Sustainable, safe and economically feasible energy concepts and technologies for European Inland Shipping

D1.1 List of operational profiles and fleet families

Identification of the fleet, typical fleet families & operational profiles on European inland waterways

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Abstract

Within the European research project PROMINENT the identification of the fleet composition, representative journeys and the operational profiles of the vessels on these journeys is a starting-point for the further research leading to a mass introduction of emission-reducing technologies. This identification is based on combining former research and available data(bases). To come to this identification, this study consists of several analyses.

Identification of the European fleet

The identification of the European fleet and the construction of a macro model of this fleet has been done by combining several databases and cross-checking the data. This macro model provides insights into the fleet composition, in the number and share of vessels in the various fleet families, resulting in a model with 12,263 vessels.

To provide information on the performance of these vessels as well, the share of the different vessel classes in the tonne-kilometre performance and in the fuel consumption has been assessed. This shows that although the smaller vessel group (<80m) represents a high share in number (37% of the fleet), the high-powered pushers (≥2,000 kW), coupled convoys and bigger motor vessels (≥110m) (11% of the number of vessels) count for a higher share in the tkm performance (49%) and fuel consumption (38%). The latter groups are also the groups with the highest average installed engine power and highest average annual fuel consumption.

The identification of the fleet on the sailing areas is mainly based on existing data from waterway authorities, collected at locks or other counting points, such as Lobith for (Lower) Rhine, lock Freudenau for (Upper) Danube and the Volkerak locks for the North-South corridor.

Identification of representative journeys and elaboration of operational profiles

For each of the sailing areas a selection of representative journeys has been made. This selection is mainly based on the freight flows (in tonnes and tkm) derived from the origin-destination matrix. The 96 relations of flows above 1,000,000 tonnes count for 50% of the tkm performance of IWT. Added to this list of representative journeys are also journeys which – based on expert knowledge – increase the representativeness of the European fleet. This has resulted in a list of 25 Rhine journeys, 10 Danube journeys, 18 on other waterways and 7 journeys with passenger vessels.

For these journeys a list has been filled out with the dimensions of the vessels normally operating these services and operational information of the journey (distance, time, speed). For many of these representative journeys a power distribution over time has been generated, providing insight into the needed power – for upstream and downstream – for each of these journeys.

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ARA	Amsterdam-Rotterdam-Antwerp
ASCII	American Standard Code for Information Interchange
CEMT	Conférence Européenne des Ministres de Transport, used for classification of European inland waterways
Hp	Horsepower
IWT	Inland waterway transport
kW	Kilowatt
kWh	Kilowatt hour
NST	Nomenclature uniforme des marchandises pour les Statistiques de Transport, used for classification of goods
NUTS	Nomenclature des Unités territoriales statistiques, subdivisions of European regions
OD	Origin-destination
RPM	Revolutions per minute, used for the rotational speed

Introduction

PROMINENT

The European research project PROMINENT (Promotion of Innovation in Inland Waterway Transport) aims at the development of standardised concepts for reducing emissions in a main share of the European inland fleet. The target is that in 2020 these concepts will be applicable to at least 70% of the European inland fleet and that the implementation costs of these concepts will be reduced by 30%. In WP2 of this project advanced concepts for mass introduction will be developed and demonstrated in pilots performed in WP5.

The foundations for the development and demonstrations of these concepts are laid in WP1, in which the state-of-art in the aforementioned field is investigated. In SWP 1.2 of PROMINENT the best available emission-reduction technologies are identified and selected which can be implemented for the majority of the European inland fleet, in order to reach the maximum impact. In SWP 1.3 the barriers for mass uptake of these concepts and technologies will be identified.

Identification of fleet families and operational profiles

For the identification of best available technologies and the further development for concepts for mass implementation, an understanding of the fleet and how this fleet is used is essential. As there are major variations between the different vessel types and the operational use (in e.g. power, fuel consumption), different technologies can be beneficial for different parts of the fleet.

For this reason, in SWP 1.1 a study is performed to gain valuable insight into the fleet and the operational use of the vessels. To gain this insight, an identification of the composition of the European inland fleet and the groups of comparable vessels ('fleet families') and the fleet composition on the main sailing areas has been performed. Besides, the main representative journeys hav been selected and the operational profiles on these journeys (characteristics of trips) hav been described.

Former research and sources

Elements of the study in SWP 1.1 were already the focus of some former research projects. In 'Contribution to impact assessment of measures for reducing emissions of inland navigation' (PANTEIA et al., 2013) a fleet assessment was performed as part of the study to the costs and benefits of measures for emission reduction. This included a fleet (in 2012) consisting of 11,459 vessels with 12,542 propulsion engines. With combining and validating new and updated data from different sources, an updated and more elaborated macro model of the European inland fleet could be created.

An overview of the fleet was also part of 'Medium and Long Term Perspectives of IWT in the European Union' (NEA et al., 2011), which also showed the transport performance of inland waterway transport. This showed the share of the different corridors in the tkm performance (information from the PLATINA project) and the modal share of IWT in the transport of different commodities. With data from Eurostat and ETISplus these statistics can be elaborated in more detail for the transport of different commodities between different NUTS-2 regions.

On the operational profiles some work has already been executed in the past. Within the European research project MoVeIT! operational profiles were measured for a push boat operating between

Rotterdam and Duisburg, a push boat operating on the Danube and a motor cargo vessel with lighter operating on the Danube. In the German research project KLIWAS hydrological data for inland waterways were derived. Based on the combination of these projects, operational profiles can be derived for several of the representative journeys.

70% of the European inland fleet

The focus of the study performed in SWP 1.1 is to come to a proposal for the fleet selection which represents 70% of the European inland fleet and maximes the impact for this share of the fleet. For this, it is important to determine the decisive factors as regards maximising impact to reduce emissions in Europe. In order to conclude on the most important vessels that are reflecting the target to reach at least 70% of the market an analysis was performed for various types of vessels as regards:

- The number of vessels in a certain vessel class;
- The fuel consumption of a certain vessel class;
- The tonne-kilometre performance of certain vessel class.

For this reason, in the macro model data on the number of vessels, fuel consumption and tkm performance are focus areas. These data, as well as the engine characteristics (such as the installed engine power (and number of engines), the rpm of the engine and the construction year of the engine) are relevant for the further development of emission-reducing concepts.

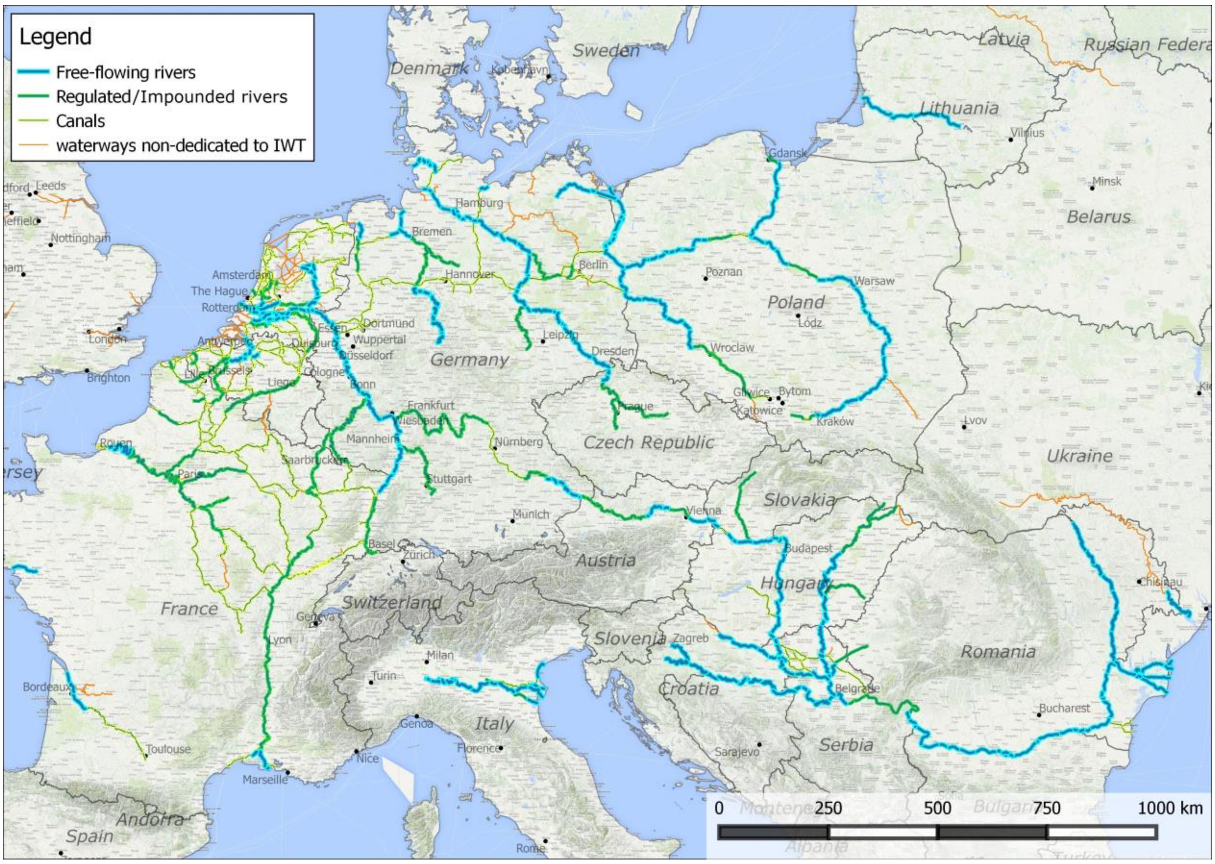


Figure 1: Type of inland waterways in Europe (Source: STC-NESTRA based on UNECE information)

Waterways

Figure 1 shows the inland waterways in Europe. In this research a subdivision of the European waterways is made into different sailing areas, namely the Rhine (and its tributaries), the Danube – as the main European waterways – and a selection of the most important and representative 'other waterways'. This subdivision will also be used throughout the rest of this report. As can be seen in Figure 2, 68% of the volume of cargo transported in inland waterway transport is on the Rhine corridor, 16% on the North-South corridor (between the Netherlands, Belgium and France) and 14% on the Danube corridor and the remaining 2% on the East-West corridor (between Germany and Poland).

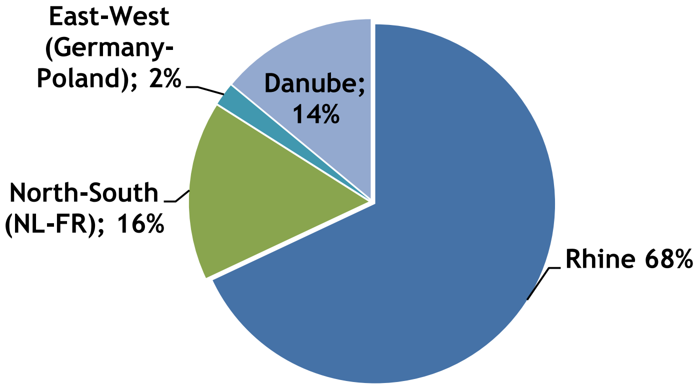


Figure 2: Transport performance in four main waterway corridors in Europe (in 2007) (Source: NEA, et al. (2011). Medium and Long Term perspective of IWT for the EU)

In the study the main focus is on journeys representing a high volume of cargo transported by inland waterway transport. To identify these journeys, the freight flows are assessed by origin-destination pairs, analysing the origin and destination ports and the main commodities transported between those ports. The most important freight flows are included in the representative journeys, completed together with some journeys which are representative for a specific CEMT class.

Elaboration of operational profiles

Detailed knowledge about the operational profile of the vessels on distinct journeys is required for the selection and implementation of different greening technologies. This information will be the outcome of different work packages within the PROMINENT project, but at the same time prerequisite to other or even the same work packages. Long term field measurements in the pilot projects will deliver more detailed data about the operation of the limited number of subjected vessels. However, to focus on developments available for the largest possible share of the fleet, is analysed in the beginning of the project in SWP 1.1 reported herein.

1. Methodology

1.1 Analysis of the European fleet and the fleet families

Fuel consumption and the environmental performance in inland navigation depends largely on the technical and operational characteristics of the active fleet. Therefore, a starting point in the PROMINENT project has been to:

- collect data on the features of the European inland fleet (i.e. number of vessels, vessel types and sizes, engine information and fuel consumption) to be able to develop a macro model;
- improve the data of the macro model (where needed);
- identify groups of comparable vessels ("fleet families");
- analyse the engine characteristics, transport performance and average fuel consumption for the fleet families identified.

1.1.1 Data collection of the European inland fleet

Geographical scope

As explained in the previous chapter, the PROMINENT project makes a distinction between: Rhine (with its tributaries Main, Moselle and Neckar), Danube and 'other waterways' (i.e. Seine, Rhône/Saône, Mittelland Canal, Albert Canal, Meuse, Dortmund-Ems Canal and Elbe). The analysis of the European fleet has taken this division into account and makes a distinction between the vessels *registered* in:

- Rhine and other waterway countries[1]: Belgium, France, Germany, the Netherlands, Luxembourg, Switzerland and Czech Republic;
- Danube countries: Bulgaria, Hungary, Croatia, Moldova, Ukraine, Austria, Romania, Serbia and Slovakia.

Information has been gathered on the *active fleet* per country in order to avoid overestimating the transport performance and fuel consumption of inland navigation.

Another important aspect is to identify where the active fleet navigates, as there are clear differences in the sailing conditions and thus fuel consumption and environmental performance per type of waterway. Therefore, data has also been collected on the *typical vessel types* sailing on the rivers aforementioned.

Vessel types

The study focusses on motor cargo vessels, push boats and passenger ships (cruise and hotel vessels). It excludes other type of vessels, such as dredgers, floating cranes, workboats, etc. Special attention has been given to the relatively larger vessel sizes (CEMT IV and higher) as these consume more energy than the smaller ones. For these vessel types, further distinction is made between the type of cargo carried (i.e. dry versus liquid cargo).

[1] The database also includes some passenger vessels registered in Cyprus and Malta, but active on the Rhine and other waterways.

Sources and available databases used
For the Rhine and other waterway countries, the following fleet data sources have been used:

IVR Ships Information System[2] for the year 2014: with information on 14,108 active vessels (including other vessel types not selected in this study). The database covers mainly the Western European fleet (i.e. Belgium, France, Germany, Luxembourg, the Netherlands and Switzerland). The database provides information for the following indicators (although not always available for all vessels):

- Vessel type;
- Vessel dimensions (length, width and depth);
- Loading capacity;
- Building year of the vessel;
- Number of main engines;
- Total propulsion power of the main engines;
- Engine manufacturer;
- Type of engine;
- Retrofit engine;
- Total hp of main engine;
- Total kW of main engine;
- Building year of main engine;
- Engine speed (in RPM);
- Propulsion type (i.e. diesel; diesel-electric; electric; schottel propulsion system);
- Main engine fuel type (i.e. bi-fuel; bio-fuel; diesel; LNG; other);
- Engine data on the auxiliary engine (*limited*).

Bunkering data from SAB for the year 2013, containing anonymised bunkering information of 5,924 vessels (including other vessel types not selected in this study). This database also provides data on vessel types, vessel dimensions and engine information (i.e. number of engines and total propulsion power).The database covers a total of 42% of the vessels selected in this study for the Rhine and other waterways.

WSV (Wasser- und Schifffahrtsverwaltung des Bundes) fleet statistics for the year 2014[3]: IVR has indicated that the fleet data for Germany is not complete due to limitations regarding privacy issues. This was especially evident for the number of passenger vessels and push boats. Particularly for these vessel types, additional statistics hav been collected from the WSV statistics.

VNF (Voies navigables de France) fleet statistics for 2013[4]: the IVR database provided a questionable number of passenger vessels. Therefore, additional information from VNF has been used to improve the available dataset.

[2] For more information on the IVR database, see: http://www.ivr.nl/registration
[3] Available at: http://www.wsv.de
[4] Available at: http://www.vnf.fr

For the Danube countries, the following fleet data sources have been used:

- **Danube Navigation Statistics** for the year 2013 presented by the Danube Commission[5]. Although the data provides useful information for all Danube countries on the number of vessels, the available information has mainly two limitations:
  - it indicates the *registered* vessels and not necessarily the number of vessels in operation;
  - the data provides information on the *total* number of vessels, *total* carrying capacity (in tonnes) and *total* power of motorised vessels (kW) for all the motorised vessels, but does not present fleet statistics per vessel size or engine power category.

To overcome the limitations aforementioned two additional data sources have been used:

- **European Hull Database**[6] for the year 2015, which provides vessel related information such as vessel dimensions, vessel types and valid sailing certificates, obtained from Vessel certification authorities and RIS Authorities. This database does not provide engine information. For the Danube countries, vessel information is available for Austria, Bulgaria, Romania and Slovakia. The European Hull Database is regulated by a strict administrative agreement and no individual vessel information could be obtained. For statistical purposes a limited set of data could be obtained if presented as a total. Therefore, a set of vessel categories needed to be defined to be able to obtain the total number of vessels per category per country. The data provided indications on the *active* fleet *per category* for the Danube countries mentioned above.

- **CO-WANDA** report from 2014 'Transnational network of ship waste reception facilities along the Danube' (WP3; Activity 3.3). As the European Hull Database did not provide information for all the Danube countries nor data on engine power, the results from the CO-WANDA report have been used. This report presents *per Danube country and engine power category* the registered number of vessels as well as an estimation of the active Danube fleet. The report concludes that approximately 800 to 900 vessels are expected to be in operation along the Danube (including other vessel types not taken into account in the PROMINENT project).

The use of these different sources and databases has enabled the development of a **macro model for the active European Fleet**.

1.1.2 Improvements of the macro model of active European Fleet

A next step has been to carry out checks and to improve the data in the macro model (*where possible and needed*). This is especially relevant for the engine information.

The quality and reliability of the engine information in the IVR database has been questioned in the past for not being always up-to-date[7]. Ship owners are not obliged to update the engine information, if a new propulsion system is installed. Therefore, additional checks and improvements needed to be carried out in order to increase the reliability of the results. Another reason to obtain more detailed engine information is to be able to identify the coupled convoys. None of the databases mentioned

[5] Available at: http://www.danubecommission.org/index.php/en_US/statistics
[6] For more information, see: http://www.ris.eu/services/european_hull_data_base__ehdb_. See also: http://www.ris.eu/docs/File/325/european_hull_database__final_report__2012_03_09.pdf
[7] The new online IVR database is aimed at solving this issue by allowing the ship-owners to access the details of their specific vessel(s) and to update or complete the information. Nevertheless, the database has not yet been updated on a large scale.

before provide information on the number of coupled units in operation nor the actual used barge formations of push boats.

For the Rhine and other waterways fleet a thorough check could be carried out on the available engine data. This was not possible for the Danube countries as the available datasets do not provide engine information for the vessels on an individual level. Engine information for the Danube fleet has been obtained for the most representative vessels either through data collection among some ship-owners active in the Danube area or information from the lock Freudenau in the east of Vienna in Austria for the year 2014. The information collected did not make it possible to incorporate the engine data into the macro model nor carry out checks of individual vessels.

The next steps have been followed to check, clean and improve the engine and vessel data in the macro model developed (for the Rhine and other waterway countries):

1) The basic engine information comes from either the bunkering data or the IVR Ships Information System (depending on the availability of the engine data).
2) If both sources provide the same engine information, no adaptations have been made.
3) If deviations appear between the engine data from these two sources, additional checks have been carried out through desk-research and using databases with updated engine information from organisations, such as: Vereniging "De Binnenvaart"; De Binnenvaartkrant and Binnenvaart.eu.
4) If both sources do not provide information for CEMT class Va motor vessels (i.e. class with large majority of coupled convoys and most important vessel size regarding transport performance in Europe) and push boats, additional checks have been carried out through the use of databases from organisations, such as: Vereniging "De Binnenvaart"; De Binnenvaartkrant and Binnenvaart.eu.
5) For the identification of the coupled convoys, the bunkering data served as a starting point. The CEMT class Va motor vessels with the largest fuel consumption appeared to be in general coupled convoys (through a check in databases from organisations, such as: Vereniging "De Binnenvaart"; De Binnenvaartkrant and Binnenvaart.eu). This provided input on the engine characteristics for the typical coupled convoys. These characteristics were also coherent with the ones presented in the (draft) report 'Engine database analysis Dutch fleet 2015' from the Ministry of Transport & the Environment and Human Environment and Transport Inspectorate (ILT). Based on these typical engine characteristics, a set potential coupled convoys were identified. A check has been carried out to see whether these vessels were indeed couple convoys, which was positive in the large majority of the cases.
6) Errors in the database have also been cleaned (where possible). For example, in case of motorised vessels with engine speeds (RPM) of zero or self-propelled vessels with no engines.
7) Motor cargo vessels with no data on dimensions were also improved.
8) A general engine data coherence check has also been carried out by comparing the results obtained with an engine database for the year 2015 from the Human Environment and Transport Inspectorate of the Netherlands (ILT), which is the authority for the registration and inspection of inland waterway vessels in the Dutch fleet. The database has anonymised engine information for 4,149 vessels that are 'under inspection' by the Dutch authorities.

A large set of vessels has been checked, which resulted in the **improvement** of vessel and engine data **for almost 1,120 vessels**. For **around 75% of the vessels** in the Rhine and other waterway countries **engine related information** has now been **provided**.

1.1.3 Identification of groups of comparable vessels ('fleet families')

Different classification systems and data sources have been used for the definition of the fleet families in PROMINENT:

- For motor cargo vessels, the **length** has been used to classify the various vessel types.
  - The CEMT classification system has been used as a basis for the division of the smaller vessel types. The motor cargo vessels of CEMT class I, II and III (mainly **below 80 meter**) are considered of regional importance and have been included into one family. No distinction is made here between dry and liquid cargo vessels.
  - For the larger and newer vessel sizes, the newer RWS classification system (RWS 2010)[8] has been used. This classification system has already identified more or less comparable vessels into 12 classes. The most representative classes in Europe have been identified using vessel traffic counts (see section 2.2 and 2.3). One of the most common vessel types used in Europe is the Large Rhine Vessel, with a reference vessel dimension of 110 metre long and 11.4 metre wide. This length has been used to identify the lower limit of the largest vessel sizes. A distinction is made between dry and liquid cargo vessels. Therefore, all the motor dry cargo vessels **equal to or above 110 metres** have been included into one family and all the motor liquid cargo vessels equal to or above 110 metres have been included into another fleet family.
  - The remaining category (i.e. **vessels between 80-109 metres**) have been included into the other fleet families for motor cargo vessels. A distinction is also made here between dry and liquid cargo vessels.

- For push boats, the vessels have been classified according to the **total propulsion power**. According to the vessel traffic counts in Europe (see section 2.2 and 2.3), the most common push barge formations (following the RWS classification system) are:
  - pusher and 1 Europa II barge;
  - pusher and 2 Europa II barges;
  - pusher and 4 Europa II barges;
  - pusher and 6 Europa II barges.

  The pusher with 1 or 2 Europa II barges are more common in specific waterways (e.g. on the North-South corridor between the Netherlands and Belgium), whereas pushers with 4 Europa II barges or more travel on larger waterways (e.g. Rhine).

