Annex addressing the following issues:

- Power system configurations
- Retrofitting of existing engine systems
- Ship structures;
- Improved hulls and operational configurations
- Improved propulsion
- Energy- and cost-efficient sailing

Continuous research and investment processes are important in order to provide the market with efficient, clean and safe technical solutions, practices and approaches. This is also needed in order to retain a competitive advantage in terms of greenhouse gases emissions and safety levels.

Specific funding opportunities for research and innovation in IWT technologies aimed at adapting to the climate change effects will have to be provided in the EU research and innovation programs like Horizon 2020 and their deployment in the Connecting Europe Facility (CEF) as well as on a transnational level in the framework of European territorial cooperation.

The situation with economic and legislative incentives to modernise is somewhat different, and varies from country to country. The study “Medium and Long Term Perspectives of IWT in the European Union” (NEA, 2011) indicated that there is a significant lack of both economic and legislative incentives for fleet modernization. The study provides an example of end-of-pipe treatment technologies which significantly reduce pollutant emissions but are often not implemented, even if subsidies are available, since they add operational costs instead of adding value to the individual entrepreneur. Additional incentives are needed and will make it easier for the engine, equipment and shipbuilding industry to develop innovative solutions to reduce vessel draught, air pollutant and greenhouse gas emissions.

The burden to adapt the vessel technology to altered navigational conditions cannot be placed on the vessel owners alone. This is particularly the case because the low capability to invest in modern vessel equipment is a consequence of the low profit margins, caused by an extremely tough competition among the barge operators. Whereas the Western European system of small business owners (Partikuliere, with just one or a few barges) limits investment capabilities, the poor infrastructure status in the east on the Danube deprives the owners of profits needed for re-investment.

The entire system of inland waterway transportation is of crucial importance for a sustainable economic development in Europe and therefore deserves the full attention of both national and supranational authorities, who will have to come up with acceptable economic and legislative incentives as well as a harmonized and transparent regulatory framework to enable easier renovation and adaptation of IWT fleet in the medium and long term.

Preparation of Ports for Efficient Handling of Adapted and Modernized Vessels

Inland ports often have been neglected in national transport policies and infrastructure development plans despite their important role as multimodal nodes and centres for regional economic development. Nevertheless, the competitiveness of inland waterways transportation and multimodal logistics chains heavily depends on the efficiency of port operations.

In order to meet the challenges of operation under predicted altered navigational conditions and with modernised and adapted inland vessels, inland ports will have to develop dedicated long-term adaption strategies and plans.

There are approximately 1.500 inland ports on the European continent. More than half of those ports are located along the main corridors of the TEN-T inland waterways network. All of them have an important regional and local role in the development of clusters of economic centres of industry and logistics, as well as in the development of job creation in the affected regions. Furthermore, they are inevitable and important links in transport chains and contribute to the added value of logistics.

Many inland ports are located in the strategic hinterland of the gateway seaports. Inland ports are therefore increasingly serving as back up and feeder for the major European seaports and can be a part of the solution for the congestion in the seaports. Taking into consideration the reality of economic and transport flows, it is clear that a sustainable European transport system requires strong co-modality and therefore more focus on inland ports as enabler of cost-effective and reliable logistics chains.

In order to meet the challenges of operation under predicted altered navigational conditions and with modernised and adapted inland vessels, inland ports will have to develop dedicated long-term adaption strategies and plans. Among the related measures there will be the following activities:

- Adaptation of working hours of ports & terminals for handling vessels adapted for continuous operations
- Provision of adequate berths, anchorages and shore equipment to handle larger number of vessels due to increased convoy size
- Infrastructure adjustments/provision of vertical quays in order to accommodate transhipment even under extreme low water conditions
- Improved fairway maintenance in port areas (eg. optimized dredging;
- Upgrade of transhipment facilities enabling transhipment under extreme low water conditions and providing cost-effective throughput capacity for alternating volumes
- Increase storage capacities for increased seasonal logistics buffers and additional value added services for logistics chain modifications
- Provision of adequate fendering systems (for vessels of higher damage sensitive lightweight structures)

Many ports, especially on the Danube, work only in two daily shifts, with total closure on weekends and during the night. Since continuous (24 hrs/day) operation is gaining in importance, inland ports will have to adjust their working hours according to the operational needs of the fleet operators and their customers.

