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

D5.6 Land based tool for evaluation of ship efficiency and navigation performance

Public

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Abstract

In Work Package 2 of the H2020 EU project PROMINENT[1], the system for energy-efficient navigation was initially specified, complemented by an economic analysis of its implementation. Based on the specification, further developments were carried out, and the necessary information on the navigation conditions of the pilot stretches was processed and compiled for the purpose of usage in PROMINENT.

In this report, the settings for the pilot tests of the energy-efficient-navigation system to be applied as land based tool for evaluation of ship efficiency and navigation performance are defined. The tool developed allows for:
- evaluation and optimisation of fuel consumption associated with different sailing strategies;
- evaluation of ship performance and efficiency (e.g. fuel consumption) compared with other vessels (e.g. with different dimensions).

The core of the report is made up of a comprehensive description of the system for energy-efficient navigation which can be applied as land based tool, too: the Efficient Navigation Tool (ENAT).

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[1] http://www.prominent-iwt.eu/

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1. Introduction

This report concerns the land based tool that allows vessel owners or trip planners to evaluate the energy performance of their vessel. This performance can be seen as a comparison of a trip compared to other trips made by the vessel, or by a comparison with similar vessels. These similar vessels may have different dimensioning of engines and driveline components. With the results, the user can build up understanding of how cost effective the used sailing policies are, mainly considering the arrival time, sailing speed and fuel consumption of the vessel.

The performance of a particular vessel depends on many factors like the sailing speed, loading condition, dimensioning of the vessel's components and the current fairway conditions. Fairway conditions are for example local water depth, current and the river cross-section, which change from day to day. The dependency on the wide set of parameters, and the dynamic behaviour of fairway conditions complicate the definition of unambiguous vessel performance indicators.

The tool created in this task makes the performance evaluation possible by using a modelled journey, and comparing journeys with different arrival times. It is well known that changing sailing speed has a strong effect on the fuel consumption. This tool makes it possible to quantify this effect. The vessel owner or trip planner can run the tool in order to predict the fuel consumption needed for a trip. For example when he has different vessels at his disposal, he can make a comparison of the fuel consumption as a function of arrival time and other conditions. In order to reduce variability in the outcomes, an (almost) optimal sailing policy is modelled, which is described in this report.

The performance model developed within PROMINENT[2] takes into account all the mentioned parameters that influence the vessel's performance, i.e. the vessel's technical characteristics and fairway conditions. In PROMINENT Work Package 5 (WP5), extensive measurements are performed on vessels on the Danube and the Rhine. Using these measurements, the models will be validated and corrected where necessary. Hereby, the goal is to create a model that approximates the real vessel's performance better and better as more measurements accumulate. Because of the complexity of the model fitting, this is the task of the engineer.

Apart from the consistency of the results achieved by using the model, there are a couple of other advantages of the modelling approach, compared to an approach where (for example) a trip history is used. The first is that this approach makes it possible to investigate vessel performance for vessels that are not extensively being monitored as generic vessels can be developed. Also, the tool is more accessible to vessel owners/users as they do not have to hand in sensitive data/measurements. Another advantage is that the user can experiment with different driveline configurations, like hybrid, or different dimensions of the components. These will be presented as different vessels in the consolidated database.

This report extensively describes how the graphical interface works, and how the calculations are performed and should be interpreted. It ends with an outlook of future extensions of the tooling.

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[2] http://www.prominent-iwt.eu/

2. The Efficient Navigation Tool - ENAT

a. Philosophy

The goal of the ENAT is to help voyage planners and skippers to reduce fuel consumption and therefore emissions. It does this by predicting the vessel's performance for a trip ahead in time, comparing the effects of different sailing policies. From the offered information, the user assesses policies with his needs, and he chooses the most relevant option, for example the average speed or arrival time as a function of fuel consumption. The ENAT helps the user because it takes into account important factors like currents and shallowness of the water. These factors are local and variable in time. Therefore, without the assistance of the ENAT, the user will face difficulties in accurately assessing the effects of the current conditions on the vessel's performance and trip planning. This may lead to the choice of a policy with an earlier arrival time, but this will also be a less fuel efficient sailing policy. The ENAT helps the user to make the most efficient choice. The advice is presented very quantitatively by displaying the expected fuel needed for the trip with different arrival times.