  The pusher with one Europa II barge has in general a propulsion power around 500 kW. In the study by PANTEIA, et al. (2013) 'Contribution to impact assessment of measures for reducing emissions of inland navigation' a range between 1000-2000 kW was used for a pusher with 2 Europa II barges. A total propulsion power above 2000 kW is more common for pushers with 4 Europa II barges or more. The other smaller pushed convoys have in general a total propulsion power below 500 kW.

[8] Rijkswaterstaat developed a new and more detailed classification system (RWS 2010). This classification system provides a further specification of the CEMT classes with the current largest motor cargo vessels and includes the dimensions of coupled units. For more information, see: Rijkswaterstaat (2011). Waterway Guidelines 2011.

In this study, the push boats have been divided into the following categories:

- Push boats below 500 kW (total propulsion power);
- Push boats between 500-2000 kW (total propulsion power);
- Push boats above 2000 kW (total propulsion power).

- Coupled convoys have been classified into one family as the large majority of them are class Va vessels sailing with a Europe II lighter.

- Passenger vessels have been classified into one family as well and include hotel and cruise vessels.

Summarising the information presented above, the proposed fleet families for the PROMINENT project are:

- **Passenger vessels** (hotel/cruise vessels);
- **Push boats <500 kW** (total propulsion power);
- **Push boats 500-2000 kW** (total propulsion power);
- **Push boats** ≥**2000 kW** (total propulsion power);
- **Motor vessel dry cargo ≥110m length;**
- **Motor vessel liquid cargo ≥110m length;**
- **Motor vessel dry cargo 80-109m length;**
- **Motor vessel liquid cargo 80-109m length;**
- **Motor vessels <80 m. length;**
- **Coupled convoys** (mainly class Va + Europe II lighter).

1.1.4 Analysis of engine characteristics, transport performance and fuel consumption

The analysis of the engine characteristics has been carried out using the improved dataset of the macro model. Extreme values have been identified as outliers in order to avoid unreliable results when calculating averages.

The transport performance (in tkm) has been estimated using assumptions on the average speed, sailing time, load transported and empty sailings obtained from various sources. The PLATINA 2 D2.3 report from 2015 ('Review of European data sets and identification of gaps. Information needs, reviewed datasets and gap analysis for providing the information basis for the determination of external costs performance in inland navigation as regards emissions to air') provided an important basis for the assumptions used on speed, load transported and empty sailings. Data on the average sailing time has been obtained from the IWT Cost model 2014 available from Rijkswaterstaat. The other sources used are also presented in section 1.2 on the determination of the representative journeys.

The bunkering data provided information on the average fuel consumption.

1.1.5 Subdivisions of the fleet used in the different sailing areas

In the macro model a subdivision in fleet families is made based on the size of the motor vessels and for push boats based on the installed power, as proposed in the list under 1.1.3. This subdivision is used in 2.1, in the elaboration of the macro model of the European fleet. The fleet per sailing area (Rhine, Danube and the main other waterways) are described in 2.2-2.4. For the identification of the fleet operating on these sailing areas, several sources were used, these sources are mainly traffic counts at locks (e.g. Freudenau, Volkerak Locks) or other points (e.g. Lobith). As there are several sources used for this, also other subdivisions were used than in the macro model:

- For the Netherlands, traffic counts are used at Lobith (Lower Rhine), Volkerak Locks (North-South corridor), Sambeek Lock (Meuse). These traffic counts were performed according to the classification of RWS 2010[9], in which 12 classes of motor vessels are used, based on the vessel dimensions, length and width. The width is a decisive factor of them, e.g. the reference dimensions of M7 are 105x9,5m and M8 are 110x11.4m, but vessels with the dimensions 105x11.4m are classified with M8. There are also 13 classes of pushed convoys and 7 classes of coupled convoys defined, based on the vessel/pusher/barge dimensions, number of barges and long and wide.
- For the Upper Danube, the traffic counts at lock Freudenau are used. For this a subdivision is made in motor tank vessels and motor cargo vessels, with each in 4 size groups (based on length) with a subdivision in the number of barges (so, also including the coupled convoys). For the pushed convoys a subdivision is made in 3 size groups with a subdivision in the number of barges. In the table of engine characteristics there is a further subdivision for the smaller motor vessels based on the width of the vessel.
- For the other traffic counts, there are other subdivisions. NV De Scheepvaart uses a subdivision based on loading capacity, in this report the vessel lengths are estimated based on the regular loading capacities. The statistics of the fleet in the Danube area (from the Danube Commission) and in the Saône/Rhône basin are based on the total sum of loading capacity and installed power (from which averages can be derived).

[9] An overview of the RWS 2010 classification can be found in: Rijkswaterstaat (2011), Waterway Guidelines: http://staticresources.rijkswaterstaat.nl/binaries/Waterway%20guidelines%202011_tcm224-320740_tcm21-37559.pdf

1.2 Determination of representative sailing areas and journeys

According to European statistics 532 million tonnes of cargo were transported in 2013 by IWT (EU28)[10], which led to a freight turnover of more than 152 billion tkm. The majority of the cargo flows is transported on the Rhine corridor (68%)[11], the North-South axis between Netherlands and France accounts for 16% of the cargo transported, the Danube corridor for 14% and the remaining 2% consists of East-West transport between Germany and Poland. An overview of how the 532 million tonnes of cargo is distributed over the European waterways is given in Figure 3 below.

Although the overview already gives insight of the representative sailing areas in Europe, a more thorough analysis is required to estimate and verify the operational profiles of vessels on representative journeys on European waterways. Based upon representative journeys, type of vessel used and type of cargo transported, a power distribution can be estimated over time.

Figure 3: Volumes transported by Inland Waterways in Europe in 2007 (Source: data PLATINA Deliverable 5.5 (2010) & Google maps, adapted by STC)

To determine and analyse (large) freight flows relations of IWT, a freight flow assessment has been carried out based upon ETISplus harmonised transport statistics[12]. By means of analysing the freight

[10] See: Eurostat - transport by type of good
[11] NEA, et al. (2011). Medium and Long Term perspective of IWT for the EU
[12] ETISplus is a European Transport policy Information System, combining data, analytical modelling with maps (GIS), a single online interface for accessing the data. It aims therefore to provide a bridge between official statistics and applications within the transport policy theme. ETISplus includes freight flow data of IWT, which can be mapped using the ETIS-NETTER or harmonised freight flow data can be downloaded for own mapping and editing purposes here. For description of available IWT data see deliverable D6-ETISplus-database Ch. 21 here. In the harmonised ETISplus data for IWT the commodities are subdivided according to the previously used NSTR classification. In the new classification (NST 2007) the commodities are

flow data of ETISplus for IWT and integrating region boundaries, freight data can be mapped using GIS software (e.g. Qgis, Mapinfo, Arcgis, etc.). For the purpose of determining representative journeys the output for harmonised inland waterways transport data in a NUTS2-NUTS2 OD matrix (provincial / state level) is sufficient, which is further divided into commodities (NST1 – standard commodity classification). In total the NUTS2-NUTS2 OD matrix includes about 500 million tonnes of freight transported by IWT, based on a compilation of national transport data of The Netherlands, France, Germany and Eurostat statistics.

Since the initial OD Matrix covered about 10,000 possible combinations, a filter was used to map flows larger than 100,000 tonnes (see Figure 4 below[13]). Although large freight flow relations are indicated by distinctive colour and magnitude, the number of representative journeys is quite large due to high density of cargo flows in especially the Rhine region.

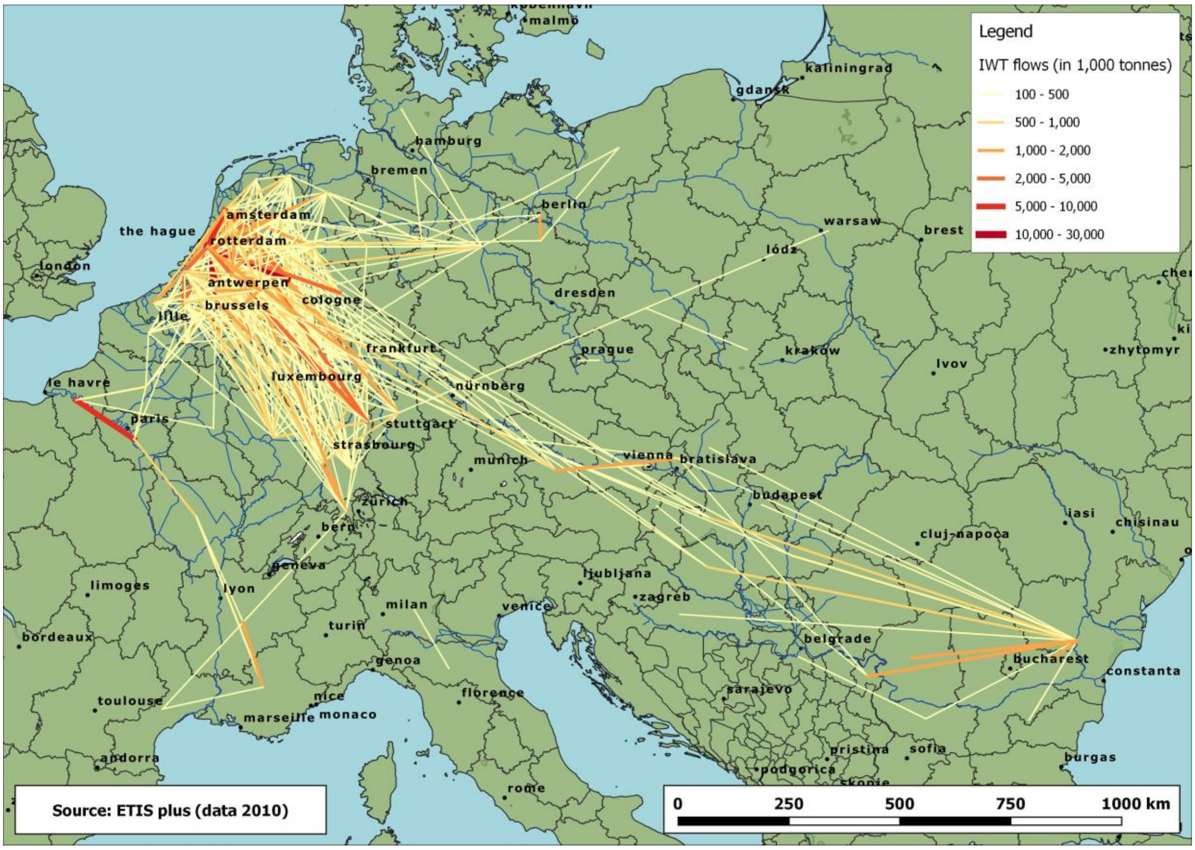


Figure 4: Selection of transport relations by Inland Waterways in Europe (>100,000 tonnes)

In order to distinguish the large freight flows which clearly reflect the top relations in Europe, a second filter was used to map flows larger than 1,000,000 tonnes (see Figure 5). In total 96 relations are illustrated in the map below, which are analysed in more detail to distinguish OD information and main commodities transported on that specific relation. The 96 relations (of about 10,000 in total) cover about 274 million tonnes of cargo transported on the European waterways, which is about 55%

categorized differently, therefore deviations may occur when comparing outcomes with Eurostat based upon national statistics of member states that have integrated the new classification. E.g. Iron ore and metal waste (NST-4) and Building materials (NST-6) are in the same category in new classification (GT03 in NST 2007).

[13] Qgis is used to map freight flow data, which is a Free and Open Source Geographic Information System (see: http://www.qgis.org/en/site/). The lines reflect freight flow data by inland waterways, although in the dataset the centre of the region is included as XY coordinate.

of the total transport volume in Europe and about 50% of the total European tonne-kilometre performance of IWT.

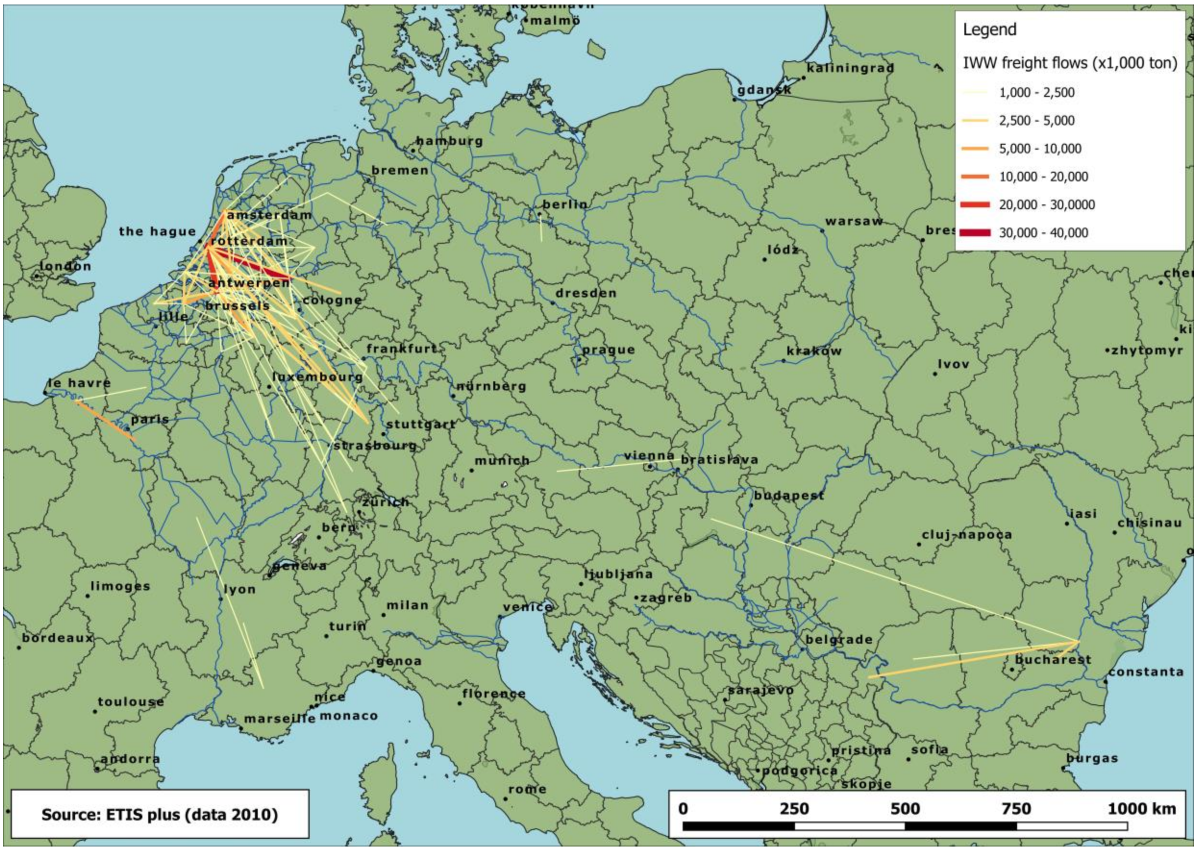


Figure 5: Selection of transport relations by Inland Waterways in Europe (>1,000,000 tonnes)

In Table 1 the top 20 relations in total volume transported by IWT is presented and the top 20 in freight turnover (in tkm). Due to the large volume of coal, ores and containers, evidently the largest IWT relation concerns Rotterdam and Duisburg. More distinctive is the large volume transported between Le Havre and Paris (Gennevilliers), mostly consisting of the transport of building materials (sand & gravel), containers and agricultural products.

Also the Danube region is represented in the Top 20 flow relations by the relation Bor District (Serbia) – Constanta (especially transport of building materials and agricultural products), Giurgiu – Constanta (through the transport of agricultural products and oil) and Constanta - Dunaújváros. Most common commodities transported on the Danube are: building materials (sand & gravel), agricultural products, oil products and coal.

OD RELATION		ESTIMATED DISTANCE KM	TOTAL (x1,000 ton)
Rotterdam	Duisburg	254	30.748
Rotterdam	Antwerp	153	21.998
Rotterdam	Amsterdam	127	13.196
Le Havre	Gennevilliers	176	9.370
Duisburg	Antwerp	353	6.159
Liège	Antwerp	172	6.118
Moerdijk	Rotterdam	99	5.547
Gent	Antwerp	87	5.541
Terneuzen	Gent	78	4.744
Terneuzen	Rotterdam	166	4.731
Amsterdam	Antwerp	244	4.568
Rotterdam	Gent	222	4.370
Genk	Antwerp	116	4.354
Rotterdam	Kalsruhe	928	3.909
Giurgiu	Constanza	275	3.825
Rotterdam	Ludwigshafen am Rhein	424	3.764
Rotterdam	Herne	344	3.601
Rotterdam	Nijmegen	168	3.558
Amsterdam	Duisburg	252	3.541
Maastricht	Rotterdam	246	3.476

OD RELATION		TOTAL (x milion tonkm)
Rotterdam	Duisburg	7.808
Rotterdam	Kalsruhe	3.628
Rotterdam	Antwerp	3.376
Amsterdam	Kalsruhe	2.462
Kalsruhe	Antwerp	2.251
Duisburg	Antwerp	2.173
Bor district	Constanza	2.001
Mainz	Antwerp	1.814
Rotterdam	Strassbourg	1.676
Rotterdam	Amsterdam	1.674
Le Havre	Gennevilliers	1.648
Strassbourg	Antwerp	1.604
Rotterdam	Ludwigshafen am Rhein	1.597
Constanza	Dunaújváros	1.422
Thionville	Antwerp	1.372
Rotterdam	Basel	1.319
Rotterdam	Breisach	1.251
Rotterdam	Herne	1.238
Amsterdam	Antwerp	1.116
Amsterdam	Offenbach	1.055

Table 1: Top 20 relations by Inland Waterways in Europe in volumes transported (left) and tkm (right)

A more detailed specification of cargo flows per OD relations (both in volume and in tkm) is given in Annex A1 and Annex A2. The cargo volumes are presented in a heat map in order to visually indicate the largest cargo volumes transported overall and per relation. Additionally the flow data is distributed amongst the standard commodity classes (NST-1) to indicate the main cargo types transported per relation. Conclusively, based upon the magnitude of total freight transported per OD relation and the distribution amongst commodities, representative IWT journeys can be selected in Europe.

1.3 Analysis of the operational profiles

The term ‘operational profile’ comprises a huge amount of data including time series or statistical data of quantities like engine rate, engine torque, loading condition, fuel consumption, rudder angles, speed over ground, velocity through the water, water depth, width of waterway, current velocity, manoeuvring in harbours, locks or encountering or passing situations etc. Within the scope of PROMINENT the engine related parameters are considered most relevant and are yet challenging to determine the list of representative journeys with given time constraints.

In a first approach interviews with experienced boatmasters were conducted to collect operational profiles. However, it is hardly possible to find people for all journeys willing to exchange experience. Based on the limited availability of operational information from boatmasters the list of journeys with sufficient information is small. Another result of the survey was that vessels are operated very differently, there could be differences in the awareness of the fuel costs between e.g. owner-operators and boatmasters in large ship-owning companies and, therefore, in the efficiency of navigation. Another parameter influencing the operational profiles is the amount of installed engine power differing significantly between ships of similar size. This empirical approach may in combination with data from former research projects yield relevant information for a selected list of journeys. For the comprehensive list of 60 clearly defined journeys (in Annex A3) the uncertainties were considered too large.

Therefore, the final operational profiles were produced with a tailored simulation approach. A cost and performance model with database structures for waterways and speed power relations of different inland vessels was already developed within the scope of the KLIWAS project, funded by the German Federal Ministry of Transport. As the primary objective was the determination of haul capacity and costs the implemented sailing policy was simple and mostly based on a set of constant power assumptions and speed restrictions. Here the speed of the vessel was determined using hydrodynamic models and existing data from model tests. Hydrological data was available for most of the river Rhine with some spatial and temporal resolution spanning 30 years.

The simulation tool was further developed with a new approach to reproduce realistic choice of speed in different environmental conditions. Multiple parameters for the ship and the waterway were combined to set a desired speed and derive the corresponding power demand. Speed limits of the waterway and the vessel, minimum speed through water for manoeuvrability, hydraulic parameters like blockage and local depth Froude numbers are the most important parameters.

Different sources for the hydrological data of many European waterways were used to fill the database with relevant data in a reasonable spatial resolution. Power-speed profiles for different draughts and water depths for various vessels were selected from different sources and altered to match the requirements for the journeys in Annex 3 if necessary. However, for some vessels like the pushed convoys on the Danube data was insufficient. Using data on power demands from pushed convoys on the Rhine was limited by the differing draughts. Therefore, the simulations for the Danube were done for pushed convoys with four barges, differing in dimension as shown in Annex 3. Where data was sufficient the waterway segments were combined and simulations were done individually for each of the representative journeys. Cargo load and draught were determined according to available water depths, bridge clearances and transport tasks. The results were statistically analysed and prepared for further use both in ASCII format and as plots for the directions of travel separately. The plots are given in this report in section 3.2.1 for the Rhine, 3.3.2 for the Danube, 3.4.2 for other waterways and 3.5 for passenger vessels. With the sailing time given in Annex 3 and a reasonable assumption for the fuel consumption per kilowatt hour the consumption per round trip can be easily derived.

2. Overview of fleet families

2.1 Overview of the European fleet

The European inland fleet for the vessel types selected in this study consists of approximately 12,263 active vessels (see Table 2). The large majority of the vessels belong to the operating fleet from the Rhine and other waterway countries (93% of the total fleet; based on the number of vessels).

One of the targets in the PROMINENT project is to develop innovative greening solutions that are applicable to at least 70% of the European inland fleet market. It is important to acknowledge that the number of vessels is not the most appropriate indicator to take into account when assessing the target. Otherwise, the target could almost be reached by focussing only on greening solutions that are applicable to the smallest motor vessel categories (<80 m. length), the less powerful push boats (<500 kW) in combination with passenger vessels (see Figure 6).

Since the main objective of PROMINENT is to focus on emission reduction, the **target groups should be based on the fuel consumption and tonne-kilometre performance**. Figure 7 and Figure 8 present the division of the active European fleet based on fuel consumption and tonne-kilometre performance. The comparison reveals that mainly the **larger vessels** have a high fuel consumption and tonne-kilometre performance and are therefore the main target group for PROMINENT.