Another important adaptation measure for the inland waterway transport fleet is the increased operation of coupled convoys where the payload can be distributed to several barges and resulting therefore in lower draught. For inland ports this means that the same quantities of cargo will have to be loaded or unloaded from from/in a higher number of vessels. This will require additional time for berthing/de-berthing manoeuvres, anchoring, loading and unloading and other operational activities. Ports will therefore have to increase the capacity of their berths by increasing capacity of loading/unloading equipment and/or by constructing additional berths with new loading/unloading equipment. Additional space for anchoring may also be needed. Furthermore, depending on the layout of the port basins, a smooth and safe entrance/exit of coupled convoys will require additional infrastructure investment or assistance for de-coupled barges with port tugs or port push-boats.

Some ports, especially those located on riverside (non-basin ports) will need infrastructural adjustments of their quays as more frequent and longer lasting low-water periods will hinder the access to the quays. In extreme cases, entire berths may end up on dry land as result of the reduced water levels and resulting into a break in transhipment operations. In less extreme cases, vessels will not be able to approach close enough to the berth in order to be moored or to be effectively loaded or unloaded from the shore. Therefore, depending on the quay foundation, ports will have to undertake either significant dredging off the affected quays and in its approaches, or to reconstruct entire quays in order to overcome these serious deficiencies.

If ports become faced with operations of ships made of lightweight structures, existing fendering systems along the berths may no longer be adequate. For damage-sensitive vessel hulls, pneumatic fenders seem to be very appropriate as they offer a high energy absorption, low reaction force and surface pressure. Low reaction force prevents the hull, quay, jetty and anchor chain from being damaged.

Stronger Cooperation of Waterway Administrations and Enhanced Use of "Smart Waterways

The cooperation between national waterway administrations has a long tradition in Western Europe in particular in the framework of the Central Commission for Navigation on the Rhine (CCNR). In the Danube region co-operation gained in importance with the enlargement process of the European Union. A good example of a successful cooperation is the project "Network of Danube Waterway Administrations" (NEWADA) and its follow-up project NEWADA DUO executed in the South-East-European Transnational Cooperation Programme (SEE). The project NEWADA duo supports the waterway management authorities of the Danube riparian states in achieving a common level of service in waterway management along the Danube and its navigable tributaries. This improved cooperation focusses on efficient and effective waterway infrastructure maintenance as well as customer-oriented services. The "NEWADA duo" approach of concerted waterway and information management procedures will translate into new benefits for the users. This international project NEWADA duo is yet another milestone in the process of enhancing the cooperation between the waterway authorities in the Danube region.

The focus should be on the development of a state-of-the-art waterway management system as well as on further standardisation and extension of waterway related information.

The existing cooperations provide very positive results and should be continued on a wider, Pan-European level and adequately stimulated through dedicated public funding schemes.

With regard to climate change adaption, a cooperation of waterway administrations will have to focus on the development of a state-of-the-art waterway management system as well as on further standardisation and extension of waterway related information. Such information shall include the following segments:

- Water level information including forecasts
- Actual information on critical / shallow sections
- Accurate information on bridges, ports, locks
- Identification of and access to responsible authorities

The increased cooperation of European waterway administrations could and should lead to enhanced use of so called "smart waterways" providing a selectable array of standardised and detailed information in a user-friendly application as part of River Information Services (RIS). The deepened exchange of knowledge and expertise gained in such a co-operation will also serve strategic aims like:

- Increase of awareness of different stakeholders on climate change impacts on IWT and related industries
- Establishment of a joint "task force" for the purposes of rapid reaction in cases of severe disturbances in navigation caused by hydrological/meteorological phenomena
- Communicating the need of secured long-term finance for infrastructure development and maintenance of the entire waterway network

- Operation of an integrated smart network of waterways across Europe
- Contributions to a comprehensive European research strategy and agenda for river engineering and waterway management as part of an European inland navigation R&D program (in the framework of Horizon 2020)
- Supporting the creation of a European river engineering and inland waterways transportation science partnership with the aim of establishing dialogue between the scientific community, the industry and policy makers

Permanent and Pro-active Cooperation of River Commissions

A stronger cooperation of river commissions should be materialized with the help of a monitoring mechanism on European level.