b. Sailing environment: German Rhine

In order to provide a decent navigation advice, the sailing conditions have to be known as well and accurately as possible. Within PROMINENT, BAW has provided modelled flow data from the German section of the Rhine. In particular, the part from Maxau to the Dutch border near Emmerich was considered. This is the stretch from Rhine km 334 to 865. To get an impression of the geography, the contours are given in the following figure.
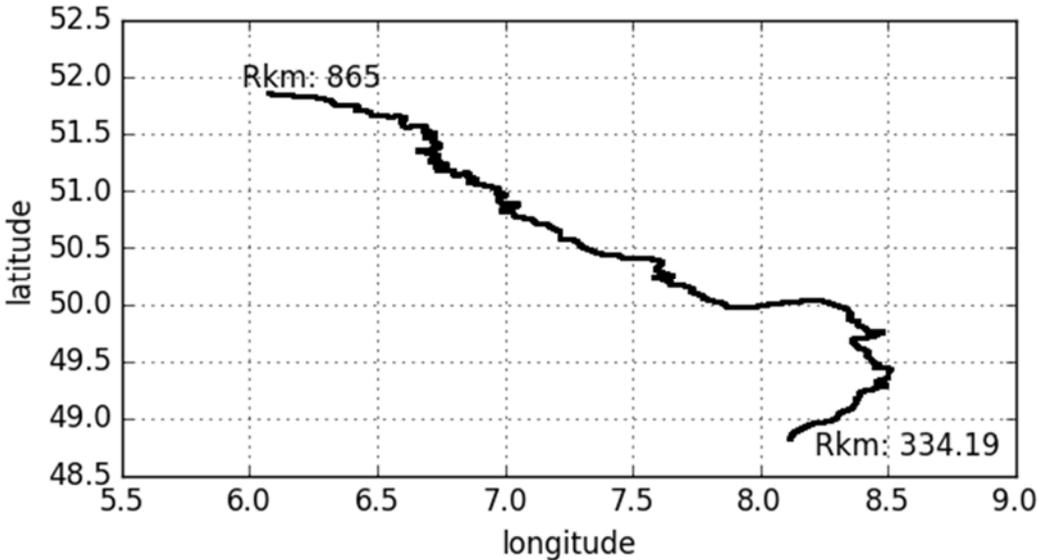

Figure 1: Rhine km's along the German Rhine section used in PROMINENT. Maxau is at approximately km 334, Emmerich near 865.

The discharge data is given for 6 different discharge conditions. For efficient navigation, the currents and water depths have to be taken into account. To give an idea of the extent of the currents that can be found on the Rhine, all currents from the database are shown in Figure 2, showing a range from 0.3 m/s to almost 3 m/s.
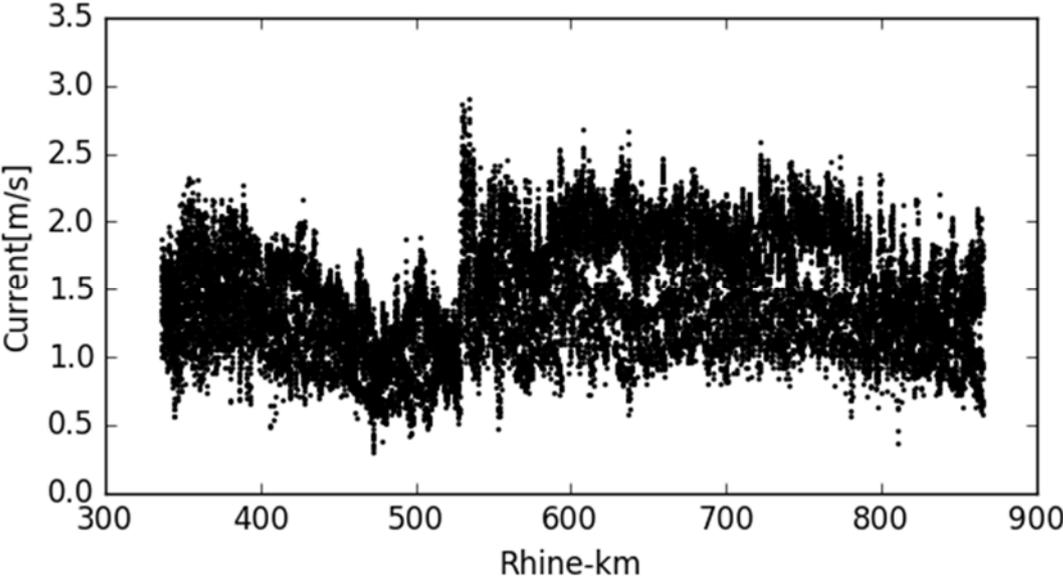

Figure 2: Current velocities along the Rhine for different discharge conditions.