Fleet families identified in PROMINENT	Total number of operational vessels in Europe	Operating fleet for Rhine and other waterway countries	Operating fleet for Danube countries
Passenger vessels (hotel/cruise vessels)	2,553	2,357	196
Push boats <500 kW (total engine power)	890	798	92
Push boats 500-2000 kW (total engine power)	520	332	188
Push boats ≥2000 kW (total engine power)	36	25	11
Motor vessels dry cargo ≥110m length	610	580	30
Motor vessels liquid cargo ≥110m length	602	599	3
Motor vessels dry cargo 80-109m length	1,802	1,713	89
Motor vessels liquid cargo 80-109m length	647	631	16
Motor vessels <80 m. length	4,463	4,285	178
Coupled convoy (mainly class Va+Europe II lighter)	140	140	*n/a**
Total**	**12,263**	**11,460**	**803**

** No detailed data available to estimate the number of coupled convoys for the Danube in a reliable way. The self-propelled units from coupled convoys are now included in the number of motor vessels.*
*** Excluding other type of vessels (e.g. dredgers, floating cranes, workboats, etc.)*

Table 2: Main fleet families of the European inland fleet for 2013/2014

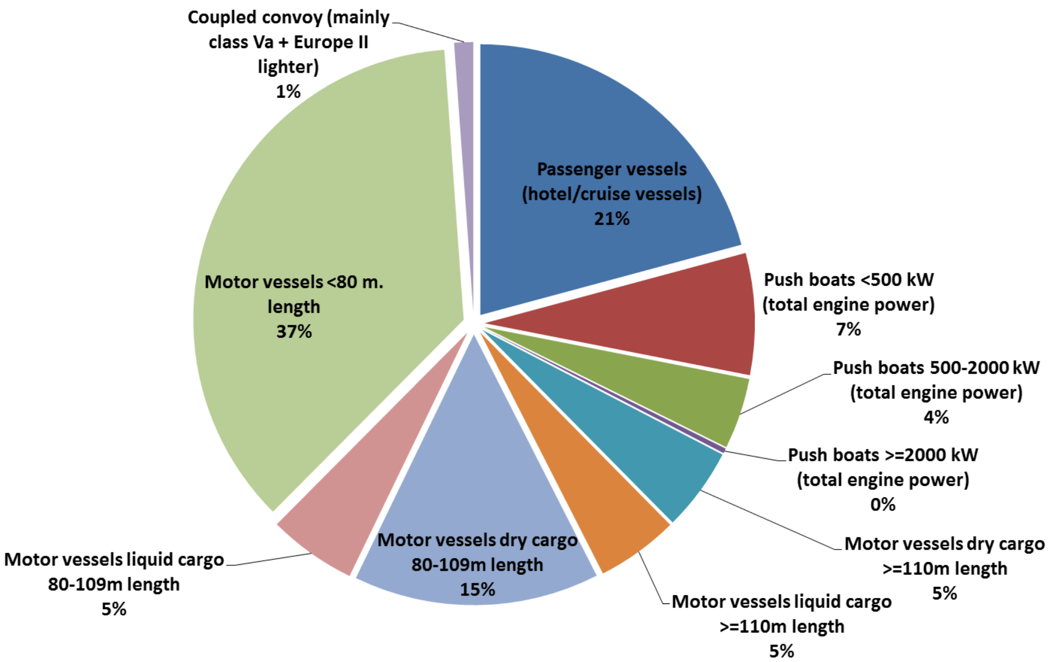


Figure 6: Shares of main fleet families in Europe based on the number of vessels

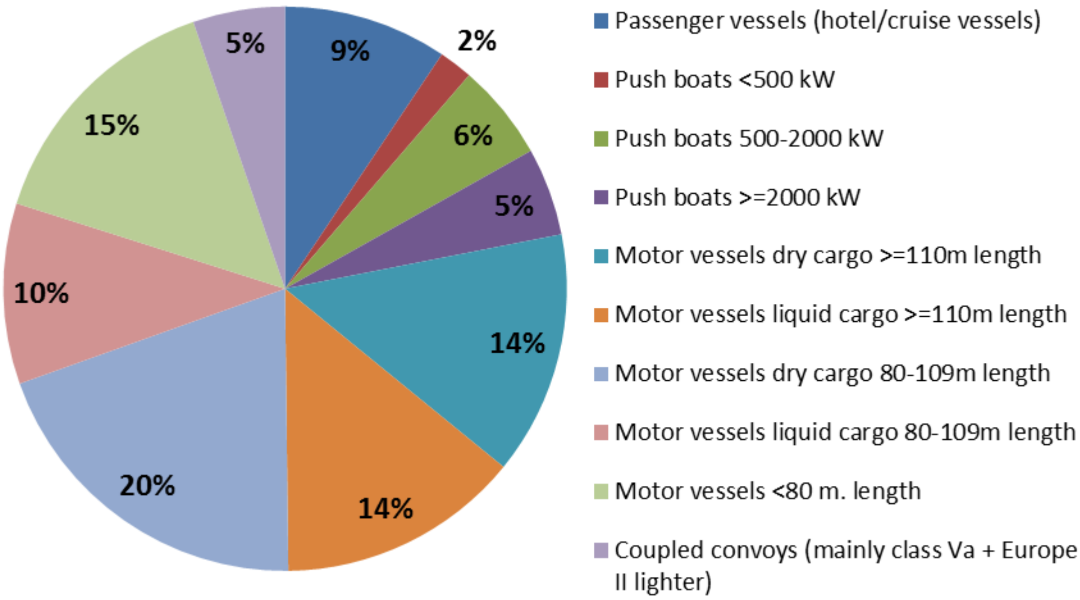


Figure 7: Share of main fleet families in Europe based on estimated fuel consumption

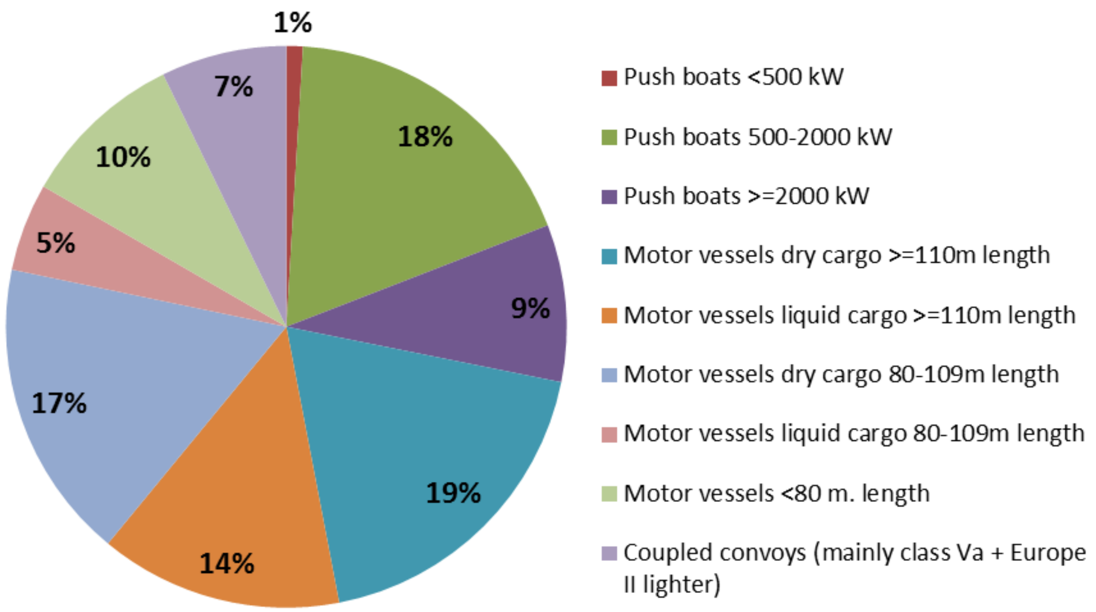


Figure 8: Share of main fleet families in Europe based on estimated tonne-kilometres transported

The average fuel consumption per fleet family is presented in Table 3. It can be seen that in particular the large push boats, the coupled convoys and the large motor cargo vessels (≥110m length) have the highest fuel consumption figures per year. For these fleet families, savings on fuel costs is very important. This can also be seen from the boxplot in Figure 9, which provides an overview of the average fuel consumption per year as well as the 25% - 75% interval of the observed data (the bunkering data is used as source).

Fleet families identified in PROMINENT	Average fuel consumption per year (in m^3)
Passenger vessels (hotel/cruise vessels)	54
Push boats <500 kW (total engine power)	32
Push boats 500-2000 kW (total engine power)	158
Push boats ≥2000 kW (total engine power)	2,070
Motor vessels dry cargo ≥110m length	339
Motor vessels liquid cargo ≥110m length	343
Motor vessels dry cargo 80-109m length	162
Motor vessels liquid cargo 80-109m length	237
Motor vessels <80 m. length	49
Coupled convoys	558

Table 3: Average fuel consumption of the main fleet families (based on detailed information from Western-European countries)

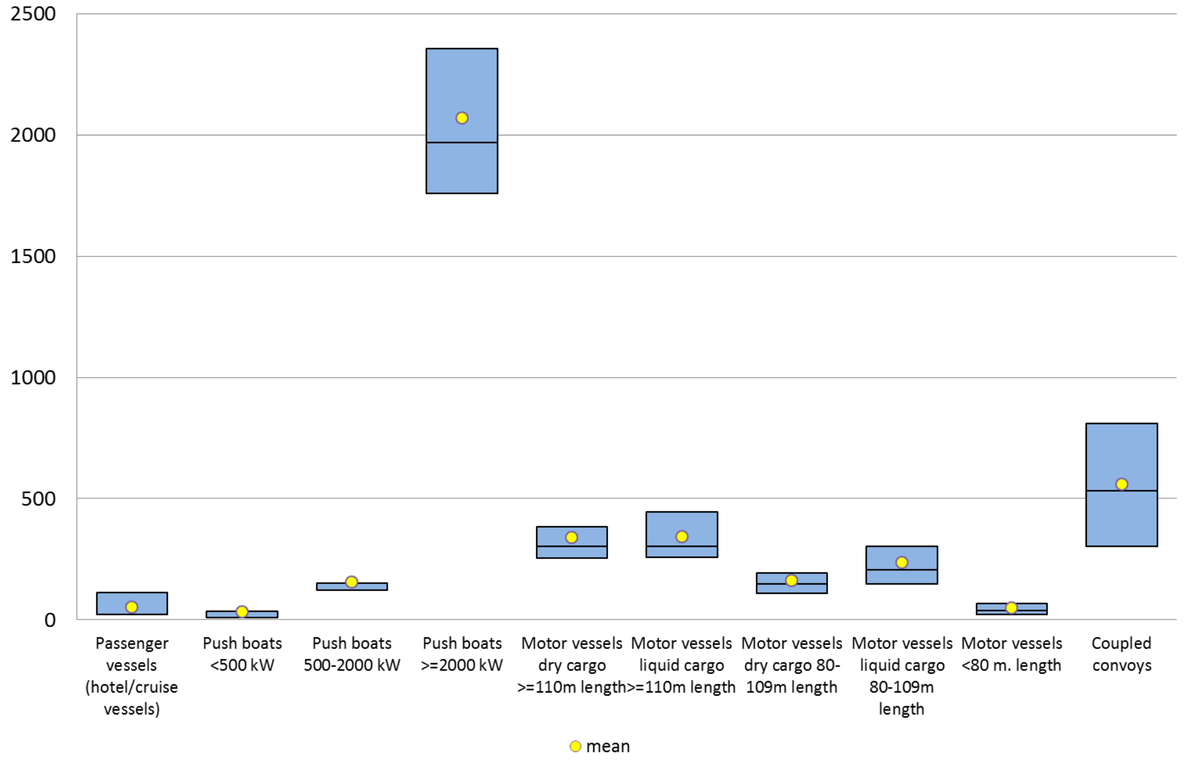


Figure 9: Boxplot of fuel consumption (in cubic metres) with mean and 25% - 75% interval (and median) of the observed data per year and main fleet families

2.1.1 Engine characteristics of the Rhine (and other waterways) fleet

Table 4 provides an overview of the average number of engines and engine power characteristics for the fleet families of the Western-European countries (mainly the Rhine and other waterways fleet). This information gives an indication of the engine characteristics of the entire European inland fleet as well, as the database used provides engine data for around 70% of the total active vessels in Europe. The table shows that the vessels with the highest average fuel consumption (i.e. large push boats and coupled convoys) have on average more engines and more total engine power installed as well.

The following figures present two boxplots indicating the averages as well as the 25% - 75% interval of the observed engine power data (in kW) of the main propulsion engine and the total power installed. It can be concluded from Figure 10 that mainly the large push boats, coupled convoys and large motor vessels have a high total engine power. The bandwidth observed is also larger for these fleet families. Figure 11 indicates that the motor vessels larger than 110 m have in general a higher engine power *per propulsion engine* installed, compared to the other fleet families with high fuel consumptions. These large motor vessels opt in general for a single, more potent, engine, whereas the large push boats and coupled convoys have 2 to 3 engines installed for their propulsion.

Fleet families identified in PROMINENT	Average number of engines installed	Power (in kW) per propulsion engine installed			Average total engine power installed (kW)
		25th percentile	Mean	75th percentile	
Passenger vessels (hotel/cruise vessels)	1.4	110	304	385	482
Push boats <500 kW (total engine power)	1.2	137	216	275	247
Push boats 500-2000 kW (total engine power)	1.6	351	542	700	847
Push boats ≥2000 kW (total engine power)	2.7	1,251	1,288	1,360	3,458
Motor vessels dry cargo ≥110m length	1.3	1,118	1,337	1,617	1,742
Motor vessels liquid cargo ≥110m length	1.3	1,118	1,390	1,660	1,780
Motor vessels dry cargo 80-109m length	1.1	520	707	880	764
Motor vessels liquid cargo 80-109m length	1.1	640	853	985	954
Motor vessels <80 m. length	1.1	165	280	368	302
Coupled convoys	1.9	956	1,178	1,388	2,237

Table 4: Average number of engines and engine power characteristics of the main fleet families (based on detailed information from Western-European countries)

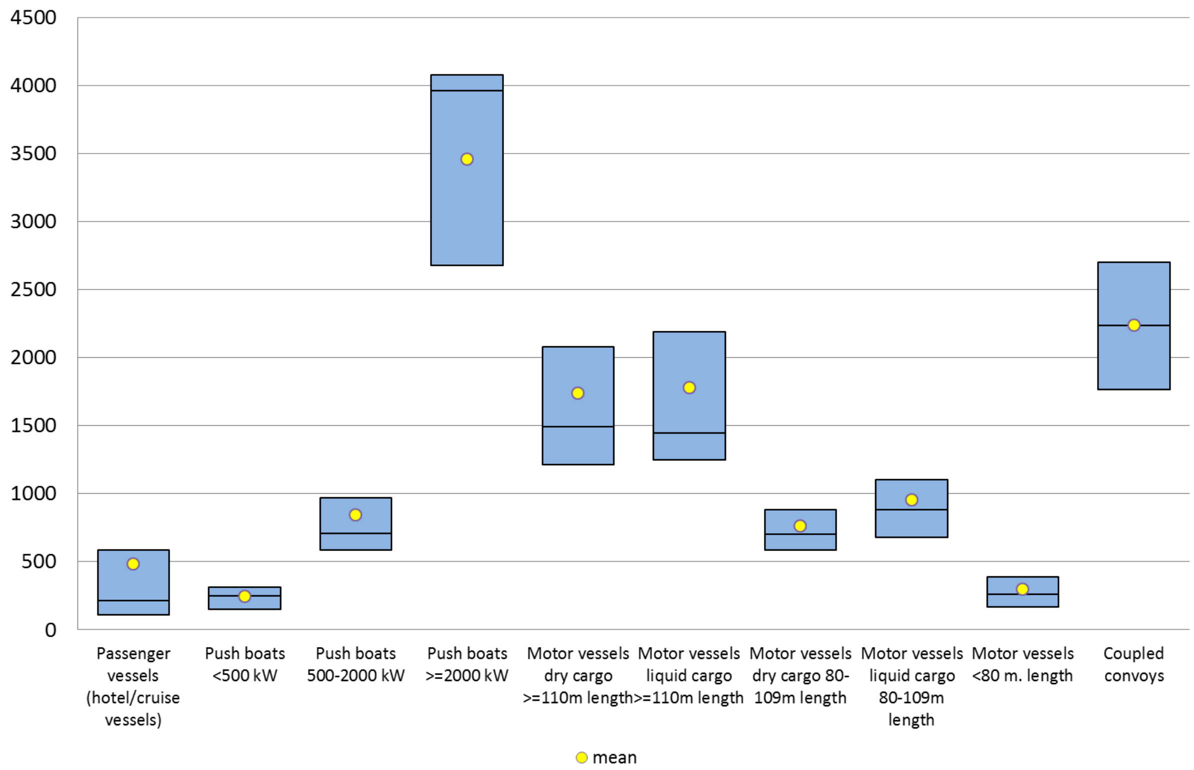


Figure 10: Boxplot of total propulsion power (in kW) with mean and 25%-75% interval (and median) of the observed data per year and main fleet families

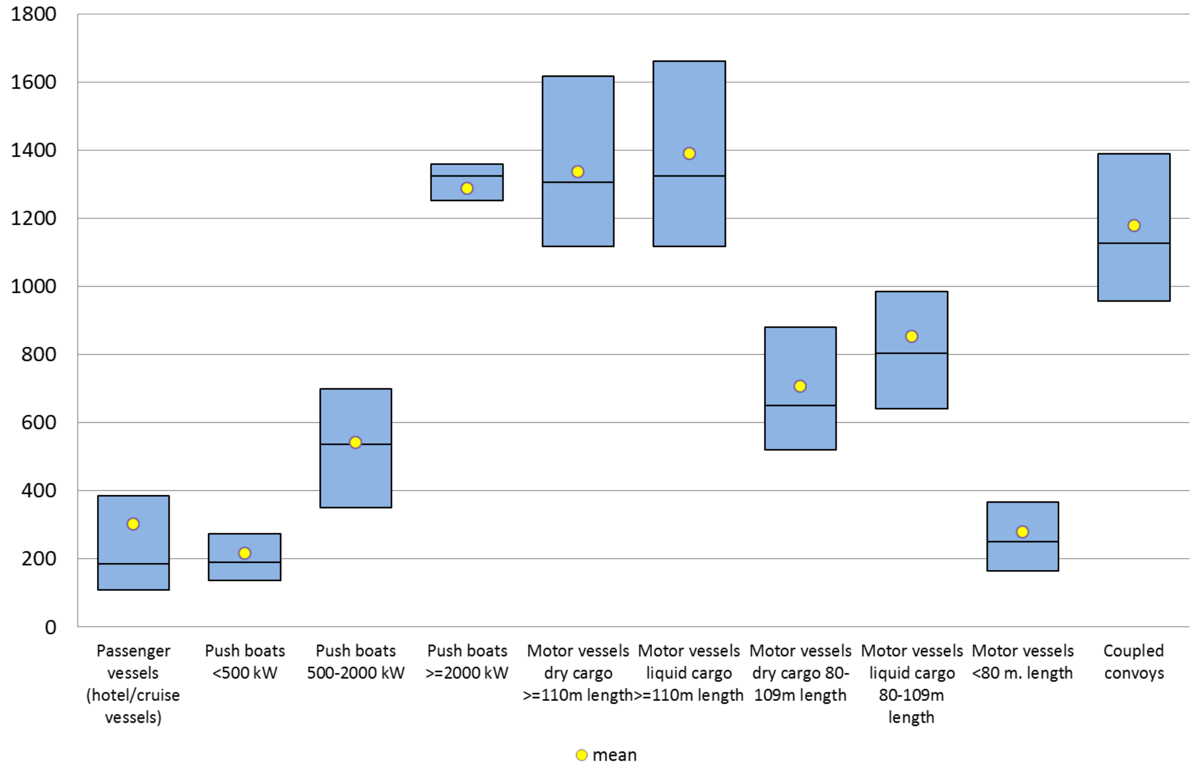


Figure 11: Boxplot of power of main propulsion engine (in kW) with mean and 25%-75% interval (and median) of the observed data per year and main fleet families

The variations in the installed power (in kW) per main propulsion engine are presented in more detail in the following figures. These figures provide input for the other activities that will be carried out in PROMINENT, as it indicates the most common power of the main propulsion engines.

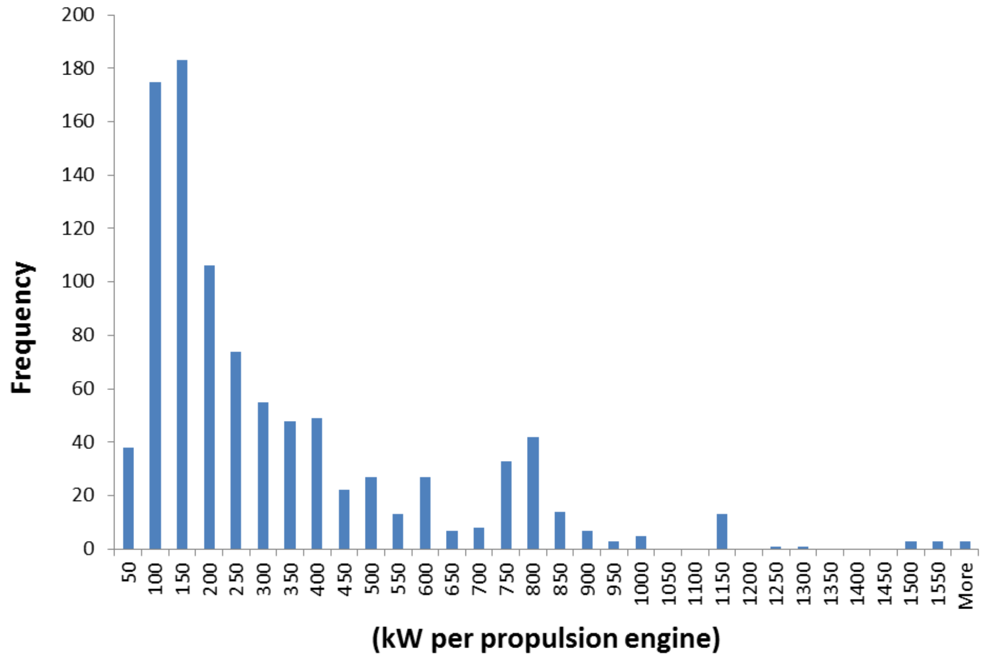


Figure 12: Histogram of power of main propulsion engine for passenger vessels (frequency represents the number of vessels)

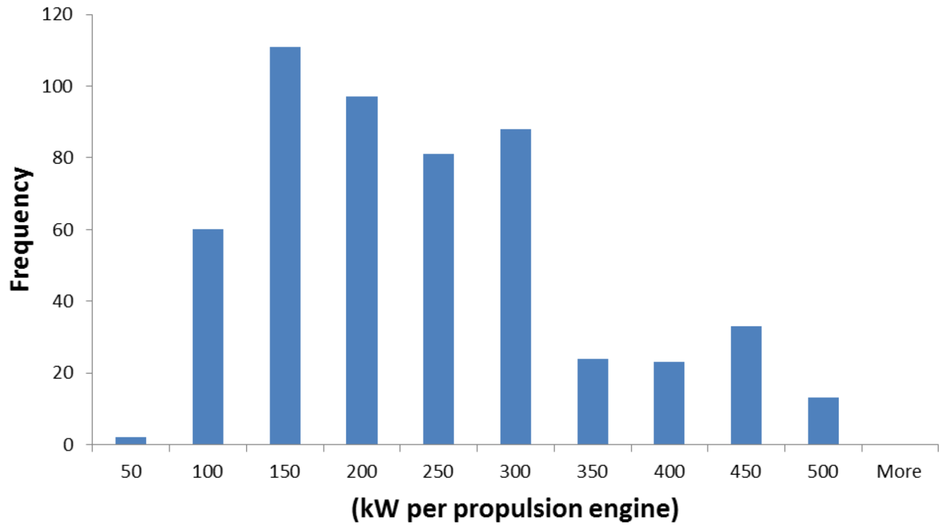


Figure 13: Histogram of power of main propulsion engine for push boats (<500kW) (frequency represents the number of vessels)