Although it is a politically sensitive issue, the discussion on the future institutional setting for inland navigation in Europe must come to a concrete output at a mid-term perspective. The magnitude of the economic challenges which the inland navigation sector will have to manage successfully in the future requires a robust and action driven institutional setting which also brings the institutional framework in line again with the achieved status of the integration process of the European Union.

As part of a new and improved institutional setting, a stronger and more detailed cooperation of river commissions should be materialized with the help of a permanent coordinating and monitoring mechanism working on European level. Among the wide array of objectives such a mechanism might have, a certain number also should refer to the adaption and mitigation of negative climate change impacts. Some of those objectives could be:

- Creating a strategy to alleviate the consequences of climate change in river systems
- Enhancing professional qualifications in the sector to ensure availability of skilled personal and attractive job opportunities and to create a business environment of the highest safety standards
- Supporting international efforts to reduce adverse air pollution attributable to waterway transportation
- Creating a European inland waterway space with minimal administrative barriers and with a maximally harmonised legislative and regulatory framework
- Support to the development of a comprehensive inland waterways transport strategy for the next ten years with the overall target to improve the efficiency, competitiveness and environmental performance of inland waterway transportation in Europe
- Support to the implementation of the Joint Statement of Environment & Inland Navigation Development by providing technical assistance
- Issuing guidelines on the application of environmental legislation relevant to ports and waterways
- Encouraging the formation of multi-sector clusters and promoting technological innovation for fleet modernisation, fleet operation, port & terminal infrastructure

Though the river commissions are mainly addressed to deploy these objectives, strong support of all member states of the commission is essential.

Logistic Management

Almost every shipper and transport operator faces the risk of supply chain disruptions. Management of logistics is necessary to identify and quantify these risks and to select appropriate measures to mitigate the effects or to solve supply chain disruptions. Risk strategies can help protect companies to the effects of climate change, as well as contribute to making companies more resilient. Provision of extra storage capacity and longer working hours are measures which have recently been adopted in the logistic process.

Management of logistics and development of risk strategies contribute to more resilient supply chains.

The existing trend towards an increase in the share of direct transhipment and the substitution of storage of goods near production sites may have to be reversed. Bottlenecks will increasingly be caused by variability in water flow conditions, so that industry customers who receive raw material via waterways will have to build storage for their goods in order to avoid delivery delays. New logistic processes, more flexible transport chains and integration with different transport modes may also help.

Navigating more hours per day by inland vessels is a relatively easy way to increase fleet capacity in periods with low water levels. The benefits are determined by estimating the extent to which the load factor of inland vessels is restricted in the low water periods. The loss of revenue that is caused by restricted load factors can then be regarded as the potential benefits that can be achieved by navigating more hours per day.

Companies will be more resilient, and better equipped to reduce damage after major disruptions and to return quickly to the original (or desired) situation, by taking measures such as redundancy, flexibility, transparency and collaboration. If stakeholders wish to prepare themselves for the effects of climate change and other disruptions, a joint effort is required to accomplish this. However, if companies are hesitant to initiate this change, government or port authorities can stimulate this process.

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Annex

Table 1: Important documents addressing the topic of adaptation

Important activities addressing the topic of adaptation	
Document	Description
National communications under the UNFCCC	The national communications (5th or initial) provide an overview of the present and future impacts of climate change and adaptation measures at country level (and one at EU level).
EU White Paper (2009)	The EU White Paper "Adapting to climate change: Towards an European framework for action" calls for a more strategic approach to climate change adaptation across different sectors and levels of governance: *inter alia*, to promote strategies which increase resilience to climate change e.g. by improving the management of water resources and ecosystems, to deliver adaptation actions for flood risk, water scarcity and drought management and river basin management through catchment-based approaches.
EU CIS Guidance No. 24 (2009)	The EU CIS Guidance document shows ways on how to integrate climate change into the 2nd and 3rd River Basin Management (RBM) cycles of the WFD with a special focus on floods and droughts, and on how to ensure that the River Basin Management Plans (RBMP's) are climate-proofed in 2015.
CLIMATE-ADAPT	The European Climate Adaptation Platform (http://climate-adapt.eea.europa.eu) provides information on expected climate change, the current and future vulnerability of regions and sectors, national and transnational adaptation strategies, adaptation case studies and potential adaptation options and tools that support adaptation planning.