Water depths are very variable along the river. Figure 3 shows the range in the average water depth that can be found along the stretch under consideration. The average water depth ranges from less than 2 metres in shallow-water sections up to over 10 metres in deep-water sections. The ENAT uses the average water depths as basis for the calculation of the vessel performance. Local bathymetry of the river has an influence on the local flow velocities and water depths, affecting the vessel performance. However, consideration of the full set of navigation conditions changing in place and time is a task being too complex to be taken into account in this early version of the ENAT. Instead, average values for the water depth and flow velocity depending on the river kilometre and time are used for simplicity, assuming this approach to be sufficient for successful application of the ENAT.
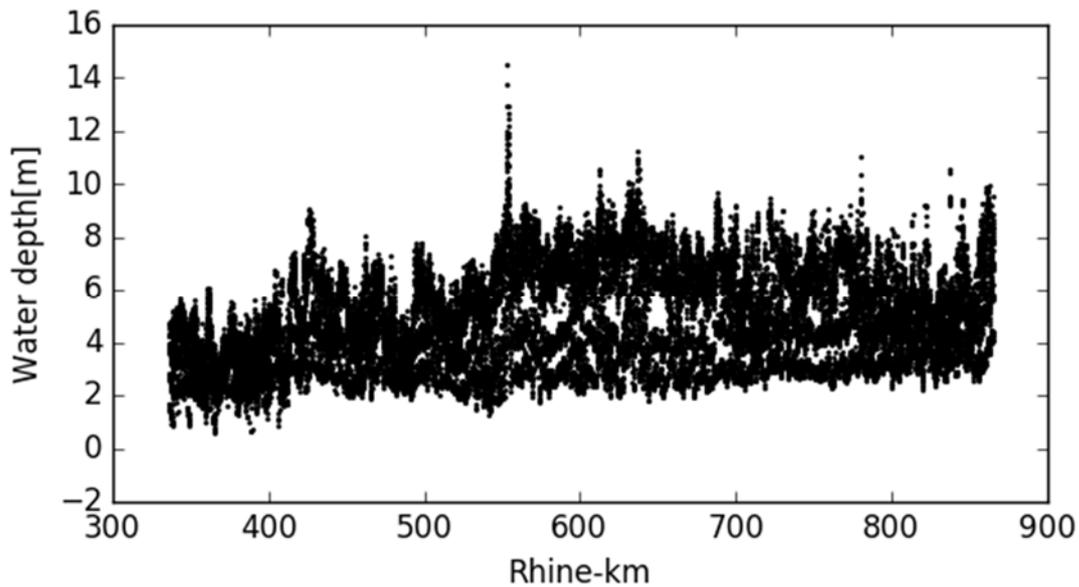
Figure 3: Water depths (averages) of the Rhine presented in m as function of the Rhine-river kilometre (Rhine-km).

c. Defining a trip

In order to allow the ENAT the evaluation of the vessel performance or provision of an advice to the user, some information relating to the requests of the user is needed. The ENAT needs to know:
- vessel type (the user can choose from a list of vessels);
- position of the vessel (GPS);
- destination of the vessel;
- draft of the vessel;
- the desired average ship speed over ground (SOG) or arrival time.

The most discussed question in the above is the desired speed as the trip may normally not be planned based on the expected speed. Alternative options are the provision of the arrival time or engine speed. The choice of arrival time will quickly lead to unrealistic or impossible ship speeds. The advantage of this choice, ship speed, is that there is a clear and intuitive relation between ship speed and arrival time. The user may hesitate on the choice of rpm that suits his journey, but the expected average speed can be estimated from the distance that the vessel has to sail and the desired time of arrival. The tool will also present three options (the requested and a lower and a higher average speed) with the corresponding arrival times.

d. A valid trip

The ENAT will first check whether a trip planning request is valid, before it models and presents the results. The following conditions are checked:
- The vessel must be represented in the database, and the configuration must be correct and complete.
- The vessel must be sailing forwards relative to the water. Up/down river sailing is taken into account.

- The actual location of the vessel must be on a river that is in the database.
- The destination must be included in the database.
- The draft cannot exceed a limit value depending on the water depth.
- The speed cannot exceed a limit value depending on the water depth.
- The rpm and power must comply with the engine characteristics.

e. A valid advice

The advice given by ENAT naturally has to be both: useful for the user and physically possible. The physical correctness is taken into account by giving realistic rpm and power advice that the vessel's engine(s) can actually deliver. Considering the relevance of the advice of the tool, the modelled journeys have to be close to the original request, as it is not expected that the chosen journey is totally changed because of the ENAT advice solely.