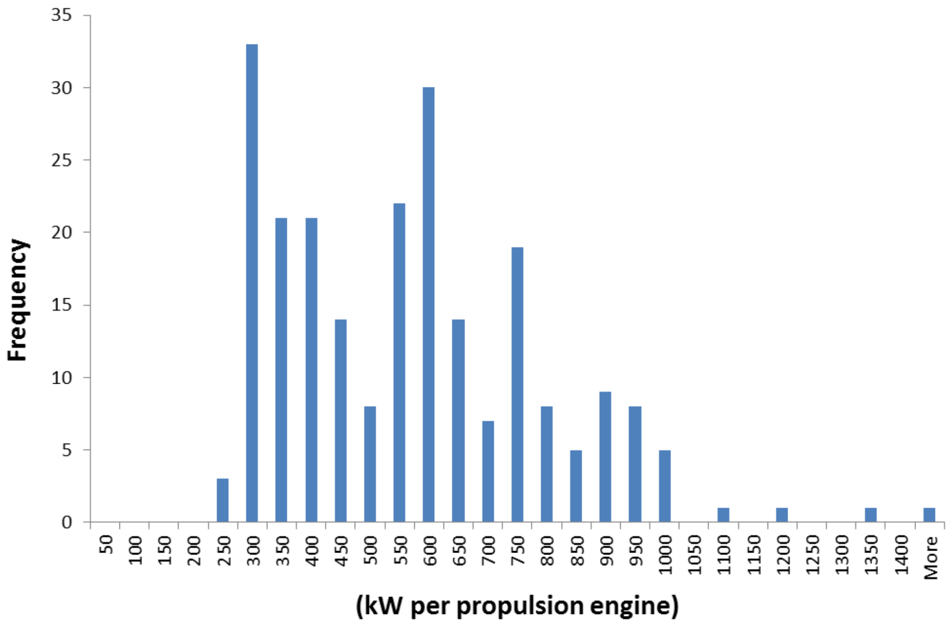


Figure 14: Histogram of power of main propulsion engine for push boats (500-2000kW) (frequency represents the number of vessels)

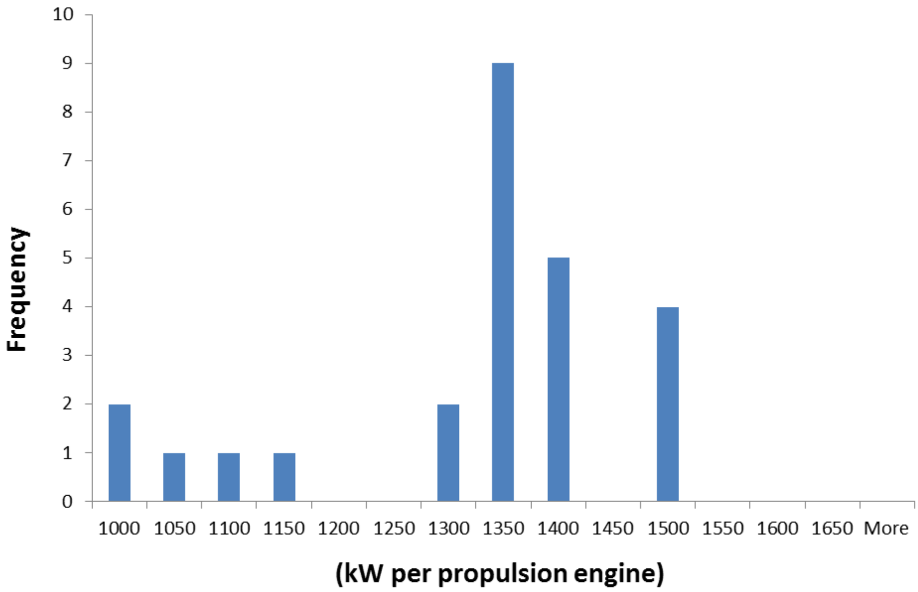


Figure 15: Histogram of power of main propulsion engine for push boats (>2000kW) (frequency represents the number of vessels)

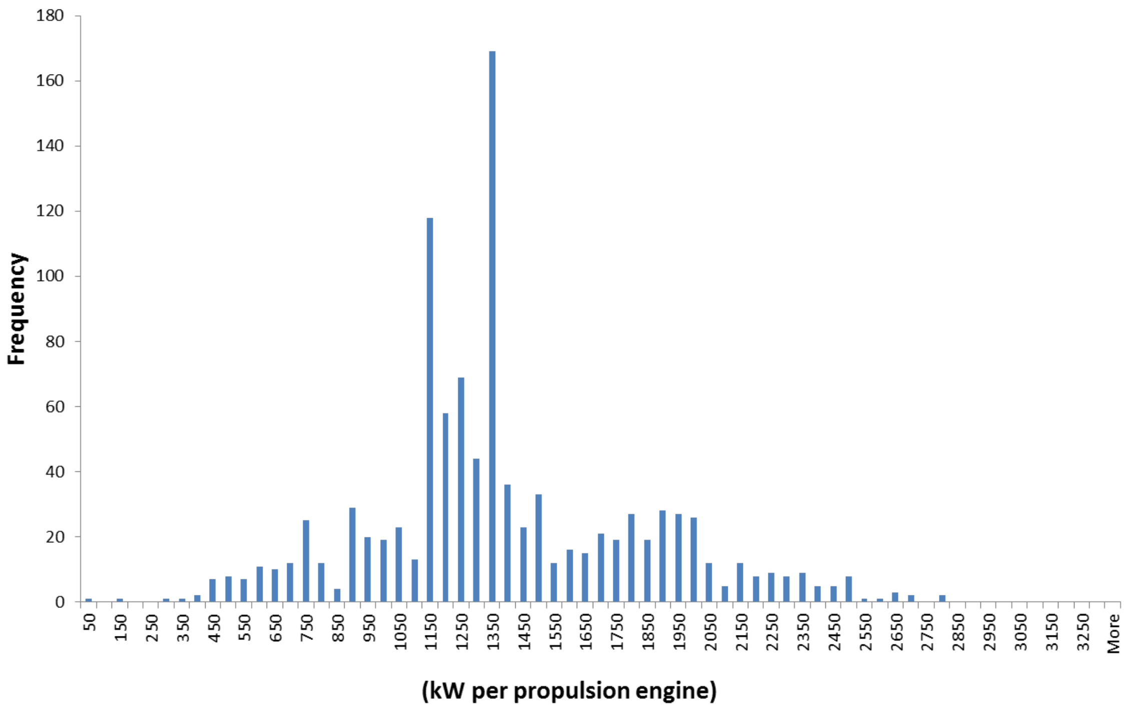


Figure 16: Histogram of power of main propulsion engine for motor vessels (≥110m; dry & liquid) (frequency represents the number of vessels)

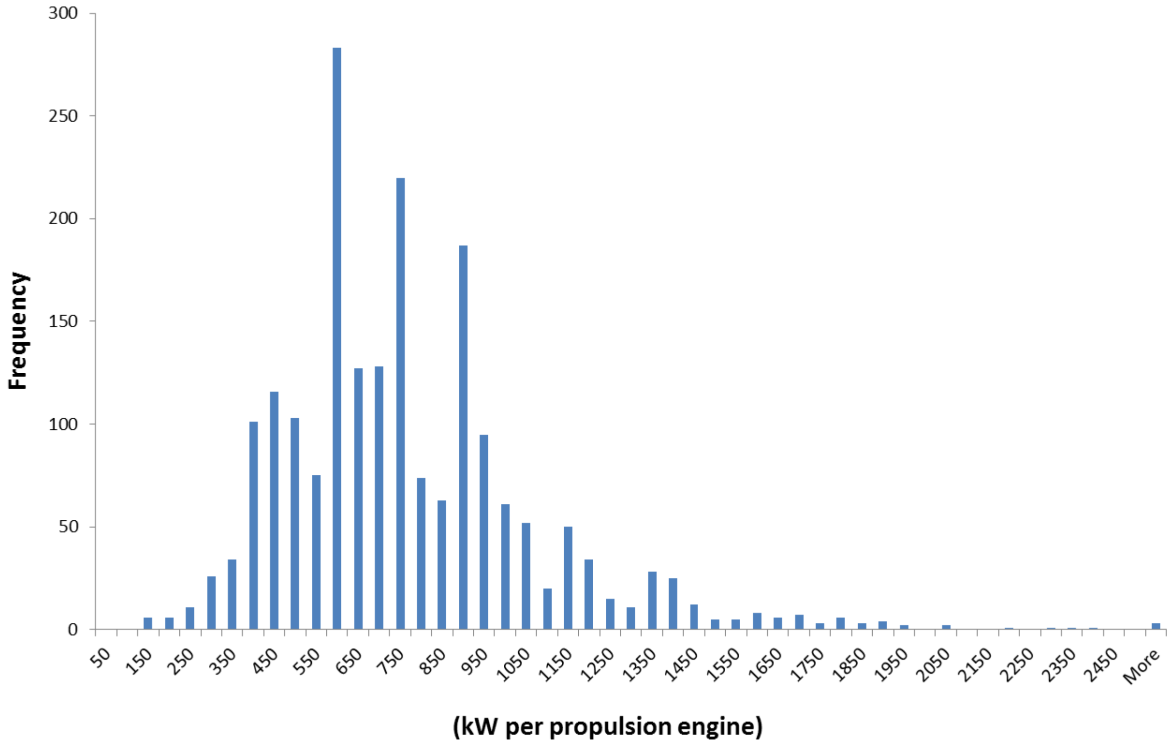


Figure 17: Histogram of power of main propulsion engine for motor vessels (80-109m; dry & liquid) (frequency represents the number of vessels)

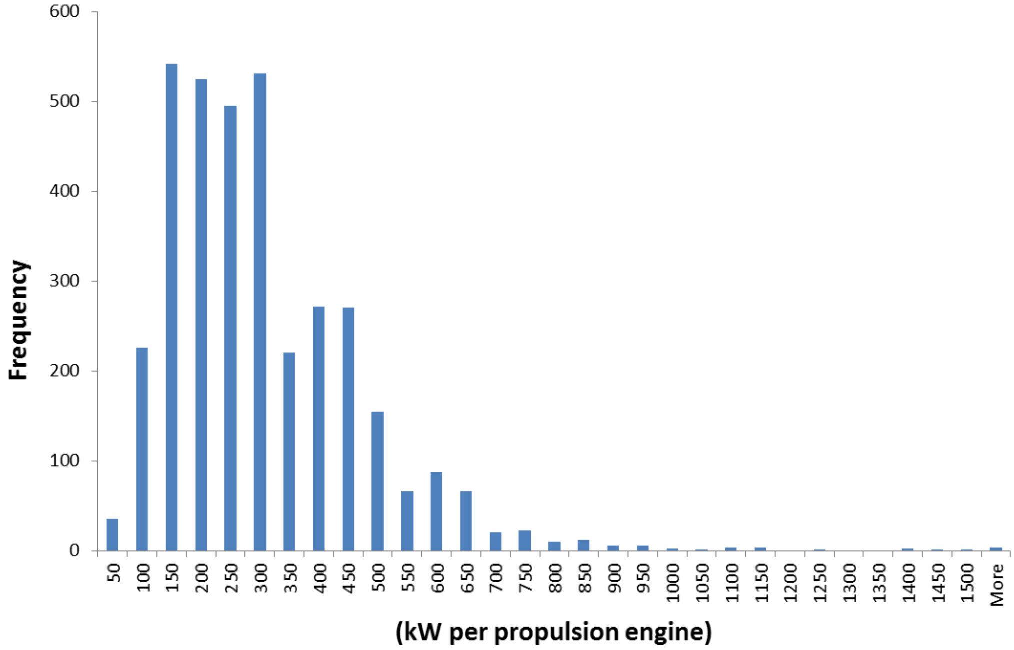


Figure 18: Histogram of power of main propulsion engine for motor vessels (<80m; dry & liquid) (frequency represents the number of vessels)

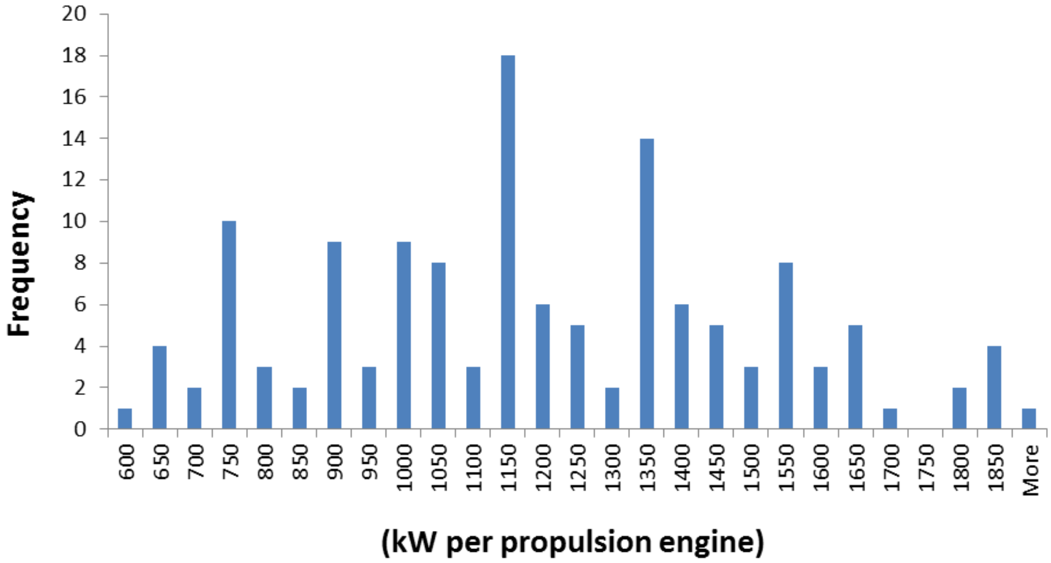


Figure 19: Histogram of power of main propulsion engine for coupled convoys (frequency represents the number of vessels)

Especially for the after-treatment systems (DPF and SCR solutions) it is important to know the engine speed (RPM) of the vessels. The following table provides an overview of the engine speed for the PROMINENT classes identified. The majority of the engines have high engine speeds.

Fleet families identified in PROMINENT	Engine speed		
	Low (<500 RPM)	Medium (500-1250 RPM)	High (>1250 RPM)
Passenger vessels (hotel/cruise vessels)	1%	1%	98%
Push boats <500 kW (total engine power)	10%	12%	79%
Push boats 500-2000 kW (total engine power)	0%	14%	86%
Push boats >=2000 kW (total engine power)	0%	67%	33%
Motor vessels dry cargo >=110m length	2%	13%	85%
Motor vessels liquid cargo >=110m length	1%	29%	70%
Motor vessels dry cargo 80-109m length	30%	14%	55%
Motor vessels liquid cargo 80-109m length	10%	13%	77%
Motor vessels <80 m. length	13%	13%	74%
Coupled convoys	1%	18%	81%

Table 5: Engine speed characteristics of the main fleet families (based on detailed information from Western-European countries)

Based on the IVR database in Table 6 and Figure 20 the information on the classes of year of construction of the main propulsion engine are presented (in case of known information: approximately 3,200 observations). It can be seen that mainly the larger vessels have already a high share of CCNR Stage-I or Stage-II engines. In particular passenger vessels, small push boats and small motor vessels are still largely equipped with old engines that are assumed to have high NOx and PM emissions per kWh.

However, as shown in Table 3 and Figure 9, these vessel types with older engines are not the most dominant ones with respect to fuel consumption.

	Unregulated (before 2003)	CCNR stage 1 engine (2003-2007)	CCNR stage 2 engine (>2007)
Passenger vessels	70%	12%	18%
Other push boats <500 kW	87%	7%	6%
Push boats 500-2000 kW	53%	29%	18%
Push boats >=2000 kW	36%	27%	36%
Motor vessels dry cargo >=110m	13%	52%	34%
Motor vessels liquid cargo >=110m	11%	32%	57%
Motor vessels dry cargo 80-109m	73%	18%	9%
Motor vessels liquid cargo 80-109m	44%	19%	37%
Motor vessels <80m	77%	16%	7%
Coupled convoys	12%	42%	45%

Table 6: Estimates on the year of construction of engines

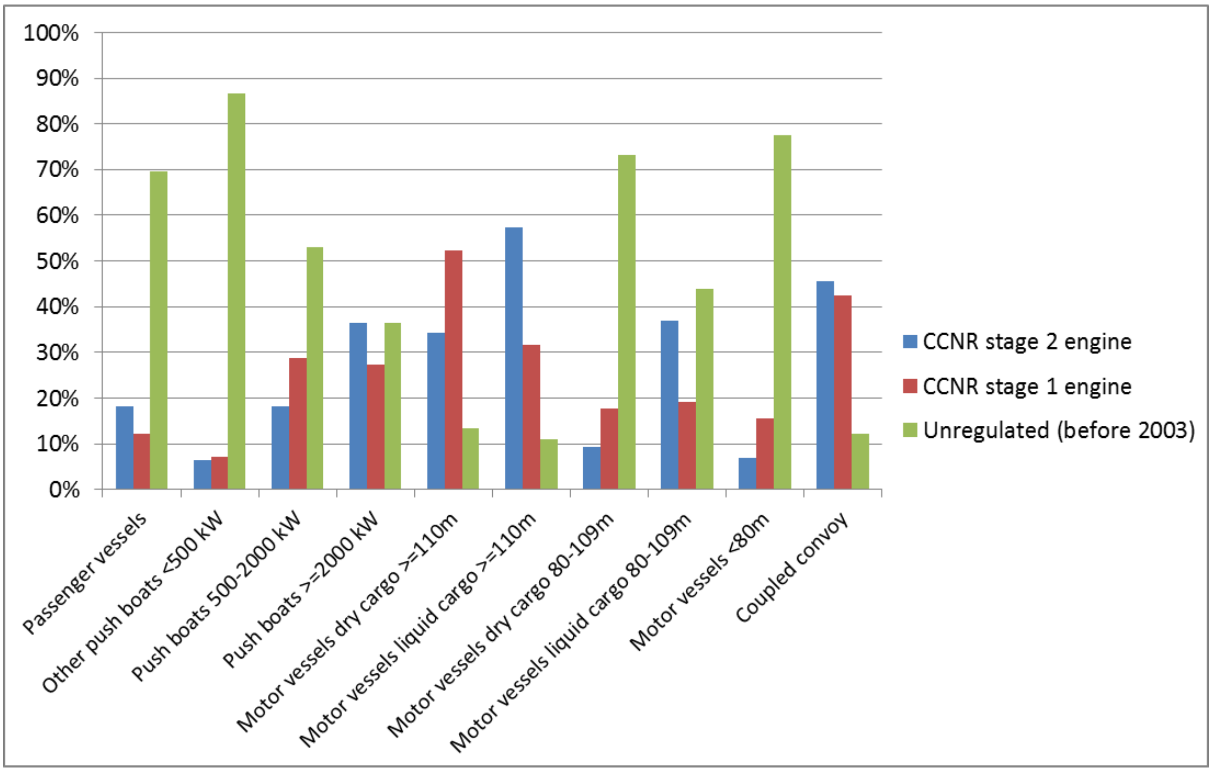


Figure 20: Engine type per main fleet family

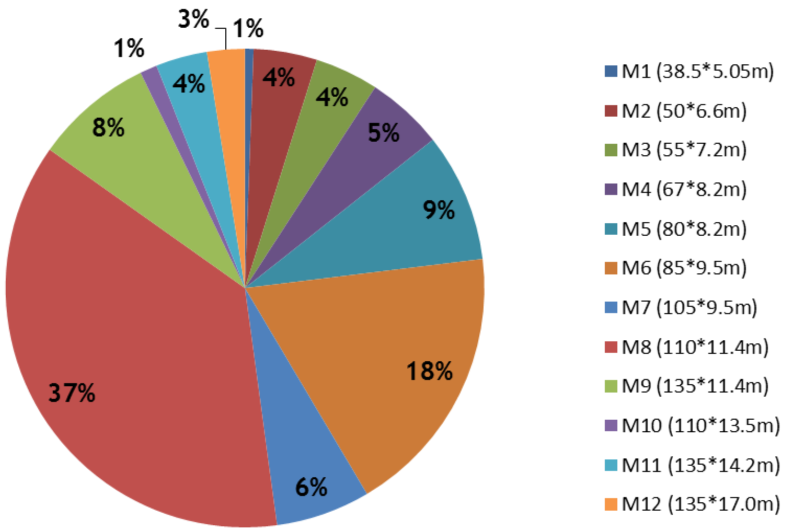
2.2 Overview of the Rhine fleet

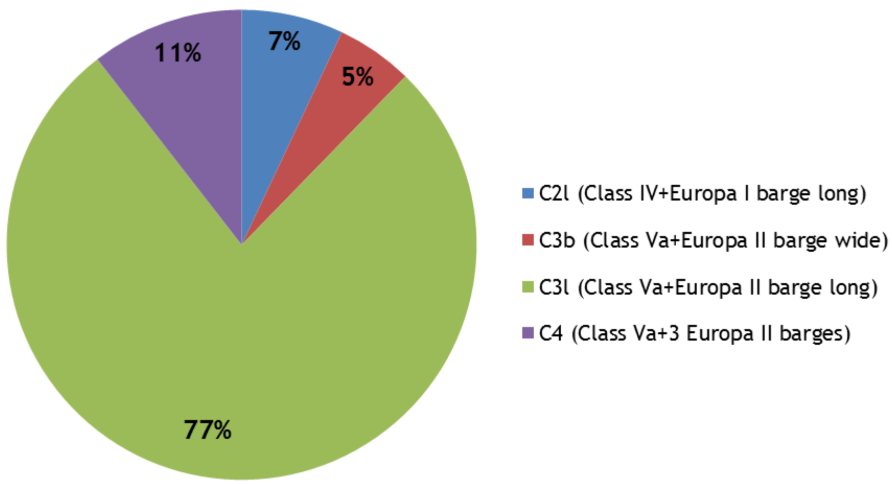
The most representative vessels on the Rhine are presented in the following table and figures. The data is based on the IVS-90 traffic counts for the year 2012 at Lobith, located on the border between the Netherlands and Germany. The vessels are classified according to the RWS 2010 vessel categories.

The most common motor vessel type on the Rhine is the M8 (reference dimension of 110x11.4 m according to RWS 2010 vessel), followed by the M6 (reference dimension of 80-85x9.5 m vessel). The large majority of coupled convoys are Class Va vessels sailing with a Europa II barge, sailing mainly in a long formation. The BII-4 (4 barges in a pushed convoy) formation is the most common push convoy on the Rhine.