Table 2: Major impacts to inland waterway transport [1]

Major impacts to inland waterway				
Heavy precipitation (high water)				
Thresholds	Impacts	Consequences to infrastructure	Consequences to operations/services	Relevant climatic zones
> Highest Navigable Water Level (HNWL) or HNWL + 90 cm (in Austria); the threshold value is locally different providing the responsible authorities with a tentative criterion for decision making	High discharge, high water levels, high flow velocities, changes in sediment transport, occurrence of driftwood, local aggradation, degradation and scour	• Modification of river and bank morphology • Damage to as well as clogging or sedimentation of navigation signs, gauges, ramps and stairs, berths, banks, tow paths, port and lock areas, dams, groins and training walls	• Usually, suspension of navigation • Delays • Vessel damage (e.g. propulsion devices by driftwood)	All
> HWL30 (water level according to a 30-year level of discharge HQ30)	High discharge, high water levels, high flow velocities, changes in sediment transport, occurrence of driftwood, local aggradation, degradation and scour	• Modification of river and bank morphology • Damage to as well as clogging or sedimentation of navigation signs, gauges, ramps and stairs, berths, banks, tow paths, port and lock areas, dams, groins and training walls • Flooding of areas protected against HWL30	• Suspension of navigation • Delays • Vessel damage (e.g. propulsion devices by driftwood)	All
> HWL100 (water level according to a 100-year level of discharge HQ100 = often design water level related to flood protection) + freeboard (approx. 0.5 – 1.0 m, depending on the location)	Very high discharge, high water levels, high flow velocities, changes in sediment transport, occurrence of driftwood, local aggradation, degradation and scour	• Severe modification of river and bank morphology • Severe damage to as well as clogging or sedimentation of navigation signs, gauges, ramps and stairs, berths, banks, tow paths, port and lock areas, dams, groins and training walls • Catastrophic flooding of areas protected against HWL100	• Suspension of navigation • Delays • Vessel damage (e.g. propulsion devices by driftwood)	All
Weather constellations of August 2002 (severe threshold), July and August 2005, January 2004, and May/June 2013 (severe threshold);	High discharge, high water levels, high flow velocities, changes in sediment transport, occurrence of driftwood, local aggradation, degradation and scour	• Severe modification of river and bank morphology • Severe damage to as well as clogging or sedimentation of navigation signs, gauges, ramps and stairs, berths, banks, tow paths, port and lock areas, dams, groins and training walls • Catastrophic flooding	• Suspension of navigation • Delays • Vessel damage (e.g. propulsion devices by driftwood)	Temperate, Alpine, Mediterra-nean

[1] EWENT: Deliverable D3.4 Consequences of extreme weather

Thresholds	Impacts	Consequences to infrastructure	Consequences to operations/services	Relevant climatic zones
Weather constellation of January 2003 as occurred in the Elbe region	High discharge, high water levels, high flow velocities, changes in sediment transport, occurrence of driftwood, local aggradation, degradation and scour; occurrence of ice and ice jams	• Modification of river and bank morphology • Damage to as well as clogging or sedimentation of navigation signs, gauges, ramps and stairs, berths, banks, tow paths, port and lock areas, dams, groins and training walls • Danger of dam overflow and catastrophic flooding of protected areas	• Suspension of navigation • Delays • Vessel damage (e.g. propulsion devices by driftwood)	Temperate
Drought				
Thresholds	Impacts	Consequences to infrastructure	Consequences to operations/services	Relevant climatic zones
Weather constellation of 2003, in particular of the summer 2003 (June, July, August); accumulation and stability of anticyclone weather conditions	Locally low discharge, low water levels, low flow velocities; mainly in free flowing sections; canalized sections are much less or not all affected	• Changes in sedimentation and aggradation processes in comparison with normal or high water conditions • Insufficient navigation conditions deviating from internationally agreed ones	• Reduced cargo carrying capacity of vessels • Increased power demand due to shallow water resistance and increased sailing times • Delays due to shallow water resistance • Possibly interruption of navigation • Increased probability of grounding of vessels	Temperate, Alpine, Mediterra-nean
Temperatures below 0° C				
Thresholds	Impacts	Consequences to infrastructure	Consequences to operations/services	Relevant climatic zones
Weather constellations of winters 1996/97 (= severe threshold), 2005/2006 and 2008/2009	Locally appearance of ice and ice jams, freezing of locks and mooring devices	• Possible damage to navigation signs and infrastructure • Prevented lock operation • Need for ice breaker assistance on selected waterways, in hydropower plant and port areas	• Suspension of navigation • Navigation at own risk due to missing navigation signs damaged by ice • Delays	Scandinavia, Temperate, Alpine