When a valid trip planning request is made, the ENAT will present trip planning for three average sailing speeds (SOG): the requested speed and a 10 % lower and a 10 % higher ship speed. It will calculate arrival time and fuel consumption for the three options. Consequently, when one of these options is chosen, the ENAT presents the trip engine rpm advice along different sections of the trip. These sections are typically 10 km long, but they may become longer if a journey with very long stretches with similar navigation conditions is considered. The visualisation will show characteristic places such as cities and cargo terminals along the trip (see Figure 7, page 17).

3. System configuration

a. Hardware

The ENAT is currently a web based software tool. The vessel and river models run on a TNO webserver. Planning requests and presentations of results are done via an internet connection and a normal browser of a computer, tablet or smart phone. Therefore, an internet connection is needed to plan trips for both the land based as well as the on-board navigation tool. There is no automated feedback with the depth and engine measurements on board of the vessel. Measurements and models are fitted offline, and the outcomes are implemented in the online vessel database. Therefore, the hardware consists of development of standard internet servers. For both, land-based and on-board users, any standard mobile device or tablet is suitable to connect. For real-time advice, the device requires a GPS antenna and an internet connection.

b. Data models

i. Used software

The ENAT is programmed in the languages Python and C++. The ENAT model runs in a Python environment, in particular, the open-source web framework DJANGO is used, which handles both the vessel and river databases. Also it manages the communication, login, as well as the security of the web framework.

ii. Vessel specifications

In WP2 of PROMINENT, the modelling of the vesel driveline was covered extensively, and deliverable D 2.3, Schweighofer et al. (2015), covers the data models containing the components with the vessel specifications. For the resistance model, either results of the tank-tests performed by DST or empirical methods subject to further validation are used. The vessel data model in the database is shown here to give an impression of the components of the vessel taken into account by the physical model.

Table 1: Vessel data model used by the ENAT.

Name	Data type
Propeller	ForeignKey-> Propeller
AuxiliaryLoad	ForeignKey-> AuxiliaryLoad
Converter	ForeignKey-> Converter
DieselEngine	ForeignKey-> DieselEngine
Gearbox	ForeignKey-> Gearbox
Hull	ForeignKey-> Hull
Resistance	ForeignKey-> Resistance
GeneratorSet	ForeignKey-> GeneratorSet
PTOI	ForeignKey-> PTOI
ShipSettings	ForeignKey-> ShipSettings
Mmsi	Interger
active	Boolean

iii. Rhine flow data

The following data model is used to store the Rhine model data as delivered by BAW.

Table 2: River data used as input to the ENAT.

Name	Data type
Crossection[m²]	Float
Breath[m]	Float
u [m/s]	Float
Depth[m]	Float
Station[km]	Float
dischargeCathegory	Text
Cycle[-]	Float
Gauge_name	Float

- Cross section is the river cross section.
- u is the average current.
- Station is the Rhine-km.
- dischargeCathegory is the name of the water level.
- Cycle refers to the internal numbering of the simulations at BAW.
- Gauge_name is the name of the nearest water level gauge.

The Rhine static data is stored in a separate table, which is needed to map station (listed specific locations) values to coordinates and vice versa.

Table 3: Rhine static data.