Vessel type	Share in the number of passages
Motor vessels (reference dimensions)	
M1 (38.5*5.05m)	0,5%
M2 (50*6.6m)	3,7%
M3 (55*7.2m)	3,7%
M4 (67*8.2m)	4,5%
M5 (80*8.2m)	7,5%
M6 (85*9.5m)	15,9%
M7 (105*9.5m)	5,5%
M8 (110*11.4m)	31,9%
M9 (135*11.4m)	6,9%
M10 (110*13.5m)	1,0%
M11 (135*14.2m)	3,0%
M12 (135*17.0m)	2,2%
Coupled convoys	
C2l (Class IV+Europa I barge long)	0,4%
C3b (Class Va+Europa II barge wide)	0,3%
C3l (Class Va+Europa II barge long)	4,4%
C4 (Class Va+3 Europa II barges)	0,6%
Pushed convoys	
BII-1 (Europe II pushed convoy)	0,2%
BII-2b (2 Europe II barges in a wide pushed convoy)	0,2%
BII-4 (4 Europe II barges in a pushed convoy)	3,2%
BII-2L (2 Europe II barges in a long pushed convoy)	0,1%
BII-6b (6 Europe II barges in a wide pushed convoy)	0,9%
BII-6l (6 Europe II barges in a long pushed convoy)	1,0%

Table 7: Traffic counts for the year 2012 at Lobith (Source: Rijkswaterstaat, 'Toekomstige Ligplaatsbehoefte Overnachtingshaven Lobith 2013')





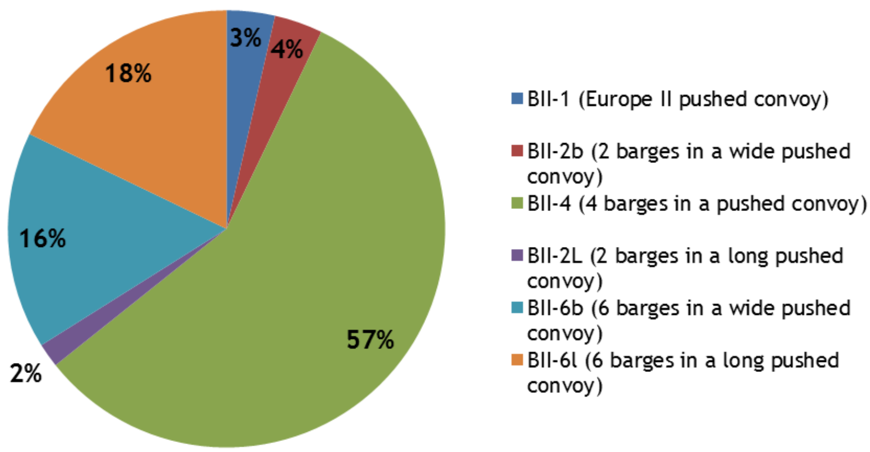


Figure 21: Traffic counts for the year 2012 at Lobith for motor vessels, coupled and pushed convoys (Source: Rijkswaterstaat, 'Toekomstige Ligplaatsbehoefte Overnachtingshaven Lobith 2013')

Detailed information on the engine characteristics and fuel consumption of the Rhine fleet has already been presented in section 2.1, as an important share of the Western-European fleet is active on the Rhine.

The following table provides information on the average power per main propulsion engine installed and the average total power for all the main propulsion engines of the vessels (in kW), specifically for the typical vessel types on the Rhine (according to Table 7 and Figure 21). In general: the longer the vessel size, the higher the average total power and number of engines installed.

Vessel type	Power (in kW) per main propulsion engine installed	Average total engine power installed (in kW)
Motor vessels (reference dimensions)		
M1 (38.5*5.05m)	189	192
M2 (50*6.6m)	267	287
M3 (55*7.2m)	375	400
M4 (67*8.2m)	428	451
M5 (80*8.2m)	552	568
M6 (85*9.5m)	675	733
M7 (105*9.5m)	826	886
M8 (110*11.4m)	1,196	1,281
M9 (135*11.4m)	1,214	2,287
M10 (110*13.5m)	1,485	1,770
M11 (135*14.2m)	1,414	2,553
M12 (135*17.0m)	1,418	2,955
Coupled convoys		
Class Va + Europa II barge(s)	1,178	2,237
Pushed convoys *		
Push boats 500-2000 kW (total engine power)	542	847
Push boats ≥2000 kW (total engine power)	1,288	3,458
*** A pusher with one Europa II barge has in general a propulsion power around 500 kW. The pusher with 2 Europa II barges has a range** of about **1000-2000 kW. A total propulsion power above 2000 kW is more common for pushers with 4 Europa II barges or more.**		

Table 8: Engine power characteristics of the Rhine fleet

2.3 Overview of the Danube fleet

Danube navigation is dominated by a relatively small number of major fleet operators carrying approximately 75% of the total freight.

The large shipping companies are, for the most part, derived from former state-owned enterprises mainly and provide cargo space for the transport of traditional bulk goods based on long term open policies. Smaller shipping companies and independent ship owners often have to be more flexible in finding cargoes and for the most part serve economic niches and short-term requirements for transport services.

On the Upper Danube small scale vessel operators from the Netherlands, Belgium and Germany connect the ARA ports and the industrial centres in North-Western Europe with Austria, Slovakia and Budapest. The vessel cooperative MSG located in Würzburg is one of the key players on the Western European route. There is currently little business activities downstream of Budapest from the North-Western European companies yet. Nevertheless, key players from the Rhine like Imperial Reederei, Lehnkering, Rhenus, etc are also present with their fleet or via subsidiaries (MDS belongs to Lehnkering, Donaulogistik to Imperial). With the further economic development of the Danube region, it can be expected that these companies will increase their engagement. In particular Rhenus which owned DDSG in the early 1990's seeks investment in ports and other logistics providers.

Most of the major fleet operators have neglected re-investment in the fleet as well as regular repair work over several years. Therefore, a significant number of vessels are practically out of commercial operations. The situation has been aggravated due to the sharp decrease in transport volumes and reduced profitability as consequence of the global financial crisis.
In total approximately 20 fleet operators (including vessel cooperatives) work on a regular basis on the Danube market. In addition to the fleet operators approximately 15 agents or freight forwarders are marketing Danube logistics services using the existing fleet operators for transport services. A high number of the clients (industrial shippers) manage their own logistics departments to interface with vessel operators.

Available data about the Danube fleet are from the Danube Commission from the year 2013. There are some limitations to these data, as mentioned under the methodology. It indicates the registered vessels and not necessarily the number of vessels in operation and provides information on the total number of vessels. Besides, German and Austrian fleets are not included in the following tables.

	Year	UA	MD (2008)	RO (2012)	BG (2012= 2010)	RS	HR	HU (2012)	SK	AT	DE	Total
Motorized vessels Number of units	2013	35	17	103	55	97	13	72	31	*	*	423
	2012	41	17	103	30	97	12	72	20	*	*	392
	%	85,4	100	100	183,3	100	108,3	100	155,0	*	*	107,9
Total power of motorized vessels (kW)	2013	56 182	3 000	53 539	31 915	37 929	7 940	*	11 946	*	*	202 451
	2012	66 920	3 000	53 539	18 651	37 929	7 355	*	11 709	*	*	199 103
	%	84,0	100	100	171,1	100	108,0		102,0	*	*	101,7
Total carrying capacity of motorized vessels (t)	2013	75 212	18 281	109 957	61 680	88 066	11 048	*	19 969	*	*	384 213
	2012	91 205	18 281	109 957	34 077	88 066	9 280	*	23 424	*	*	374 290
	%	82,5	100	100	181,0	100	119,1		85,3	*	*	102,7
Tugs Number of units	2013	5	10	64	13	94	30	49	2	*	*	267
	2012	9	10	64	13	94	31	49	2	*	*	272
	%	55,6	100	100	100	100	96,8	100	100	*	*	98,2
Total power of tugs (kW)	2013	3 640	8 977	22 059	4 668	24 768	8 748	*	915	*	*	73 775
	2012	6 728	8 977	22 059	6 116	24 768	8 834	*	915	*	*	78 397
	%	54,1	100	100	76,3	100	99,0		100	*	*	94,1
Pusher vessels Number of units	2013	71	1	163	42	65	10	23	39	*	*	414
	2012	73	1	163	38	65	10	23	37	*	*	410
	%	97,3	100	100	110,5	100	100	100	105,4	*	*	101,0
Total power of pusher vessels (kW)	2013	109 445	1 500	172 781	43 425	55 388	5 294	*	37 666	*	*	425 499
	2012	112 483	1 500	172 781	36 723	55 388	5 205	*	36 916	*	*	420 996
	%	97,3	100	100	118,3	100	101,7	*	102,0	*	*	101,1
Towed barges Number of units	2013	36	26	391	29	228	69	11	11	*	*	801
	2012	78	26	391	44	228	72	11	11	*	*	861
	%	46,2	100	100	65,9	100	95,8	100	100	*	*	93,0
Total carrying capacity of towed barges (t)	2013	57 707	24 653	238 074	32 793	294 001	39 011	*	6 747	*	*	692 986
	2012	125 362	24 653	238 074	47 122	294 001	40 056	*	6 747	*	*	776 015
	%	46,0	100	100	69,6	100	97,4		100	*	*	89,3
Pushed barges Number of units	2013	305	*	740	132	180	50	274	130	*	*	1 811
	2012	335	*	740	122	180	50	274	135	*	*	1 836
	%	91,0	*	100	108,2	100	100	94,2	96,3	*	*	98,6
Total carrying capacity of pushed barges (t)	2013	445 913	*	1 231 674	218 574	169 101	47 507	*	211 749	*	*	2 324 518

		Year	UA	MD (2008)	RO (2012)	BG (2012=2010)	RS	HR	HU (2012)	SK	AT	DE	Total
		2012	486 491	*	1 231 674	202 861	169 101	47 500	*	219 447	*	*	2 357 074
		%	91,7		100	107,7	100	100,0		96,5			98,6
TOTAL	Total number of vessels (unit)	2013	452	54	1461	271	664	172	429	213	*	*	3 716
		2012	536	54	1461	247	664	175	429	205	*	*	3 771
		%	84,3	100	100	109,7	100	98,3	100	103,9	*	*	98,5
	Total power of fleet (kW)	2013	169 267	13 477	248 379	80 008	118 085	21 982	*	50 527	*	*	701 725
		2012	186 131	13 477	248 379	61 490	118 085	21 394	*	49 540	*	*	698 496
		%	90,9	100	100	130,1	100	102,7		102,0	*	*	100,5
	Total carrying capacity of fleet (t)	2013	578 832	42 934	1 579 705	313 047	551 168	97 566	*	238 465	*	*	3 401 717
		2012	703 058	42 934	1 579 705	284 060	551 168	96 836	*	249 618	*	*	3 507 379
		%	82,3	100	100	110,2	100	100,8	*	95,5	*	*	97,0

* not available or magnitude "0".

Table 9: Overview of the Danube fleet (Source: Danube Commission, 2013 - http://www.danubecommission.org/uploads/doc/STATISTIC/Statistics%202012-2013%20Rev%201%20EN.pdf)

The following table provides a general overview of the fleet operating on the Danube with information about the total engine power and the payload, as well as the reduction of the quantity between the years.

Year	number of vessels	Engine Power (kW)	Payload (t)
2011	3.924	753.589	3.692.017
2012	3.771 (- 3,9%)	710.070 (- 5,77%)	3.507.379 (- 5%)
2013	3.715 (- 1,49%)	701.719 (- 1,18%)	3.401.011 (- 3,03%)

Table 10: General overview of number of vessels, engine power and payload for the Danube fleet (Source: Danube Commission: Statistik der Donauschifffahrt für die Jahre 2012-2013)

In the tables in Annex A4 examples are shown of the most typical vessels used on the Danube, provided by ship-owning companies operating in the Danube area.

Upper Danube: Lock Freudenau

In order to give an overview of the actual fleet operating on the Upper Danube, the lock records of viadonau are processed and analysed. The lock considered is the lock Freudenau in the east of Vienna (Austria). This lock can be considered also as proper in order to describe the part of the fleet operating on the Danube.

In Table 11, the amount of motor cargo vessels and pushers locked in the lock Freudenau in the year 2014 are presented, in which:

- L = length of the vessel;
- MCV = motor cargo vessel (dry cargo);
- MTV = motor tank vessel;
- PUSH = pusher (= pusher or tug, whereby the share of locked pushers is around 99%);
- 0B = vessel without barge (lighter);
- 1B = vessel with one barge (lighter).

The total amount of locked cargo vessels amounts to 7821. According to their appearance in the lock Freudenau, the following vessel categories are the most significant ones, covering approximately 75 % of vessels locked:

1) Single motor cargo vessel with a length between 94 and 136 m (16.92 %)
2) Single motor tank vessel with a length between 94 and 136 m (15.07 %)
3) Single motor cargo vessel with a length between 79 and 86 m (13.80 %)
4) Pusher with a length between 22 and 24 m pushing two lighters (12.99 %)
5) Pusher with a length between 31 and 39 m pushing two lighters (8.84 %)
6) Motor cargo vessel with a length between 94 and 136 m pushing one lighter (7.48 %)

In Table 12, the average engine power of vessels locked in the lock Freudenau between the years 2009 and 2011 is presented. The engine data were derived from various external and internal sources e.g. websites of ship owners. 669 different vessels, comprising approximately 80 % of vessels locked between the years 2009 and 2011, whereby each vessel is considered only once even when it was e.g. 10 times in the lock. The table provides an overview of the installed power of the main engines for each vessel category, as well as which vessel types are most significant in the operating fleet of the Upper Danube. The majority of the fleet in operation consists of the following vessel types (motor cargo vessel = dry cargo and liquid cargo):

1) Motor cargo vessel with a length of 110 m (1150 kW)
2) Motor cargo vessel with a length of 105 m (950 kW)
3) Motor cargo vessel with a length of 80 m and a width of 8.2 m (600 kW)
4) Motor cargo vessel with a length of 85 m and a width of 9.5 m (750 kW)
5) Motor cargo vessel with a length of 85 m and a width of 8.2 m (600 kW)
6) Pusher with a length of 57 m (1470 kW)

It is interesting to note that the Steinklasse vessel (length of 95 m) is not the representative motor cargo vessel for the Upper Danube, although it was considered to be the typical Danube vessel. Further, the lengths of the most common representatives of the fleet in operation are in the range between 105 and 110 m, which actually complies with the outcome of the Innovative Danube Vessel project[14], where an optimum length of 105 m was determined for a motor cargo vessel operating on the Danube.

[14] Study available at: http://www.danube-navigation.eu/item/663115

Vessel type	Nr. of passages	Nr. of passages [%]	Total
L 94-136 MCV 0B	1323	16,92%	3199
L 94-136 MCV 1B	585	7,48%	
L 94-136 MCV 2B	13	0,17%	
L 94-136 MCV 3B	20	0,26%	
L 94-136 MCV 4B	1	0,01%	
L 94-136 MTV 0B	1179	15,07%	
L 94-136 MTV 1B	78	1,00%	
L 79-86 MCV 0B	1079	13,80%	1600
L 79-86 MCV 1B	173	2,21%	
L 79-86 MCV 2B	5	0,06%	
L 79-86 MCV 3B	1	0,01%	
L 79-86 MTV 0B	341	4,36%	
L 79-86 MTV 1B	1	0,01%	
L 66-68 MCV 0B	43	0,55%	44
L 66-68 MCV 1B	1	0,01%	
L 56-58 MCV 0B	6	0,08%	336
L 56-58 MTV 0B	2	0,03%	
L 56-58 PUSH 0B	19	0,24%	
L 56-58 PUSH 1B	18	0,23%	
L 56-58 PUSH 2B	262	3,35%	
L 56-58 PUSH 3B	28	0,36%	
L 56-58 PUSH 4B	1	0,01%	
L 31-39 PUSH 0B	84	1,07%	1079
L 31-39 PUSH 1B	58	0,74%	
L 31-39 PUSH 2B	691	8,84%	
L 31-39 PUSH 3B	53	0,68%	
L 31-39 PUSH 4B	192	2,45%	
L 31-39 PUSH 5B	1	0,01%	
L 22-24 PUSH 0B	239	3,06%	1563
L 22-24 PUSH 1B	275	3,52%	
L 22-24 PUSH 2B	1016	12,99%	
L 22-24 PUSH 3B	26	0,33%	
L 22-24 PUSH 4B	7	0,09%	
	Σ	100,00%	7821

Table 11: Amount of motor cargo vessels and pushers locked in the lock Freudenau in the year 2014.

Vessel	Average brake power	Number of vessels
	[kW]	
MCV L = 135 m	1800	31
MCV L = 115 m	1400	9
MCV L = 115 m, B = 22.8 m	1800	4
MCV L = 115 m, B = 11 m	1100	5
MCV L = 110 m	1150	103
MCV L = 105 m	950	72
MCV L = 100 m	850	28
MCV L = 95 m (all)	1300	35
MCV L = 95 m, B = 11 m	1544	16
MCV L = 85 m (all)	700	138
MCV L = 85 m, B = 9.5 m	750	47
MCV L = 85 m, B = 8.2 m	600	40
MCV L = 80 m (all)	600	109
MCV L = 80 m, B = 9.5 m	700	22
MCV L = 80 m, B = 9.0 m	650	23
MCV L = 80 m, B = 8.2 m	600	52
MCV L = 67 m (all)	425	34
MCV L = 67 m, B = 8.2 m	450	15
MCV L = 67 m, B = 7.2 m	400	13
Pusher 57 m x 8.6 m x 1.7 m	1470	35
Pusher 38 m x 10 m x 2.0 m	1800	7
Pusher 35 m x 11 m x 1.9 m (all)	1600	32
Pusher 1 35 m x 11 m x 1.9 m	1000	13
Pusher 2 35 m x 11 m x 1.9 m	1700	8
Pusher 3 35 m x 11 m x 1.9 m	2000	5
Pusher 4 35 m x 11 m x 1.9 m	2500	6
Pusher 32 m x 11 m x 1.8 m	1700	8
Pusher 32 m x 11.4 m x 2.0 m	2600	4
Pusher 23 m x 8.9 m	1000	24

Table 12: Average engine power of vessels locked in the lock Freudenau between the years 2009 and 2011.

2.4 Overview of the fleet on the other waterways

Related to the freight flow assessment in Chapter 1.2, a selection of “other waterways” is made to analyse the typical fleet on popular OD relations in Europe. The definition of “other waterways” refers to the pre-dominantly used sections of the Rhine, Danube and ARA regions. By means of desk research, traffic data has been analysed to give an overview of the fleet on the following waterways:

- Belgium: Albert Canal
- France: Seine, Saône/Rhône;
- Germany: Mittelland Canal, Dortmund-Ems Canal, Elbe;
- The Netherlands: North-South corridor, Meuse.

2.4.1 Fleet on main waterways in Belgium

In terms of volume transported, the Albert Canal is the main waterway for IWT in Belgium. Based on a traffic count by NV De Scheepvaart in 2008, an estimation of the most representative vessels operating on the Albert Canal could be determined. The overview is provided in the table below. Although no coupled convoys and/or pushed convoys can be distinguished from the data, the overview clearly indicated that especially vessels larger than 2,000 tonnes are used on the Albert Canal. Therefore the most common vessels used must be approximately 110m in length of larger, be a coupled convoy and/or a pushed convoy.

Vessel type		Share in the number of passages
Loading capacity [tonnes]	Estimated vessel length [m]	
=< 300	< 38.5	0.6%
301 - 650	38.5 - 55	19.1%
651 - 800	55 - 70	6.8%
800 - 1350	70 - 80/86	21.8%
1350 - 2000	80 - 105	16.5%
>= 2000	>= 110	35.2%

Table 13: Overview fleet Albert Canal (Source: NV De Scheepvaart, Statistiek 2008)

2.4.2 Fleet on main waterways in France

The waterways in France are well known for their Freycinet lock systems and related vessel types (38.5 x 5.05m). There are also exceptions to the small waterway classes in France, namely the Seine-Oise and the Rhône-Saône basins. It is on these waterways, where the larger freight flows are found due to the relation of the sea ports of Le Havre and Fos-sur-Mer and their hinterland, respectively Paris and Lyon (and beyond).

As the overview of the fleet statistics on the Seine in Figure 22 indicates, in 2008 there were 161 self-propelled vessels with a total loading capacity of 177,000, which means that the average loading capacity of vessels is approximately 1,100 tonnes. Additionally there were also 271 push barges with an average loading capacity of 1,370 tonnes.

Vessels which typically circulate on the Seine have a capacity of 800 tonnes to 1,350 tonnes (between 55m and 86m in length). Convoys of barges vary in length between 40 - 80m, which can typically transport between 3,000 tonnes and 5,000 tonnes depending on the barge arrangement (single or double pushed convoy). More recently larger vessels have been introduced for the purpose of container transport, such as self-propelled vessels of 135m and also 2 barge pushed convoys are used with a capacity of 352 TEU (in 4 levels).

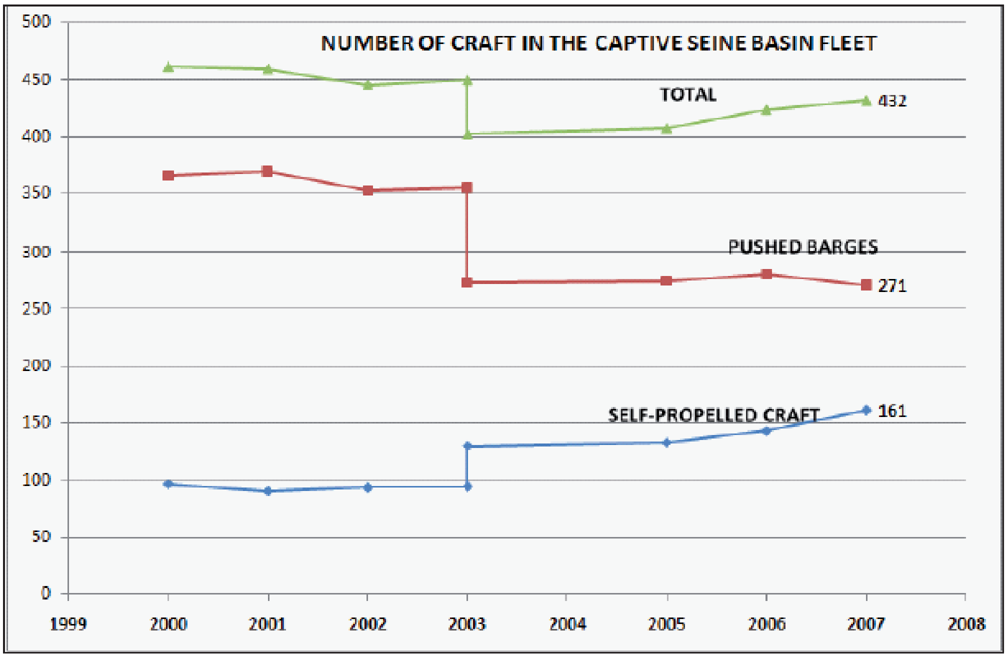


Figure 22: Overview fleet Seine-Oise basin (Source: UNECE (2011), White paper on Efficient and Sustainable Inland Water Transport in Europe based upon VNF estimates)

In Table 14 an overview is provided of the amount of vessels operating on the Saône / Rhône basin in 2008. The total capacity of 182,562 tonnes divided over 95 vessels, results in an overall average capacity of almost 2,000 tonnes. Conclusively the type of vessels used relate to the governing CEMT class V on these waterways up to Pagny-la-Ville, making it feasible to operate self-propelled vessels up to a length of 110m (3,000 tonnes) and convoys up to approximately 5,500 tonnes.