Thresholds	Impacts	Consequences to infrastructure	Consequences to operations/services	Relevant climatic zones
Reduced visibility = decision of the master of a vessel (formerly < 1 km according to CEVNI 2007);	Reduced speed, interruption of navigation of vessels without radar		• Delays	All
Wind				
Thresholds	Impacts	Consequences to infrastructure	Consequences to operations/services	Relevant climatic zones
18 m/s for large motor cargo vessels (110 m x 11.4 m x 3.1 m) carrying containers, and pushed convoys in ballast without bow thrusters in the Danube region close to the Iron Gates	Increased side forces on vessels and cargo on deck, increased heel and rolling, reduced manoeuvrability	• Possible material damage due to collisions	• Possible sliding of empty unlashed containers on deck and loss of cargo • Suspension or interruption of navigation • Flooding of cargo holds and loss of stability, capsize • Accidents with material damage • Increased time for manoeuvring operations • Delays	All (however, the threshold is valid mainly for the Danube at the Iron Gates)

Table 3: Research activities in the field of adaptation and modernization of IWT fleet[2]

Research activities in the field of adaptation and modernisation of IWT fleet			
Topic to be addressed	Technology solution	Description	Remarks
Power system configurations	Usage of liquified natural gas (LNG) for ship propulsion	Inland waterway vessels use instead of gasoil LNG for propulsion .	In initial stage of implementation; promoted by the EC[3] and LNG Master Plan for the Rhine-Main-Danube[4]; first applications in inland waterway transport existing; commercial advantage and feasibility possible due to large difference in gasoil and LNG price.
Retrofitting of existing engine systems	Exchange of old engines	Old engines with high fuel consumption are exchanged by new ones with better environmental performance and lower fuel consumption.	The return on investment can be within a few years. Improved competition by reduced operational costs and better image. Most likely foundations, shaft line and propellers have to be exchanged, too. Note: Elder engines can have a lower fuel consumption than new ones, depending on the construction year and engine type.
Ship structures	Alternative steel structures	Steel structures with improved structural strength	Reduced draught by less ship weight. However, the effect is only minor.
	Sandwich Plate Systems	Metal plate - foam layer (e.g. elastomer) - metal plate solutions	Reduced draught by less ship weight. However, the effect is only minor. Difficult to integrate in existing structures due to joints. Mainly applicable to specific parts of a vessel.
	Composite materials	Glass fibre, carbon fibre structures	Reduced draught by less ship weight. However, the effect is only minor. Expensive solution. Did not enter the inland waterway vessel market yet.
	Aluminium	Structures built of aluminium	Reduced draught by less ship weight. The effect is minor. Expensive solution compared with steel. Manufacture can cause difficulties (welding). However, nowadays, the technology is proven.
Improved hull configurations, improved propulsion	Reduced maximum draught	To be achieved by altered main dimensions or utilisation of smaller vessels	Fairway conditions and route travelled are of greatest importance. Competitivenss of smaller vessels is poorer at good fairway conditions.
	Optimisation of hull form and propulsion devices for service conditions	To be achieved by numerical methods and model testing	Currently, due to higher initial costs, the majority of inland waterway vessels is not optimised using advanced optimisation methods. Depending on the vessel, hull-form/propulsion-device optimisation can lead to substantial savings in fuel consumption.
	Operation of vessels in a convoy; increase of the number of transportation units	A single motor cargo vessel is operated together with a lighter; the number of lighters of a convoy is increased (e.g. from four up to six).	The capacity increase leads to a decrease in specific transportation costs. Considerations with respect to proper machinery and propulsion, sufficient manoeuvrability, as well as costs of additional lighters have an impact on the economic feasibilty of the measure.
	Lengthening of vessel	The length of a vessel is increased, increasing the cargo carrying capacity.	Lengthening of a vessel leads to reduced transportation costs per ton as well as improved economic operation at lower water levels.
	Air lubrication	Creation of an air layer attached to the ship hull, reducing the skin friction.	The reduction in skin friction leads to a decrease of the resistance and power demand. In the initial stage of development for inland waterway vessels. Loss in cargo-carrying capacity may jeopardize the benefits in fuel consumption at low water levels.
	Closure of gap between hulls	The gap between two vessels is closed either by a particular design of the stern of the pushed vessel, or a trapeze-like element between the pushing and the pushed vessels.	Closure of the gap between two vessels avoids the occurrence of separation and vortices there. The resistance and the fuel consumption can be reduced significantly. Limitations of operational flexibility and effects at different draughts are to be taken into account.
	Adjustable tunnel aprons	Moveable flaps on the sides of a propeller.	The flaps are attached to the hull in deep-water condition, resulting in reduced resistance and fuel consumption compared with a rigid tunnel. In low-water condition, the flaps are folded to the sides of the propeller preventing air-suction, allowing for a proper propeller operation at limited water depth.