Name	Data type
Lat	Float
Lon	Float
Station[km]	Float

c. Set up of servers and databases

In Figure 4, a schematic overview of the databases and servers is shown. Shortly explained:
The land-based and the ENAT tools are websites, which are hosted on www.iwtnavigator.eu. It also has a user management system for which TNO is the admin. This server is managed by a web developing company from Delft. It developed and programmed the graphical part of the ENAT.
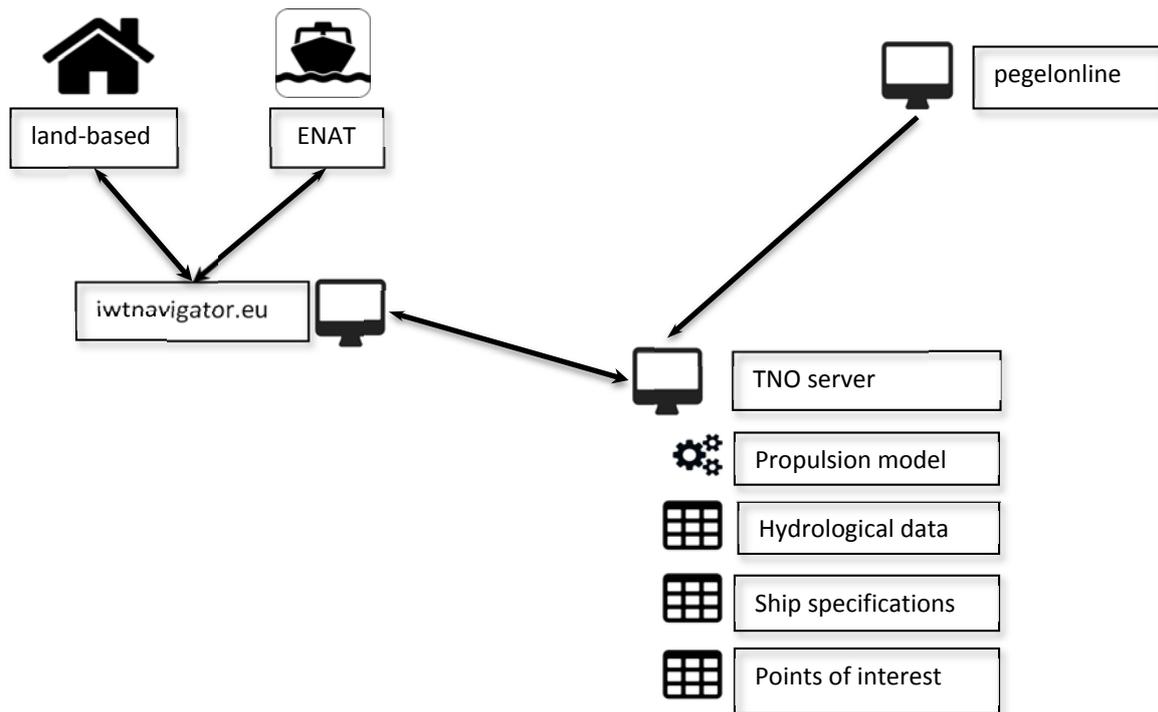
Figure 4: Graphical interpretation of the user, database and server configuration of the land-based tool and the ENAT.

d. Security and privacy

The website www.iwtnavigator.eu can only be accessed over HTTPS (secure HTTP). This is also a requirement for the browser to be allowed to consult for the phone's GPS. The system only allows logged in connections, and users have to be registered.

4. Graphical user interface (GUI)

a. ENAT workflow

i. GUI, devices and scaling

The ENAT's design is optimised for mobile devices as phones and tablets. There is no limitation, however, to use it from a computer as well. The preferred browser for the computer is Google Chrome. Other browsers can be used as well, but optimization and testing was done using Chrome. When used as a land-based tool, it is important to turn off any GPS plugin in the browser (if one is installed).

The section below also includes some explanation of the real-time advice, as it is very present in the user interface.

ii. Start

The ENAT always requires registration and login which TNO provides. When the user logs in, he is redirected to the start menu. Here the vessel and journey are defined by choosing the specific vessel, and the journey specification. More than one vessel can be coupled to a user login. He has to choose the vessel that is currently being planned. Then the draft is entered in cm.

The destination is chosen from a list of options. This list can be made use (or route) specific, but for now each user gets the same list. For example, container terminals can be made available only if the user sails on a container vessel. The last choice is the preferred average speed at which the skipper expects to be sailing.

Note that when the ENAT asks for access to the device position, this should not be allowed. Otherwise the ENAT may start acting like the real-time on-board tool.

Figure 5: Example trip choice.

iii. Choosing from different advices

After "start" has been pressed, the model needs 5 to 15 seconds to calculate an advice. A waiting screen is displayed during this period. The advice is then displayed as in Figure 6. It comprises several options, currently 3[3]. The difference between the advices is the average SOG. We start off with advices for a speed increase and decrease of 10 %. This often leads to numbers that are not nicely rounded, experience will tell whether this is a problem to the user.

The different average speeds are associated with different arrival times which are indicated as well. Only the arrival time is currently shown, not the day. This is OK when the trip takes less than 24 hours. This will be improved in the future.

Also the estimated fuel consumption in litres is indicated, enabling the skipper to make a cost/benefit analysis of the different advices. It may be beneficial to arrive later if the savings are significant. Fuel consumption rises sharply with increased speeds, especially in shallow water conditions.

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[3] This number automatically changes with the number of advices sent in from the backend.