	No	Tonnes	power kW	Average capacity (t)
Dry cargo fleet	79	147 240	32 524	1 864
Self-propelled vessels	41	59 335	32 524	1 447
Pushed barges	38	87 905		2 313
Tanker fleet	16	35 322	8 290	2 208
Self-propelled vessels	7	13 898	8 290	1 985
Pushed tanker barges	9	21 424		2 380
Total	**95**	**182 562**	**40 814**	**1 922**

Table 14: Overview fleet Saône / Rhône basin (Source: UNECE (2011), White paper on Efficient and Sustainable Inland Water Transport in Europe based upon VNF Lyon estimates)

2.4.3 Fleet on main waterways in Germany

The most representative vessels on the other German waterways, which are not covered by the analysis of operational profiles of the Rhine journeys, are the following: Mittelland Canal, Dortmund-Ems Canal and Elbe river (although transport on the Elbe is very limited due to draught limitations). An overview of the type of vessels operated on these waterways is given in Annex A3. In the figure below, a fleet overview is given of a German inland shipping enterprise which operates on the West-East corridor in Germany. As indicated in the figure the typical length of the motor vessels is between 67 and 80 meters, with an average loading capacity of about 1,000 tonnes. Additionally also barges are used in various formations and lengths.

Schubschiffe / Typ	Anzahl	kW (von – bis)
Schubschiff 26 flachgehend	5	448 – 894
Schubschiff 27	6	574 – 890
Schubschiff 25 / 26	16	352 – 1.102
Schubschiff 24	28	220 – 588
Schubschiff 22 / 23	17	69 – 366
Schubschiffe gesamt	72	
Motorschiffe / Typ (Länge / Breite / Tiefgang; Meter)	Anzahl	Tragfähigkeit t (von – bis)
Trockenmotorschiffe (67 – 80 m / 8,2m / 2,35 m)	30	922 – 1.146
Tankmotorschiffe (80 m / 8,2 m / 2,35 m)	2	1.000 – 1.100
Motorschiffe gesamt	32	

Schubleichter /Typ (Länge / Breite / Tiefgang; Meter)	Anzahl	Tragfähigkeit t (von – bis)
Containerschubleichter TC 1000 (71 m / 10,45 m / 2,5 m)	15	1.450 54 TEU
Containerschubleichter SL 65 – 9,50 (65 m / 9,5 m / 2,4 m)	26	1.190 54 TEU
Trockenschubleichter SL 65 (65 m / 8,2 m / 2,33 m)	44	975
Containerschubleichter SL 36/37 – 9,50 (32,5 m / 9,5 m / 2,17 m)	13	530 24 TEU
RoRo-Schubleichter GSP 65 (65 m / 9,5 m / 2,27 m)	3	1066
RoRo-Schubleichter GSP 54 (54 m / 11 m / 2,06 m)	3	960
Trockenschubleichter SL 36/37 (32,5 m / 8,2 m / 2,1 m)	214	bis 470
Wannenschubleichter (32,5 m / 8,2m / 2,1 m)	61	430
Mörtelschubleichter (32,5 m / 8,2 m / 2,1 m)	2	430
Trockenschubleichter Finow (31,3 m / 5,04 m / 1,7 m)	6	210
Tank- und Produktentankschubleichter (32,5 – 65 m / 8,2 m / 2,15 m)	5	500 – 1.023 m^3
Schubleichter gesamt	392	

Table 15: Overview typical fleet German canals and Elbe (Source: Deutsche Binnenreederei (BDR), 'Gütertransport per Binnenschiff')

2.4.4 Fleet on main waterways in The Netherlands

Most representative vessels operating on the North-South corridor

The most representative vessels operating between Rotterdam and Antwerp and additional relations on the North-South corridor are presented in Table 16. The data is based on the IVS-90 traffic counts for the year 2008 at the lock of Volkerak, located in The Netherlands in the province of Noord-Brabant. The vessels are classified according to the RWS 2010 vessel categories.

Similar to the traffic counts on the Rhine, the most common motor vessel type on the North-South corridor is the M8 (110x11.4 m vessel), followed by the M6 (80-85*9.5 m vessel). Although small in number, yet large in transport capacity, the large majority of coupled convoys are Class Va vessels sailing with a Europa II barge in a long formation. The sum of BII-2b and BII-2l formations (2 barges in a pushed convoy in either long or wide formation) are the most common push convoys on the North-South corridor, together with a single Europe II push convoy (95 – 110 m). Also large capacity pushed convoys with 4 and 6 barges are regularly registered on the North-South corridor.

Vessel type	Share in the number of passages
Motor vessels (reference dimensions)	
M1 (38.5*5.05m)	2.38%
M2 (50*6.6m)	6.03%
M3 (55*7.2m)	5.69%
M4 (67*8.2m)	5.70%
M5 (80*8.2m)	7.86%
M6 (85*9.5m)	13.56%
M7 (105*9.5m)	6.11%
M8 (110*11.4m)	32.05%
M9 (135*11.4m)	3.99%
M10 (110*13.5m)	2.74%
M11 (135*14.2m)	1.48%
M12 (135*17.0m)	1.63%
Coupled convoys	
C1b (Class coupled convoy of M1 wide)	0.09%
C1l (Class coupled convoy of M1 long)	0.29%
C2l (Class IV+Europa I barge wide)	0.13%
C2l (Class IV+Europa I barge long)	0.23%
C3b (Class Va+Europa II barge wide)	1.07%
C3l (Class Va+Europa II barge long)	2.72%
C4 (Class Va+3 Europa II barges)	0.42%
Pushed convoys	
BI (Europe I pushed convoy)	0.57%
BII-1 (Europe II pushed convoy)	1.24%
BIIa-1 (Europe IIa pushed convoy)	0.51%
BII-2b (2 Europe II barges in a wide pushed convoy)	0.80%
BII-4 (4 Europe II barges in a pushed convoy)	1.07%
BII-2L (2 Europe II barges in a long pushed convoy)	0.42%
BII-6b (6 barges in a wide pushed convoy)	0.00%
BII-6l (6 Europe II barges in a long pushed convoy)	0.98%
B01 (pushed convoy of 55*5.2*1.9m)	0.00%
B02 (pushed convoy of 60-70*6.6*2.6m)	0.02%
B03 (pushed convoy of 80*7.5*2.6m)	0.04%
B04 (pushed convoy of 85-105*9.5*3.0m)	0.20%

Table 16: Traffic counts for the year 2008 at Volkerak (according to the RWS 2010 vessel categories) (Source: Deltares, 2011. Volkeraksluizen - effect zoutdrempel op scheepvaart)

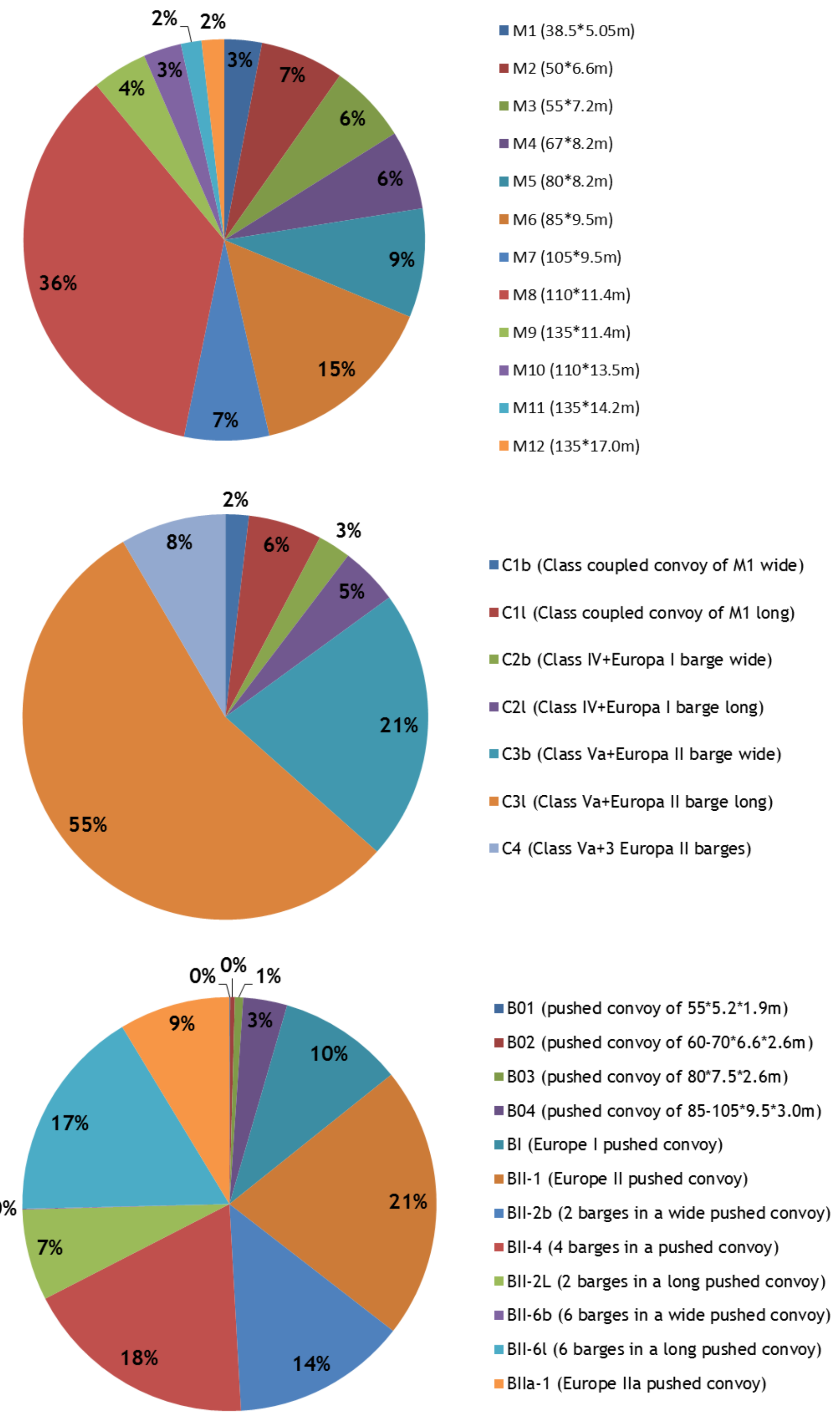


Figure 23: Traffic counts for the year 2008 at the Volkerak lock for motor vessels, coupled and pushed convoys (according to the RWS 2010 vessel categories) (Source: Deltares, 2011. Volkeraksluizen - effect zoutdrempel op scheepvaart)

Most representative vessels operating on the Meuse

The most representative vessels operating on the Meuse are based on traffic counts at the lock of Sambeek, located in the province of Limburg in The Netherlands. The vessels are classified according to the RWS 2010 vessel categories. An overview of the vessels typically operating on the Meuse is given in Table 17.

The most common motorvessel type used on the Meuse is the M4 (67 x 8.2 m vessel), followed by the M8 (110 x 11.4 m vessel). However, in the nearby future this image is going to change. As of 2018 the section between Maastricht and Nijmegen, the Meuse will have been upgraded to a CEMT-class Vb waterway allowing 2 barges in a long pushed convoy to operate on this section of the Meuse, with a maximum allowed dimension of 190 x 11.4 x 3.5 m.

Vessel type	Share in the number of passages
Motor vessels (reference dimensions)	
M1 (38.5*5.05m)	1.56%
M2 (50*6.6m)	15.08%
M3 (55*7.2m)	13.30%
M4 (67*8.2m)	20.73%
M5 (80*8.2m)	14.06%
M6 (85*9.5m)	14.75%
M7 (105*9.5m)	5.52%
M8 (110*11.4m)	15.00%
Pushed convoys	
BII-2L (2 Europe II barges in a long pushed convoy)	0.00%

Table 17: Traffic counts at the Sambeek lock for motor vessels, coupled and pushed convoys (according to the RWS 2010 vessel categories) (Source: Royal Haskoning (2008), 'MER Hoogwatergeul Well-Aijen' based upon the MIT Verkenning Born-Ternaaien (Ecorys, 2007))

3. Overview of operational profiles

3.1 Operational profiles of the European fleet

3.1.1 Representative journeys

Related to the freight flow analysis in chapter 1.2, in Table 1 a total selection of 60 representative journeys is presented for common IWT relations on European waterways in cargo and passenger transport. The selected journeys in cargo transport have been selected with reference to Annex A1 and Annex A2, based on the most common OD relations and largest type of commodity transported on the most common OD relations. For passenger transport reference is made to the growing market of river cruises all over European waterways.

To determine the operational profile per representative journey and power distribution over time, the following input has been determined per journey:

- Trip from Port A to Port B;
- Type of cargo and commodity transported;
- Vessel type and related typical dimensions;
- Transport performance in tonne-kilometre on relation;
- Maximum payload and Payload carried;
- Number of installed engines in vessel and Power of main engines;
- Payload carried;
- Average operational hours per year;
- Distance roundtrip and sailing time;
- Whether the vessel returns empty to port of origin or continues to pick up a return load;
- Sailing time loaded / empty;
- Waiting times during (un)loading;
- Total time round trip, including waiting time for (un)loading.

The input is largely based on sources used in the macro model on fleet statistics, described in previous chapters. For the remaining input the following sources are used:

- Estimates regarding operational hours per year are based on the Rijkswaterstaat IWT cost model 2014;
- The PLATINA 2 D2.3 report from 2015 ('Review of European data sets and identification of gaps. Information needs, reviewed datasets and gap analysis for providing the information basis for the determination of external costs performance in inland navigation as regards emissions to air') provided an important basis for the assumptions used on speed, load transported and empty sailings.
- Detailed information of the MoVe-IT! Project;
- Distance of trips were estimated using the routeplanner of Periskal on the website of Promotie Binnenvaart Vlaanderen.[15]
- Remaining input not mentioned was estimated on expert judgement, to be verified by means of interviews in a later stage of the PROMINENT project.

[15] pbv.periskal.com

General information regarding the selection of representative journeys, commodities transported and vessel types is given in the following sections. More detailed information per representative as indicated above can be found in Annex A3.

3.1.2 Operational profiles

The operational profiles in terms of used propulsion power are mostly determined by the characteristics of the vessel and even more by the boundary conditions of the waterway. For most vessels more than 50 % of the installed power is only utilised going upstream on free flowing river sections with sufficient high water depth and for manoeuvring. On smaller channels or downstream sections only a limited amount of power is applied. Where the keel clearance is small, excessive power use leads to increased squat and consequently may cause grounding. In general very little data is available in the public domain on the day to day operation of inland navigating vessels. The full scale measurements planned within the PROMINENT project will bring an important gain of knowledge in this area.

The profiles generated within SWP 1.1 were derived from dedicated simulations according to the list of representative journeys (see Annex 3). For each simulated journey a set of power profiles according to the principle dimensions and installed engine power of the vessel was extracted from DST's database. The draught was set according to the information in the list of journeys and reduced if required by the loading-relevant water levels for journeys on waterways with temporally resolved data. However, they are massively influenced by the underlying assumptions and the resolution and quality of both data on vessel and waterway characteristics. For some of the 60 selected journeys no profiles could be produced for various reasons. The waterway data had to be collected, segmented or combined and prepared for every single journey. For some segments no spatial resolution of hydrological data was available in the public domain or within the PROMINENT consortium. For some vessels even DST's database of speed-power profiles was not sufficient. Most model tests are conducted in a very narrow speed range for trial conditions while the simulations need to cover small speeds for sailing downstream or on channel sections as well. For these cases performance predictions were derived from existing data by means of empirical approaches to account for differing vessel dimensions or waterway conditions where feasible.

3.2 Operational profiles of the Rhine fleet

3.2.1 Representative journeys

In determining the representative journeys on European waterways, the focus is not primarily on the largest volumes transported or largest contribution in tonne-kilometres. For example if the selection would be solely based on the magnitude of the cargo flows transported by IWT, table 18 would include eight times the OD relations Rotterdam – Duisburg for different commodities.

The variety of relations and commodities transported by IWT are taken into consideration. Evidently common relations are included, such as:

- Transport of ore and containers between Rotterdam – Duisburg;
- Transport of containers between Rotterdam – Antwerp and Rotterdam - Basel;
- Transport of crude oil between Rotterdam – Karlsruhe and Amsterdam – Rotterdam.

However, to include a variety of freight flow types and type of waterways, for example also the following relations are included:

- Transport of animal fodder between Amsterdam – Heilbronn;
- Transport of metal scrap between Rotterdam - Herne;
- Transport of sand & gravel between Wesel – Enkhuizen;
- Transport of container between Alphen a/d Rijn – Rotterdam[16].

	Port A	Port B	Type	Vessel type	Commodity	mln tkm
1	Rotterdam	Duisburg	Dry bulk	Push B4	Ore	4074
2	Rotterdam	Antwerp	Container	C3L/B	Containers	3067
3	Rotterdam	Karlsruhe	Liquid Bulk	MTS 135m	Crude oil	2478
4	Amsterdam	Karlsruhe	Dry bulk	C3L/B	Coal	2219
5	Rotterdam	Basel	Container	C3L/B	Containers	1094
6	Antwerp	Thionville	Dry bulk	MVS110m	Coal	1075
7	Amsterdam	Antwerp	Container	C3L/B	Containers	983
8	Rotterdam	Krotzenburg	Dry bulk	C3L/B	Coal	976
9	Amsterdam	Rotterdam	Liquid Bulk	MTS 135m	Oil	968
10	Antwerp	Mainz	Container	MVS 135m	Containers	827
11	Breisach	Cuijk	Dry Bulk	MVS 110m	Sand&gravel	803
12	Antwerp	Duisburg	Container	C3L/B	Containers	677
13	Rotterdam	Duisburg	Container	MVS 110m	Containers	620
14	Rotterdam	Ludwigshafen	Liquid Bulk	MTS 86m	Chemicals	571
15	Rotterdam	Kampen/Zwolle	Liquid Bulk	MTS 110m	Oil	282
16	Rotterdam	Strassbourg	Dry Bulk	MVS110m	Agribulk	254
17	Amsterdam	Heilbronn	Dry bulk	MVS 105m	Animal Fodder	196
18	Duisburg	Antwerp	General cargo	MVS 110m	Metal products	181
19	Rotterdam	Alphen a/d Rijn	Container	MVS 105m	Containers	
20	Terneuzen	Rotterdam	Liquid Bulk	MTS 110m	Chemicals	166
21	Wesel	Enkhuizen	Dry Bulk	MVS 67m	Sand&gravel	
22	Rotterdam	Herne	Dry Bulk	MVS 86m	Metal (scrap)	43
23	Dusseldorf	Antwerp	Dry Bulk	MVS 110m	Agribulk	40
24	Antwerp	Gent	Dry bulk	MVS 110m	Coal	98
25	Rotterdam	Duisburg	Dry bulk	MVS 86m	Agribulk	14

table 18: Selection of representative journeys in the Rhine/ARA region

[16] The inland container terminal in Alphen a/d Rijn was not open yet in 2010 and therefore cargo flows are not yet included in European IWT freight flow statistics.

For the selection of the vessel types reference is made to the analysis of the European fleet in Chapter 2. Respectively in Figure 6, Figure 7 and Figure 8, the number of vessels reflecting the main fleet families in Europe and their estimated share according to fuel consumption and tonne-kilometre, it is clear that although vessels of 110m and larger have a respectively low share in the amount of vessels (about 10%) the share in estimated fuel consumption and tonne-kilometre performance is large.

Therefore for both the representative journeys of dry bulk (MVS) and liquid bulk (MTS) commodities a vessel type of 110m or 135m is often chosen as representative vessel for a representative journey. This is also confirmed when analysing the IVS'90 traffic count data at Lobith and Volkerak (lock system between Rotterdam and Antwerp), see Chapter 2.2. Similarly, coupled convoys (C3L/B) have a small share in the total number of European vessels, however have an estimated share of 7% in the tonne-kilometre performance. Therefore also this type was selected more frequent as vessel type for representative journeys, especially on container and coal transport relations.

As identified in Figure 6, Figure 7 and Figure 8 also motor vessels in the range of 80 – 109m have an eminent share according to the estimated fuel consumption and tonne-kilometre performance.
Based on the IVS'90 traffic statistics at Lobith (see Chapter 2, Table 7), especially vessels of 86m are commonly used to transport cargo on the Rhine corridor and/or further East into Germany.
Therefore this vessel type has also been selected on a number of occasions.

3.2.2 Operational profiles

In this section the derived operational profiles for the Rhine area are presented. Depending on the waterway sections the temporal and/or spatial resolution of the hydrological data is clearly visible in the distribution over the 25 power bins. While for example the resolution of the profiles for journeys 1, 3, 4 and 5 benefit from the variation in water levels and corresponding flow velocities and draughts over 30 years of hydrological data on the Rhine, journeys 2 and 7 have to deal with low resolution of available data or more or less constant waterway conditions. Hence, these operational profiles unrealistically pronounced time shares in very few power bins. All the profiles were provided to the project partners in ASCII format and as plots. In combination with a model for the main engines, the operational profiles can be used to derive the fuel consumption for these vessels and journeys. Some profiles were additionally prepared as scatter tables listing the time shares of delivered propulsion power against speed through water. Table 19 shows a sample for journey 01. This data is helpful to split the delivered power with given propeller characteristics and wake fractions into the engine rate and torque to calculate the operating conditions of the prime movers and detailed fuel consumptions.