[2] Based on results of the FP7 EU projects ECCONET and MoVe IT!, as well as the project Innovative Danube Vessel carried out within the framework of the EU Strategy for the Danube Region.
[3] COM(2013) 18 final
[4] http://www.prodanube.eu/index.php?option=com_content&view=article&id=49&Itemid=3

Topic to be addressed	Technology solution	Description	Remarks
Improved hull configurations, improved propulsion cont'd	Adjustable tunnel aprons + diesel-electric drive	The positive effects of the adjustable tunnel are combined with a shift of machinery weight from the stern to the bow, resulting in a decreased trim and the ability of operation at lower water depths.	Considering a large motor cargo vessel (length = 110 m), the solution gives economic benefits already today. The benefits may become significant at severer and longer lasting low-water conditions (e.g. as projected for the second half of the 21st century).
	Diesel-electric drive + multiple propeller	The minimum draught is reduced by usage of propellers with smaller diameter and shift of machinery weight from the stern to the bow, resulting in a decreased trim and the ability of operation at lower water depths.	Considering a large motor cargo vessel (length = 110 m), the solution may become economical at severer and longer lasting low-water conditions (e.g. as projected for the second half of the 21st century).
	Nozzle	The propeller is surrounded by a ring, improving the inflow to the propeller and creating additional trust under heavy-load conditions and low speeds.	If a vessel is not equipped with such a device then an installation can make economic sense. Most vessels with heavily loaded propellers are equipped with nozzles. The reduction in fuel consumption can be substantial.
	Schneekluth wake equalising duct	Device located in front of the propeller, improving the inflow to the propeller.	The effect on fuel consumption is depending on the operational profile of the vessel.
	Improved propeller geometry	The shape and main dimensions can be altered in agreement with operational conditions of the vessels.	The design condition of a propeller may deviate from the true operational conditions in inland waterway transport due to changing waterway parameters, resulting in non-optimal performance of propellers and higher fuel consumption.
	"Pump propeller"	A novel device under development for application in inland waterway transport. It consists of a dedicated propeller, a nozzle and blades in front of the propeller, improving the inflow to the propeller.	Numerous applications for fishing vessels are existing. Substantial reduction in fuel consumption can be achieved. Suitability for inland waterway transport is investigated in the FP7 EU project MoVe IT!
Energy- and cost-efficient sailing	Assistance systems	Hardware and software providing information on economic speed and route of a vessel, as well as how much cargo can be loaded.	In principle, these systems can be used for all existing vessels. However, consolidation navigation conditions and the vessels behaviour when navigating are rather complex issues to be tackled. However, first limited applications are already existing in the Netherlands.
	Education and training standards	Inclusion of economic sailing in curricula.	Sailing with a proper ship speed (not faster than demanded) can reduce the fuel consumption significantly.
	Classes	Inclusion of economic sailing in training.	Sailing with a proper ship speed (not faster than demanded) can reduce the fuel consumption significantly.
	Facilities	Development and usage of simulators	Modelling of ship behaviour and inclusion of navigation conditions is a challenge. Economic sailing can be trained as well as navigation at difficult waterway conditions e.g. due to high water or low water.

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