To continue to the trip advice, the skipper clicks on one of the advices by tapping on the screen.
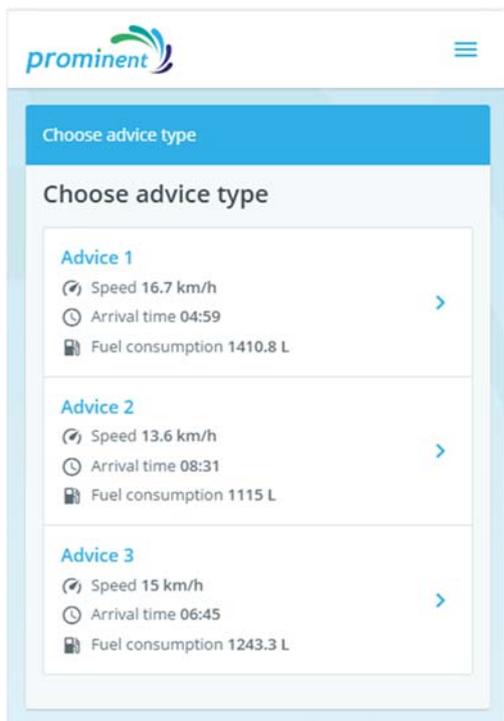

Figure 6: Example choice from three advices.

iv. The trip

After choosing one of the advices (average ship speed options), an overview of the track is shown. Along the way, the vessel has to pass waypoints, and it crosses sections where different engine settings are considered economically preferable.

The main features in the screen are (the numbers correspond to the numbers in Figure 7 :

1. (Not relevant for the land-based tool). The condition of the GPS signal. The options are "Good", "Not precise" and "N/A". "N/A" gives a link that takes user to a general page about GPS and how to enable it.
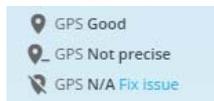
2. This allows the user to show the history of the route travelled so-far, cancel the route, and restart the route.

3. These blocks indicate the different sections with the time at which they are entered, the recommended engine speed and the expected sailing speed. This speed can be used by e.g. the skippers as a reference to check on the advice and give some intuitive support.

4. (Not relevant for the land based tool.) Here the advice is updated; as the ENAT is new and still under development, deviations in arrival times and expected speeds will exist for several reasons. Besides limitations in the implemented models of vessel and waterway, there are influences due to the traffic situation or manoeuvring (river bends, passing, encountering etc.). The skipper can also choose not to follow the advice (recommended engine speed). The ENAT will automatically calculate the remaining section of the route and arrival time every 60 minutes. The skipper can also choose to do this manually in between by clicking on the link that starts the update. Therefore, the remaining section of the route is updated when the user clicks the "update advice" button. Also it is indicated when the last update took place. A warning is shown when an update was not possible, for example because of loss of internet connection. If the user doesn't update the advice manually, it is done automatically every 60 minutes[4].
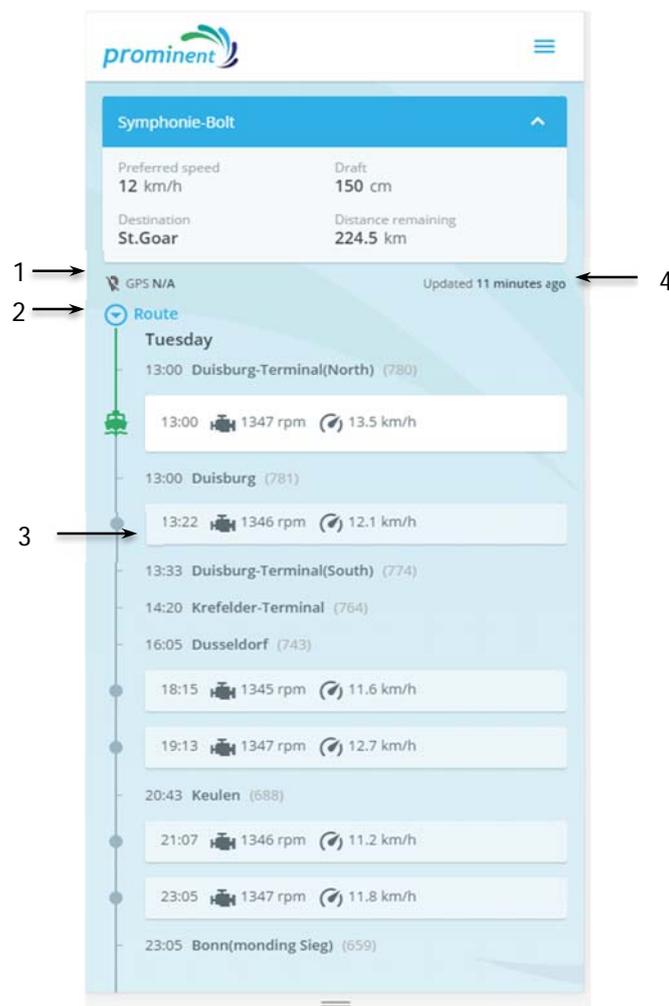

Figure 7: Real time trip advice. 1) GPS quality, 2) extra route options, 3) section speed advice, 4) update trip advice.