		Speed through water [km/h]								
		6.9	7.6	8.4	9.2	9.9	10.7	11.4	12.2	13.0
Delivered power [kW]	0									
	169									
	338									
	506									
	675		0.02							
	844		0.4							
	1013		0.84							
	1181		0.59	0.11		1.3				
	1350	0.04	0.51	0.17		1.02	0.04			
	1519	0.11	0.21	0.17		0.9	0.42			
	1688	0.17	0.09	0.27		0.32	0.07			
	1856	0.08	0.08	0.31		0.24	0.08			
	2025	0.07	0.05	0.37		0.25	0.15			
	2194	0.01	0.01	0.5		0.33	0.24			
	2363			0.52		0.35	0.29			
	2531			0.57		0.6	0.29			
	2700			0.61		0.92	0.28			
	2869			0.61		1.04	1.21			
	3038			0.62		1.15	4.1	0.23		
	3206			0.71	0.01	1.53	0.21	0.48		
	3375			0.32	0.12	1.92		0.49		
	3544			0.21	0.12	3.23		0.17	0.32	
	3713			0.2	0.11	3.03			0.18	
	3881			0.2	0.17	20.84			0.13	
	4050			0.11	0.25	0.79			0.04	6.71

Table 19: Scatter Table with Frequency of Occurrence [%] of Power against Speed through Water for Journey 01 (upstream)

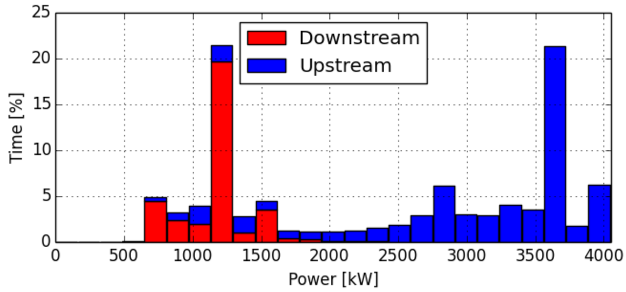


Figure 24: Operational Profile for Journey 01 (Pushed Convoy, Rotterdam - Duisburg, Ore)

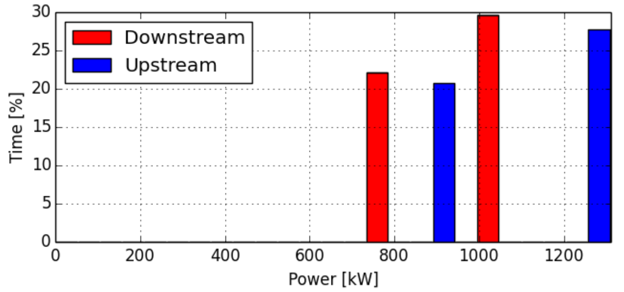


Figure 25: Operational Profile for Journey 02 (Coupled Convoy, Rotterdam - Antwerp, Containers)

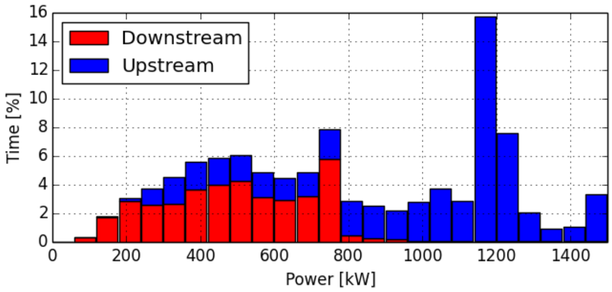


Figure 26: Operational Profile for Journey 03 (135m MTS, Rotterdam - Karlsruhe, Crude Oil)

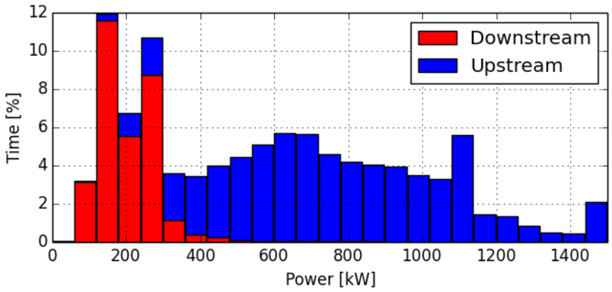


Figure 27: Operational Profile for Journey 04 (Coupled Convoy, Amsterdam - Karlsruhe, Coal)

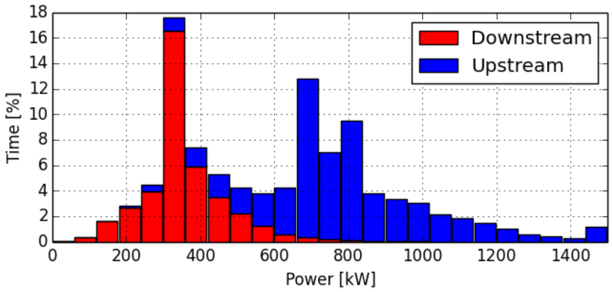


Figure 28: Operational Profile for Journey 05 (Coupled Convoy, Rotterdam - Basel, Containers)

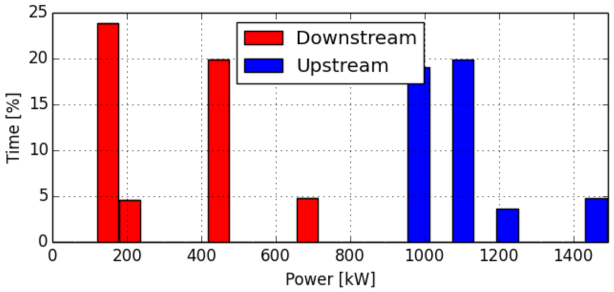


Figure 29: Operational Profile for Journey 07 (Coupled Convoy, Amsterdam - Antwerp, Containers)

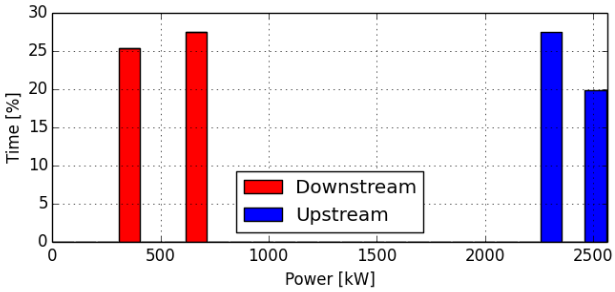


Figure 30: Operational Profile for Journey 09 (135m MTS, Amsterdam - Rotterdam, Oil)

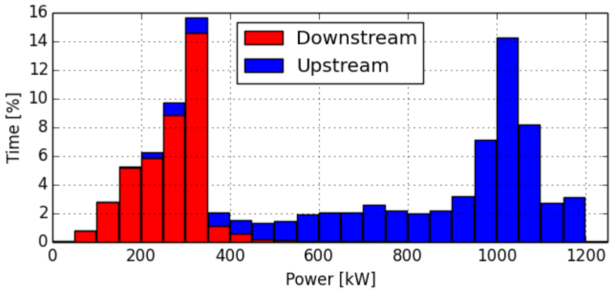


Figure 31: Operational Profile for Journey 10 (135m MVS, Antwerp - Mainz, Containers)

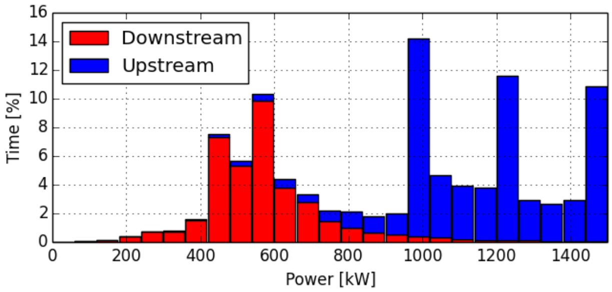


Figure 32: Operational Profile for Journey 12 (C3L/B, Antwerp - Duisburg, Containers)

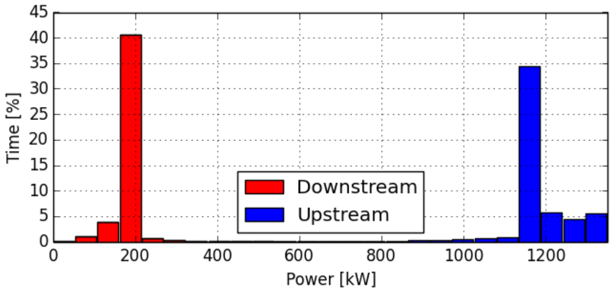


Figure 33: Operational Profile for Journey 13 (110m MVS, Rotterdam - Duisburg, Containers)

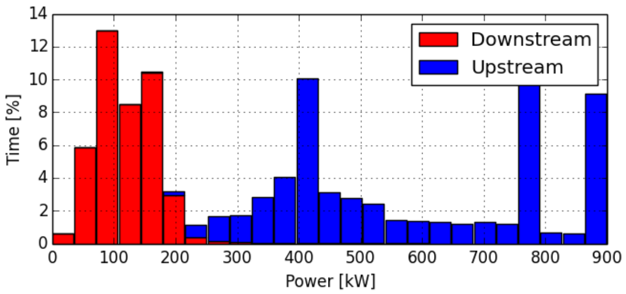


Figure 34: Operational Profile for Journey 14 (86m MTS, Rotterdam - Ludwigshafen, Chemicals)

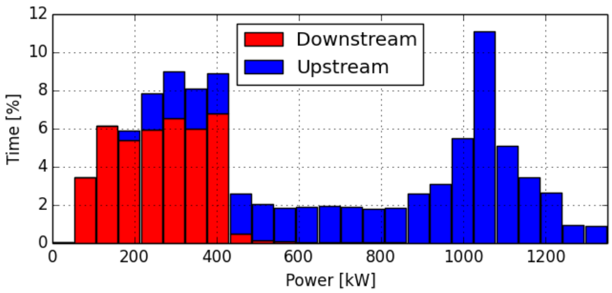


Figure 35: Operational Profile for Journey 16 (MVS 110m, Rotterdam – Strasbourg, Agribulk)

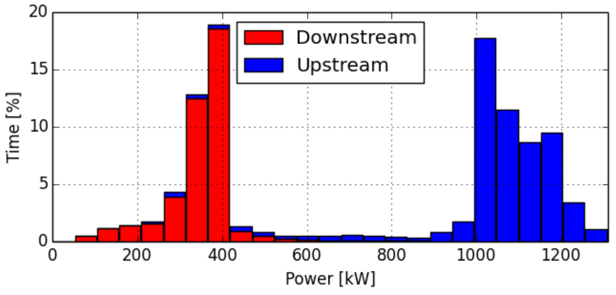


Figure 36: Operational Profile for Journey 18 (MVS 110m, Duisburg – Antwerp, Metal Products)

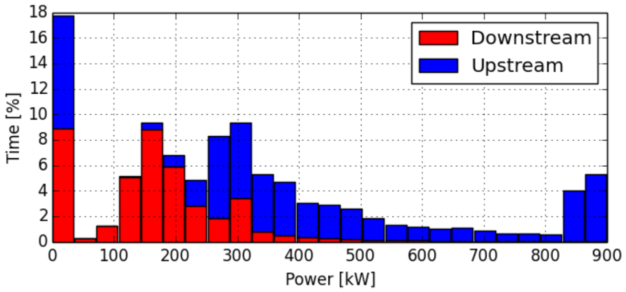


Figure 37: Operational Profile for Journey 22 (MVS 86m, Rotterdam – Herne, Metal (scrap))

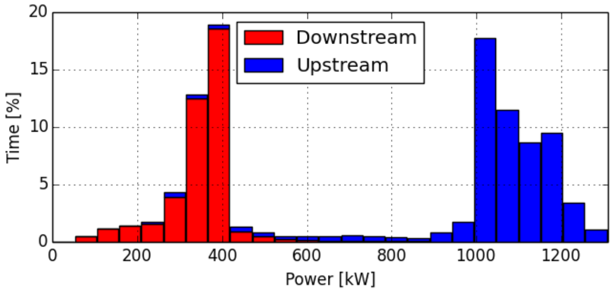


Figure 38: Operational Profile for Journey 23 (MVS 110m, Düsseldorf – Antwerp, Agribulk)

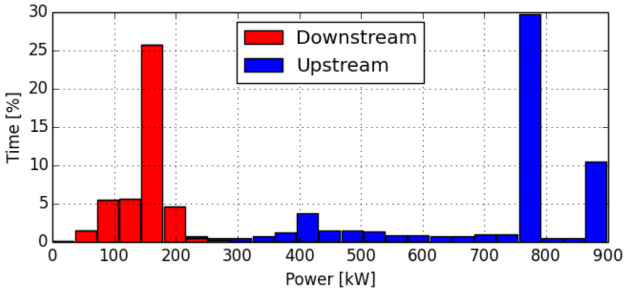


Figure 39: Operational Profile for Journey 25 (86m MVS, Rotterdam - Duisburg, Agribulk)

3.3 Operational profiles of the Danube fleet

3.3.1 Representative journeys

Table 20 gives an overview of 10 representative journeys in Danube relations (excluding e.g. ARA – Black Sea relations). Some of the data are assumptions based on the experience in this issue, caused by a lack of data on the Danube as well as missing willingness by relevant companies to provide information. Several data are provided by the project partner NAVROM to get a compact overview. Voyage and cargo reporting in the Danube region are not that well advanced e.g. as in the Rhine region. An obligation for reporting is valid only for dangerous cargo transporting vessels and (in some countries) for passenger vessels. This means that official statistics are based on port statistics, however, this could lead to discrepancies. Some organisations have their own methodology to “clean” the port data, but the potential revision of the calculation methodology is of relevance. To gap this data lack, Pro Danube has contacted the largest Danube fleet operators, but the willingness to provide business data (cargo volume, cargo type, O/D relations etc.) was low. On the other hand it can be stated that characteristics of the vessels (particularly the pushers) are nearly the same as shown in chapter 2.3, however, some operators decided to upgrade their fleet with state-of-the-art engines etc. E.g. engine control monitoring software were installed on the NAVROM pushers (taking part in WP5), whereas generated data can potentially still be used during the PROMINENT project to update the input data to the models.

	Port A	Port B	Type	Commodity	Mln tkm
1	Bor district	Constanza	Dry bulk	Agribulk	972
2	Bor district	Constanza	Liquid Bulk	Petroleum products	725
3	Constanza	Dunaújváros	Dry bulk	Coal	682
4	Giurgiu	Constanza	Dry bulk	Building mat. / minerals	537
5	Calafat	Constanza	Dry bulk	Building mat. / minerals	337
6	Bratislava	Linz	Dry bulk	Ores and Building mat. / minerals[17]	330
7	Calafat	Constanza	Dry bulk	Agribulk	237
8	Constanza	Dunaújváros	Dry bulk	Agribulk	216
9	Giurgiu	Constanza	Dry bulk	Agribulk	143
10	Giurgiu	Constanza	Dry bulk	Ores	118

Table 20: Selection of representative journeys on the Danube

[17] For this representative journey Ores and Building materials / Minerals were taken together, with a combined transport performance of 330 mln tkm (59 mln tkm for Ores and 271 mln tkm for Building materials, according to the calculations of ETISplus 2010)

These journeys are all performed with the same type of vessel:

- **Vessel type:** pushed convoys with 9 barges (all, except journey 6. For journey 6: 4 barges)
- **CEMT Class:** VI
- **Operational hours/year:** 4318
- **Installed engines:** 2
- **Total engine power main engines [kW]:** 2x1000=2000

The rest of the data is included in Annex A3.

3.3.2 Operational profiles

In this section the derived operational profiles for the Danube area are presented. The highly limited spatial resolution of the hydrological data and the lack of temporal differencing are clearly visible. Most journeys span only two or three segments, resulting in very pronounced peaks of the profiles. Another issue for the Danube profiles comes from the lack of valid speed-power profiles for the selected pushed convoys. Conversion of data from the Rhine convoys introduced significant uncertainties for small draughts, especially on low or high water depths, and small speeds. Therefore, differing from the conditions listed in Annex 3 all simulations for the Danube were done with a convoy with 4 barges. Some journeys differ only in very small details like the transported goods. The corresponding influences are not covered by the simulation approach. Here redundant output was avoided in the report. The figure captions indicate where the plot corresponds to more than one representative journey.

All the profiles were provided to the project partners in ASCII format and as plots. In combination with a model for the main engines, the operational profiles can be used to derive the fuel consumption for these vessels and journeys.

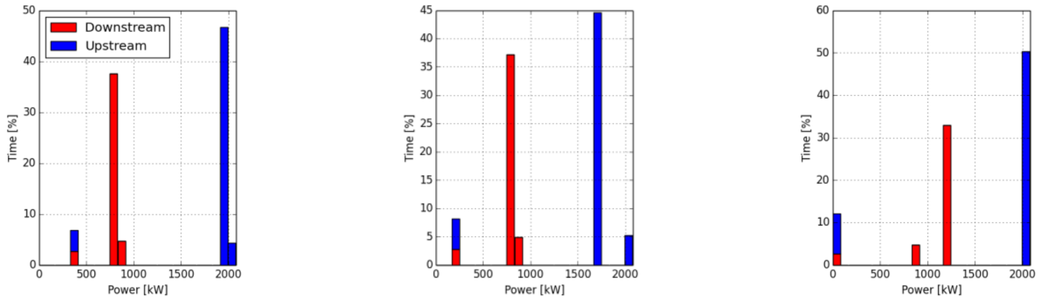


Figure 40: Operational Profile for Journey 1 and 2 (left to right: low, medium and high water level), Bor District - Constanta, Agribulk)

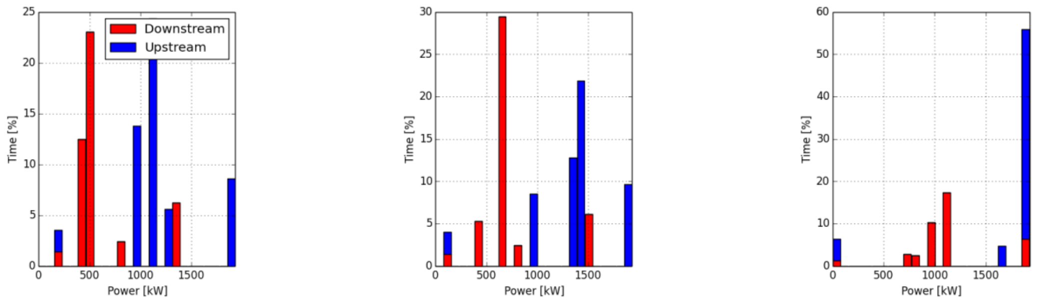


Figure 41: Operational Profile for Journey 3 and 8 (left to right: low, medium and high water level), Constanta - Dunaujvaros, Coal)

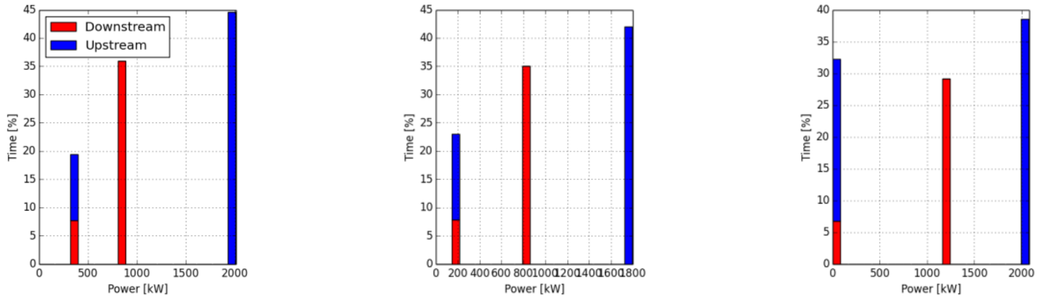


Figure 42: Operational Profile for Journey 4, 9 and 10 (left to right: low, medium and high water level), Giurgiu - Constanta, Minerals)

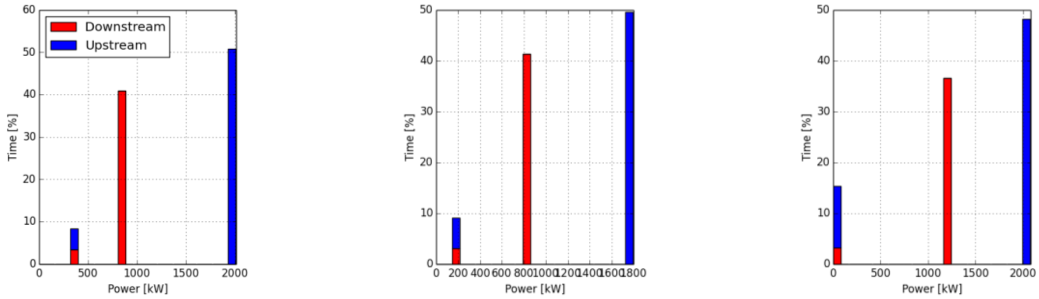


Figure 43: Operational Profile for Journey 5 and 7 (left to right: low, medium and high water level), Calafat - Constanta, Minerals)

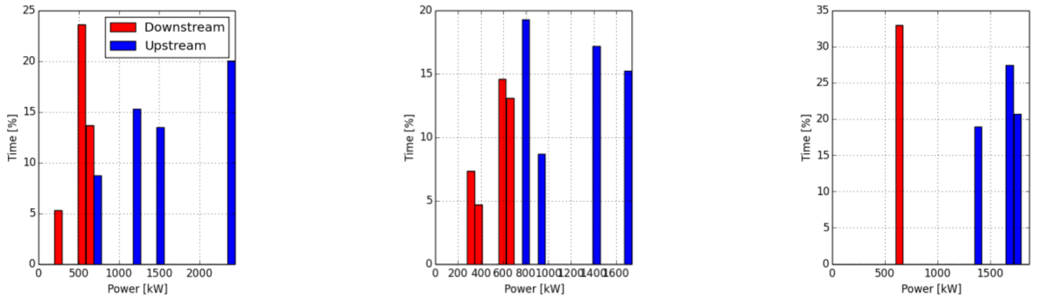


Figure 44: Operational Profile for Journey 6 (left to right: low, medium and high water level), Bratislava - Linz, Ores and Minerals)

3.4 Operational profiles of the fleet on the other waterways

3.4.1 Representative journeys

In additional to the representative journeys and operational profiles of the Rhine/ARA and Danube region, for cargo transport the representative journeys for the remaining waterways in Europe are consolidated in Table 21.

In total 18 journeys have been selected, which include the following waterways entirely or partially:

- Belgium: Albert Canal; several waterways along North-South corridor
- France: Seine, Rhône / Saône;
- Germany: Mittelland Canal, Dortmund-Ems Canal;
- The Netherlands: Meuse.

As indicated before, the OD relations for the other waterways are based on the freight flow analysis in Chapter 2 with reference to Annex A1 and Annex A2. This is also indicated in the last column of Table 21 through the inclusion of the tonne-kilometre performance on the specific relation.

	Waterway	Port A	Port B	Type	Vessel type	CEMT Class	Commodity	mln tkm
1	Seine	Le Havre	Gennevilliers	Dry bulk	MVS 80m	V	Building mat. / minerals	961
2	Seine	Le Havre	Gennevilliers	Container	PushB2L	V	Containers	1648
3	Seine	Le Havre	Gennevilliers	Dry Bulk	MVS110m	V	Agribulk	178
4	Rhone/Saone	Fos-sur-Mer	Chalon-sur-Saone	Dry Bulk	PushB2	Vb	Agribulk	462
5	Rhone/Saone	Fos-sur-Mer	Lyon	Liquid Bulk	MTS110m	V	Chemicals	249
6	Rhone/Saone	Fos-sur-Mer	Lyon	Dry Bulk	MVS110m	V	Agribulk	104
7	Mittellandkanal	Rotterdam	Hannover	Dry Bulk	MVS 86m	IV	Agribulk	
8	Mittellandkanal	Duisburg	Wolfsburg	General goods	MVS 86m	IV	Steel coils	
9	Albertkanal	Antwerp	Meerhout	Container	MVS135m	V	Containers	24
10	Albertkanal	Amsterdam	Liège	Dry bulk	MVS110m	V	Metal products	129
11	Albertkanal	Rotterdam	Liège	Dry Bulk	PushB2	Vb	Coal	296
12	Albertkanal	Antwerpen	Liège	Liquid bulk	MTS 110m	V	Oil	364
13	Maas	Amsterdam	Born	Dry bulk	MVS 110m	Vb	Coal	174
14	Maas	Rotterdam	Wanssum	Container	MVS110m	V	Containers	179
15	Maas	Rotterdam	Stein	Liquid bulk	MTS110m	V	Chemicals	324
16	Dortmund-Ems	Rotterdam	Oldenburg	Dry Bulk	MVS 80m	III / IVa	Animal Fodder	335
17	Dortmund-Ems	Rotterdam	Lingen	Liquid Bulk	MTS 86m	IV	Oil	
18	North South	Amsterdam	Nesle/Compiegne	Dry Bulk	MVS 55m	III	Agribulk	256

Table 21: Selection of representative journeys on other waterways

Representative journeys on waterways in Belgium

The Albert canal is one of the most frequently used waterways in Belgium to transport cargo between the Port of Antwerp and the Port of Liège (one of the largest inland ports in Europe). With reference to the freight flow analysis described in Chapter 1, various OD relations are found to and from the Port of Liège as indicated of which 3 relations have been selected as representative journeys (see Table 21). Large commodities transported to and from Liège are metal products, coal and oil, for which commonly used vessels are self-propelled vessels of 110m or 2 barge pushed convoys.

Additionally located at Meerhout, along the Albert Canal, an inland container terminal is situated with daily services to Antwerp. One of the largest inland container vessels is selected as representative vessel of the journey.

Representative journeys on waterways in France

On the waterways in France in total 6 OD relations have been selected, of which 3 on the Seine and 3 on the Rhône / Saône. With reference to the freight flow analysis, on the Seine there is a strong relation between the Port of Le Havre and Gennevilliers. Most common transported commodities are building materials, containers and agribulk.

For the transport of containers there is a full continue service and several types of barges are operated. A representative vessel for the transport of containers between Le Havre and Gennevilliers is a 2 barge push convoy.[18]

Representative journeys on waterways in Germany

The main tributaries of the Rhine in Germany, namely the Main, Moselle and the Neckar, are already included in the representative journeys specified for the Rhine in Section 3.2. With reference to the freight flow analysis in Section 1.2, see also Figure 4, other OD relations on German waterways include the Dortmund-Ems and Mittelland Canal. Therefore also representative journeys on these waterways have been selected, although these annual flows are not necessarily larger than 1,000,000 tonnes in transported volume.

Representative journeys on waterways in The Netherlands

Besides the large volumes transported in the Rhine/ARA region in The Netherlands, there are also strong IWT relations between other provinces in The Netherlands due to its extensive network of inland waterways. As indicated in Table 21, a total of 3 OD relations have been selected from the freight flow analysis between the province of Limburg and the seaports of Amsterdam and Rotterdam. Although to a large extent it is allowed to operate vessels up to a length of 190 meter on the sections of the Meuse in The Netherlands, the most representative vessel used on waterways in The Netherlands is self-propelled vessel of 110x11.4m. Therefore this vessel type has been selected on the representative journeys as indicated in Table 21.

3.4.2 Operational profiles

In this section the derived operational profiles for the selected journeys on other waterways are presented where possible. The highly limited spatial resolution of the hydrological data and the lack of temporal differencing are clearly visible. Most journeys span only few segments, resulting in very pronounced peaks of the profiles. For the journeys including segments on the Saone, Rhone or Seine no hydrological data was available. In daily practice people are mostly interested in very few spots of the waterway relevant for acceptable draught and loading. The journeys on the channels are dominated by the speed limits on the different sections with to large extent constant cross sections. Additional scatter of the profiles would result from the manoeuvring in encountering or at locks. However, these effects are not covered by the used simulation environment.

All profiles were provided to the project partners in ASCII format and as plots. In combination with a model for the main engines, the operational profiles can be used to derive the fuel consumption for these vessels and journeys.

[18] For more information: http://www.cft.fr/

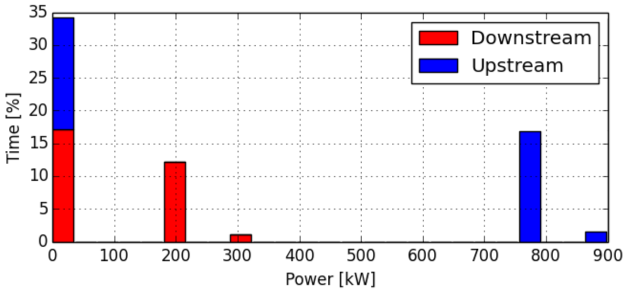


Figure 45: Operational Profile for Journey 7 (MVS 86m, Rotterdam – Hannover, Dry Bulk)

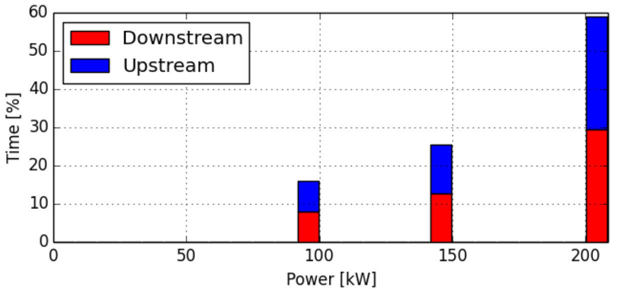


Figure 46: Operational Profile for Journey 8 (MVS 86m, Duisburg – Wolfsburg, Steel Coils)

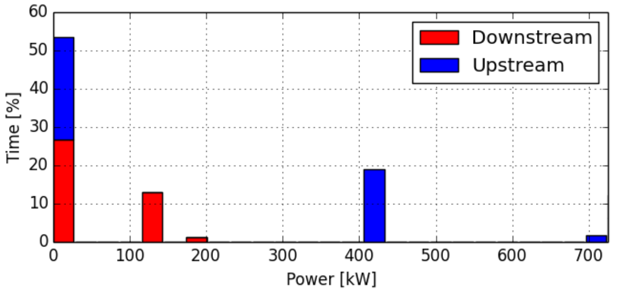


Figure 47: Operational Profile for Journey 16 (MVS 80m, Rotterdam – Oldenburg, Dry Bulk)

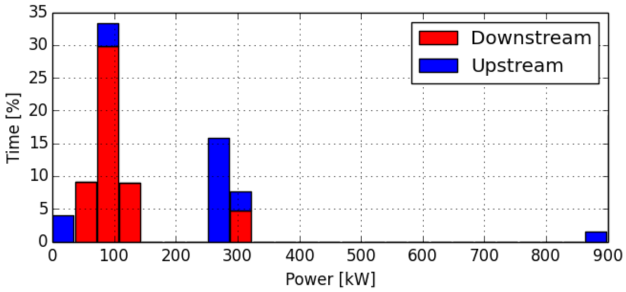


Figure 48: Operational Profile for Journey 17 (MTS 86m, Rotterdam – Lingen, Liquid Bulk)

3.5 Operational profiles of passenger vessels

The representative journeys for passenger vessels have been based on analysis of the tour schedules of the most dominant river cruise operators, namely: Viking River Cruises[19]; Avalon Waterways[20]; and AmaWaterways[21]. These three cruise operators jointly possess a fleet of about 90 cruise vessels, which are deployed all over Europe as illustrated by means of the representative journeys for passenger vessels in the table below. The operational profiles for three of these journeys can be seen in Figure 49 to Figure 51.

	Waterway	Port A	Port B	Type	Vessel type
1	ARA/Rhine	Amsterdam	Basel	Inland Pax	PAX 135m
2	Rhine/Main/Danube	Amsterdam	Giurgiu	Inland Pax	PAX 110m
3	Danube	Passau	Budapest	Inland Pax	PAX 135m
4	Moselle/Rhine	Trier	Basel	Inland Pax	PAX 135m
5	Seine	Rouen	Paris	Inland Pax	PAX 135m
6	Elbe	Magdenburg	Melnik	Inland Pax	PAX 95m
7	Rhone - Saone	Arles	Dijon	Inland Pax	PAX 110m

Table 22: Selection of representative journeys for passenger vessels

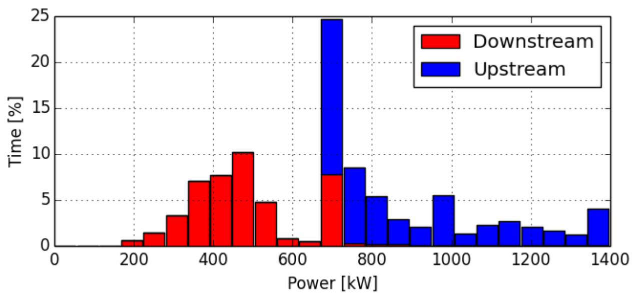


Figure 49: Operational Profile for Journey 1 (135m, Basel - Amsterdam)

[19] http://www.vikingrivercruises.com/
[20] http://www.avalonwaterways.com/
[21] http://www.amawaterways.com/

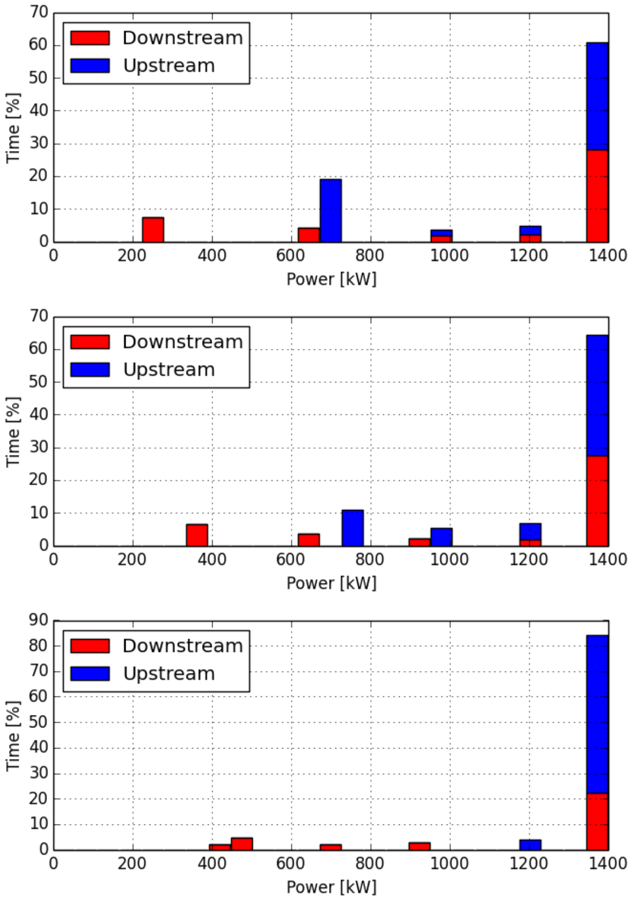


Figure 50: Operational Profiles for Journey 3 (135m, Passau – Budapest – low (top), medium (middle) and high water level (bottom))

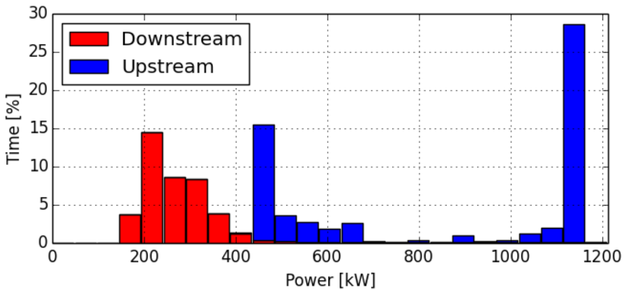


Figure 51: Operational Profile for Journey 6 (95m, Melnik – Magdeburg)

Conclusions and recommendations

The macro model of the European fleet consists of 12,263 active vessels, mainly established in the Rhine and other waterway countries (93% of the number of vessels). This macro model provides insight into the number of motor vessels in different size classes, as well as push boats (subdivided in installed power classes), coupled convoys and passenger vessels. Before this research the number of coupled convoys has been difficult to determine, as the composition of convoys (whether or not navigating with a barge) can differ and is not registered as such. For this reason, the number of coupled convoys resulting from this research is a valuable outcome.

Also, the differences between the power configurations provide interesting insight, e.g. the difference between the power configuration of a coupled convoy (mostly equipped with 2 engines with a lower average power per engine) and a normal motor vessel ≥110m (mostly equipped with 1 engine with a higher average power). Knowledge of these power configurations is necessary for the further development of most of the emission-reducing concepts. The macro model also gives an insight in the engine speed characteristics of the different fleet families.

Recommendations concerning the representativeness of the fleet

Based on the macro model, it becomes also possible to determine the focus of the further research, in order to get to the target of PROMINENT to reach 70% of the fleet with emission-reducing technologies. There are several options to fulfil this target:

- To reach 70% of the number of vessels, in this the biggest groups are motor vessels under 80 metres (37%), passenger vessels (21%) and motor vessels dry cargo 80-109m (15%);
- To reach the vessels responsible for 70% of the tonne-kilometre performance, which represents the most important share of the inland fleet for the amount of goods transported. In this the biggest groups are motor vessels dry cargo ≥110m (19%), push boats 500-2,000 kW (18%), motor vessels dry cargo 80-109m (17%) and motor vessels liquid cargo ≥110m (14%);
- To reach the vessels responsible for 70% of the fuel consumption by the inland fleet, as there is a relation between the fuel consumption and the absolute emissions. In this the biggest groups are motor vessels dry cargo 80-109m (20%), motor vessels under 80 metres (15%) and motor vessels dry cargo ≥110m and liquid cargo ≥110m (both 14%).

There is a relation between fuel consumption and the absolute emissions, so it is important to pay the most attention to the groups with the highest fuel consumption. The highest fuel users within the Western-European fleet are the push boats ≥2,000 kW, consuming on average 2,070 m^3 per year, followed by coupled convoys (558 m^3) and motor vessels dry cargo ≥110m (339 m^3) and liquid cargo ≥110m (343 m^3). These groups have also on average the highest installed engine power. However, these groups have also the highest share of emission regulated engines (CCNR Stage-I or Stage-II), reducing the air pollutant emissions in g/kWh. It would be recommendable to gain more insight into the actual emissions for all of these groups. This can be done by the combination of the macro model with an emission model, such as emission factors of TNO.

Recommendations for the pilot selection

Based on the statistics of the fleet composition on the Rhine and other Western-European waterways a recommendation was presented for the pilot selection and deployment on these waterways (in Table 23):

Type of vessel	No.
Push boats <500 kW	0
Push boats 500-2000 kW	2
Push boats >=2000 kW	1
Motor vessel dry cargo >=110m length	6
Motor vessel liquid cargo >=110m length	4
Motor vessel dry cargo 80-109m length	3
Motor vessel liquid cargo 80-109m length	1
Motor vessels <80 m. length	1
Coupled convoys	2
Total number of vessels for pilots	**20**

Table 23: Recommended number of vessels according to fleet families identified in PROMINENT

Recommendations concerning the validation of the representative journeys

The representative journeys are based on the freight flows for inland waterway transport between two NUTS-2 regions, which are given in Annex A1 (in tkm performance, freight flows above 1,000,000 tkm) and Annex A2 (in volume, freight flows above 1,000,000 tonnes). The list with flows above 1,000,000 tonnes resulted in 96 relations (of about 10,000 in total) which cover together about 274 million tonnes of cargo transported on the European waterways, 50% of the total tkm performance of IWT in Europe. This resulted in a list of 60 representative journeys, 25 in the Rhine/ARA region, 10 on the Danube, 18 on other waterways and 7 passenger journeys. The information on these representative journeys, such as the vessel dimensions, distance, sailing time, sailing speed were based on several sources.

This list provides a good overview of the representative journeys and the ways these journeys are operated. However, some attention should be paid to the fact that not all inland vessels operate always on the same journeys and transport the same commodity. Round-trips are more common in especially the transport of containers (navigating between an inland container terminal and one or more seaports), some segments of the tankers (chemicals and crude oil) and push boats (mainly ore). Other segments operate more on demand, on the ‘spot market’. The information should be validated in the pilot projects and in interviews with ship-owning companies and IWT operators.

Recommendations concerning the further elaboration of the operational profiles

Currently there are operational profiles available for respectively 16 of the 25 representative journeys on the Rhine, all of the 10 Danube journeys (some combined), 4 of the 18 journeys on the other waterways and 3 of the 7 passenger journeys. These operational profiles provide insight into the power distribution of inland vessels during the most representative journeys and thereby the power needed for these journeys. Due to several limitations other operational profiles were not available, e.g. because of a lack of hydrological data for the French waterways. Also there are some limitations to the operational profiles that were generated, e.g. there isn’t yet good speed-power distributions for the Danube pushers available.

It would be recommended to further elaborate the operational profiles, also deriving the fuel consumption per journey. The fuel consumption per journey is relevant for amongst others the concept of energy-efficient navigation. The full-scale measurements that will be performed in the pilot projects will give valuable data and could serve as a validation of the operational profiles that were generated.

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Annexes

A1. Flows above 1,000,000 tkm

A2. Flows above 1,000,000 tonnes

A3. Representative journeys freight transport and passenger vessels

A4. Danube fleet

The following table gives an overview of some relevant operating companies on the Danube and their fleet. The information provided is based on “The Blue Pages” (www.blue-pages.at) and websites of the companies.

Company Name	Motorized vessels	Barges / non motorized vessels	Total capacity [tons]
Ukrainian Danube Shipping (UDP) Jsc	91	423	n.a.
Navrom S.A. Galati	52	348	n.a.
Bulgarian River Shipping PLC	17	100	152.000
Slovak Shipping and Ports JSC	33	110	n.a.
Touax Rom SA	7	49	110.000
Jugoslovensko recno brodarstvo (JRB) AD	16	88	n.a.
HRB Dunavski Lloyd Sisak d.o.o.	14	34	n.a.
MSG Mainschifffahrts-genossenschaft eG	70	n.a	n.a.
MULTINAUT Donaulogistik GmbH	41	13	92.860
Euro Bevrachting Germany AG	20	12	50.000
Bavaria Schiffahrts- und Speditions-AG	25	n.a	45.000
Kühne & Nagel Euroshipping GmbH	25	4	n.a.
Gebr. Väth KG	12	n.a	n.a.
First-DDSG Logistics Holding GmbH	58	160	311.202
Rhenus Mierka Danube Shipping GmbH	9	18	34.200
MSG Mainschiffahrts-Genossenschaft eG	71	0	135.000
Reederei Jaegers GmbH	198	30	n.a.
Donau-Tankschiffahrtsgesellschaft m.b.H.	7	6	22.600
Fluvius Schifffahrts und Speditions GmbH	6	1	12.253
Coöperatie NPRC U.A.	400	n.a.	180.000
CFND AD	4	14	30.000

In the forthcoming tables some examples are shown of the most typical vessels used on the Danube.

Characteristics of the pushers of NAVROM that will be part of the pilot in WP5 operating on the Danube (NAVROM has of course a larger fleet in total):

Name	Vessel type	Length (m)	Width (m)	Draught max. (m)	Type of engine	Engine power (kW)
MERCUR 205	pusher	34,66	10,09	1,70	CAT 3512 B n=1.600rot/min	2 x 955
MERCUR 206	pusher	34,66	10,09	1,70		2 x 955
MERCUR 207	pusher	34,6	11,04	2,00		2 x 955
MERCUR 301	pusher	34,6	11,04	2,04	CAT 3512 B-HD n=1.600rot/min	2 x 1249
MERCUR 303	pusher	34,6	11,04	2,04		2 x 1249
MERCUR 304	pusher	34,6	11,04	2,04		2 x 1249
MERCUR 305	pusher	34,6	11,04	2,04		2 x 1249
MERCUR 306	pusher	34,6	11,04	2,04		2 x 1249
ANINA, ROVINARI 8	pusher	20,72	7,78	1,5	VOLVO PENTA D 12D-C MH n=2.800 rot/min	2 x 300

Source: NAVROM - Technical data for river pushers

Vessels of RUBISHIPS LTD operating on the Danube:

Name	Vessel type	Length (m)	Width (m)	Draught max. (m)	DWT (t)	Engine power
RUBISHIPS - III	self-propelled	80,05	9,5	2,53	1254,58	Deutz 2 x 408 HP
RUBISHIPS - IV	self-propelled	85	9	2,54	1240	Deutz 680 HP
RUBISHIPS - VI	self-propelled	90,6	11,5	2,5	1700	Deutz 2 x 600 HP
RUBISHIPS - VII	self-propelled	95	9,5	2,87	1802,78	MWM 800 MP
RUBISHIPS - VIII	self-propelled	86	11,08	3,09	1944	MWM 1200 MP
RUBISHIPS - XII	self-propelled	85,99	10,25	2,97	1803	2 x Storktype RHD158K, 507 kW, 690HP
RUBISHIPS - XIII	self-propelled	95,08	9,5	2,82	1710,19	Caterpillar 3512 EUI, 1380 HP
RUBISHIPS - XIV	self-propelled	99,92	9	2,7	1678	MWM 800 MP

Source: http://www.rubiships.com/fleet.php

Vessels of Fluvius Transporte e. K. operating on the Danube:

Name	Vessel type	Length (m)	Width (m)	Draught max. (m)	DWT (t)	Engine power
MS Ulm	self-propelled	105	9	2,81	1827	736 kW
MS Elsava	self-propelled	105,04	9,49	2,5	1605	589 kW
MS Herso	self-propelled	84,95	9,5	2,7	1381	780 kW
MS Eljo D	self-propelled	73,54	8,99	2,02	902	383 kW
MS Johanna	self-propelled	101,88	9,83	2,76	1806	810 kW
MS Melanie	self-propelled	64,92	11,4	3	2095	2 x 940 kW
SL Leonie	barge	70,75	10,44	2,47	1427,734	-
SL Melanie	barge	76,42	11,4	3	1851	-

Source: http://www.fluvius.hu/flotte

Vessels of Euro Bevrachting Germany AG. operating on the Danube:

Name	Vessel type	Length (m)	Width (m)	Draught max. (m)	DWT (t)	Engine power
MGS Lu-Ma	self-propelled	109,5	11,45		3206,44	2400 PS
MGS Regensburg	self-propelled	85,92	8,25		1131	1100 PS
MGS Danube 1	self-propelled	84,97	8,2		1217	960 PS
MGS Karin	self-propelled	85	9,2		1170	750 PS
MGS Johannes	self-propelled	84,25	8,22		1148,92	862 PS
MGS Straubing	self-propelled	75,44	8,2		1067,9	625 PS
MGS Panda	self-propelled	84,98	9,5		1418,6	800 PS
MGS Hamburg	self-propelled	84,94	9,5		1349,94	800 PS
MGS Fürth	self-propelled	84,98	9,5		1425	800 PS
MGSS Stadt Nürnberg	self-propelled	104,85	9,5		2225,5	1302 PS
MGSS Carmel	self-propelled	85,2	9,5		1336,5	1156 PS
SB Wodan	pusher	23,78	9,2			2029 PS
SB Anton	pusher	33,16	10,17			2556 PS
SL Bojan	barge	76,5	11		1881,28	-
SL 2500	barge	82,6	10,15		1520,67	-

Sorce: http://www.eurobevrachting.com/en/The_fleet/

Vessels of SPAP (Slovakia) operating on the Danube:

Technical data of vessels

Tugboats

Type	Length [m]	Width [m]	Height [m]	Draught [m]	Power [kW]
TR 1000	36	11,2	3,2	1,66	1030
TR 1618	34,8	11,2	2,8	2,0	1618
TR 2000	46,5	14	3,3	2,2	2000
TTR 2000	57,6	8,7	2,3	1,7	1472
TTR 1100	28,9	10,16	2,7	1,6	945
TR Mufl�n	23,1	8,9	2,0	1,2	566/840

TR - push tug
TTR - tow-pusher

Danube motor cargo ships

Type	Length [m]	Width [m]	Height [m]	Draught [m]	Loading capacity [t]	Power [kW]
DNL 2000	101,8	14,18	3,6	2,4	2000	1030
DNL 1000	79,5	10,16	2,4	2,0	900	721
MNL 1500	106	11,2	3,2	2,4	1500	1030

DNL - Danube cargo motor ship
MNL - motor cargo ship

Barges

Type	Length [m]	Width [m]	Height [m]	Draught [m]	Loading capacity [t]
KVC 1000 t	80	10	2,5	1,9	900
UC 1500 t	81	11	2,7	2,2	1200
DE II.b	76,5	11	3,2	2,7	1600
TTC 1500	79,2	11	3,2	2,4	1570
TTC 1600	80,4	10	2,9	2,5	1600
TTC 1400	76,5	11,4	3,5	2,6	1600
Vlecne tanky	76,8	10	2,5	1,8	850
Ro-Ro	82	11,4	2,2	1,6	970

KVC - standard towing barge
UC - universal barge
DE - standard pushing barge (of Danube-Europe type)
TTC - standard pushing tanker barge
Ro-Ro - a special Ro-Ro-barge