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[4] This interval can be changed by the admin.

v. Route recovery and screen on

If the tablet or phone is turned off, or the browser is (accidentally) closed, the advice is not lost. The user can simply go to www.iwtnavigator.eu to get back to the route screen. This is also the case when the phone is locked or goes to some stand-by mode. An important thing to note is that the browser is not allowed to keep the screen on, although some workaround is implemented in the tool to keep the screen on after all. Some browsers may still not be able to keep the screen on.

5. Optimisation algorithm

The ENAT system uses a synchronous HTTP request-response cycle. This means that the server/website has to answer before the browser times out. Although the time-out time can be changed, the goal for the ENAT is to respond within 15 seconds.

The ENAT's nature of combining data and models for real-time advice leads to a system with a high level of complexity in different ways: The data storage and structure has to be well defined so that the relation between the tables and the ship model is clear. Also the vessel model has to be well defined so that the advice is clear an interpretable (self-explanatory). Requested trips can be invalid for many reasons and have to be checked on the way (by the algorithm/during processing). Some mistakes in the requests can already be observed when the user makes a request, the others appear during the calculation of the most efficient trip.

a. Ingredients for optimisation

Technical aspects of the ship and the fairway have to be gathered to give an accurate sailing advice. Note that for PROMINENT all parameters are handled in SI units unless stated otherwise.

i. Evaluation of vessel performance using towing tank tests

The advanced optimisation of the sailing policy in terms of energy efficient navigation requires a detailed vessel performance model. To evaluate the consumed fuel for each discretised section of the journey, detailed waterway data and the speed-power profiles of the vessel are required. The power demand and the corresponding fuel consumption are determined by numerous factors including speed and loading condition, as well as the dominant external factors water depth and flow velocity. To be able to quantify the savings and to get the maximum benefit out of the pilot on energy efficient navigation, extensive model tests were conducted for the three pilot vessels operating on the Rhine at DST's test facilities.

Results derived for the passenger vessel FGS Symphonie are shown in Figure 8. The results show clearly how rapid the vessel resistance increases when the water becomes shallow. When unrealistically high speeds are given as input for the ENAT, high fuel consumption and engine rating will be returned. With this information, the user can judge whether the advice is feasible or not. In the future, a warning or error can be displayed when the ENAT judges the request as unfeasible.
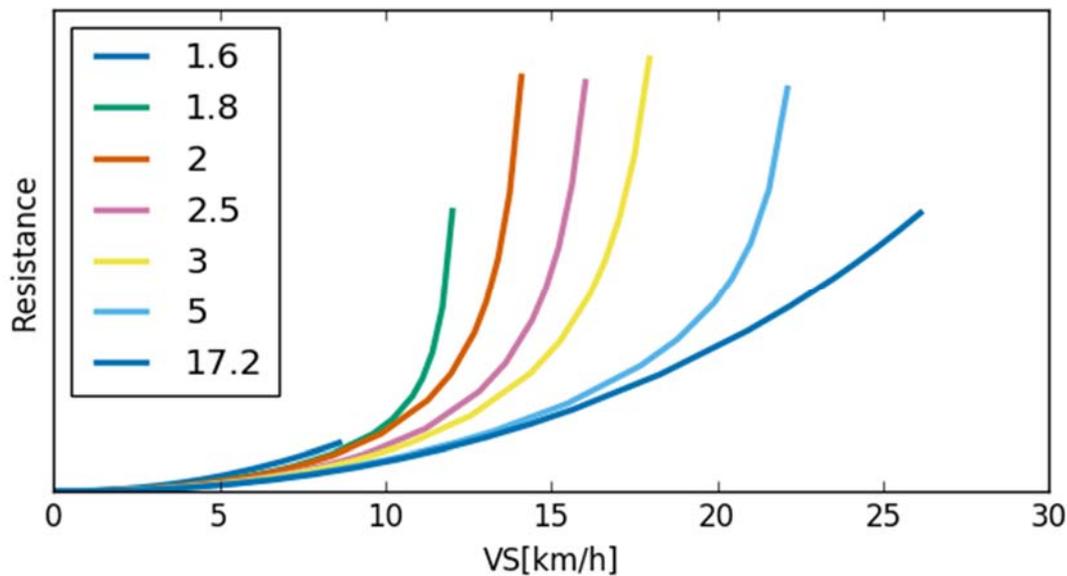
Figure 8: Resistance tests for the FGS Symphonie, provided by DST for different water depths ranging from 1.6 m up to 17.2 m.

No towing test available

When no towing test info is available, generic models based on empirics can be used (along with some calibration/fitting points). The parameters of the vessel geometry needed are: length, draft and the beam. The draft will be given a default value for the vessel, but in the ENAT it has to be entered by the user as well (for each trip). Note that when towing tank tests have been performed, these geometry parameters (length and beam) are not used as they are implicitly available from the vessel model.

The propeller is defined by its diameter, pitch over diameter ratio, ratio of the blades area surface and propeller disk, number of blades and the water density. The propeller models for open and ducted propellers differ, and the latter need additional information. Both ducted as well as open propellers can be used, and if needed, additional or customized propellers can be implemented easily.

ii. Fairway data

From the fairway static data, the following parameters are needed for the model: cross-section, width, base-depth and a decent coordinate system along the river. For the Rhine, the coordinate is the Rhine-km, and it is provided by BAW. The mapping of the Rhine-km to coordinates is also needed to translate the GPS on board of the vessel to the Rhine-km location. Fairway data needs to be provided on a reasonable resolution, in PROMINENT, we have 10 points per kilometre available on both sides of the river. For now, only one of the sides is used in the project.

For dynamic conditions, the current and actual water depth is needed for these points as well. In PROMINENT, BAW has made 1-D flow data available for 6 discharge conditions of the river. It is determined in real time which discharge condition is applicable. The discharge state of the river can be variable along the Rhine, and it is therefore determined in all parts individually.

iii. WSV's Pegelonline

At the moment when the user sends a request for a new or updated advice, the water levels are retrieved from the website www.pegelonline.wsv.de. WVS offers a good and relatively stable[5] application programming interface (API) that has the latest water levels at a long list of gauges along the Rhine. This works as follows:

A URL is constructed which contains the name of a gauge which is being consulted. The URL is given below, and "GAUGE NAME" must be replaced by the gauge name in question:

https://www.pegelonline.wsv.de/webservices/rest-api/v2/stations/GAUGE NAME /W/currentmeasurement.json

To get the water levels for all stations and a list of available stations go to
https://www.pegelonline.wsv.de/webservices/rest-api/v2/stations/

The ENAT uses the following sections and corresponding names to retrieve the real time water levels.

Table 4: Water level gauges consulted by the ENAT, as received from BAW.

Reference gauge	Rkm	Range	
		from	until
MAXAU	362,327	334,00	384,00
SPEYER	400,600	384,00	410,50
MANNHEIM	424,733	410,50	431,50
WORMS	443,400	431,50	462,00
MAINZ	498,270	462,00	511,00
BINGEN	528,360	511,00	540,00
KAUB	546,300	540,00	566,00
KOBLENZ	591,490	566,00	601,00
ANDERNACH	613,780	601,00	624,00
OBERWINTER	638,190	624,00	660,00
KOELN	688,000	660,00	710,00
DUESSELDORF	744,200	710,00	763,00
DUISBURG-RUHRORT	780,800	763,00	794,00
WESEL	814,000	794,00	837,00
EMMERICH	851,900	837,00	857,40

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[5] During development of the ENAT, the API has been offline once.

The API returns information as "JavaScript Object Notation" type (which is a standard on the internet), and it looks like in the following presented:

```
{
    timestamp: "2016-09-21T09:15:00+02:00",
    value: 441,
    trend: 0,
    stateMnwMhw: "normal",
    stateNswHsw: "normal"
}
```

The timestamp gives the latest update time and time zone. The "value" field gives the water level in centimetres.

iv.   Database queries

From the preceding paragraphs, it is known which information must be queried from the database. The database tables for the ship specifications and which level of river stream conditions are needed. These are queried from the database and consolidated into a single json file that can be interpreted by the numerical model.

b. Optimisation algorithm

i.   Step 1

As first step in the optimisation process, the numerical vessel model "sail" calculates the trip a number of times at different speeds over ground. This gives the "fingerprint" of the power and engine rpm of the coming trip. In Figure 9 and Figure 10, the relevant finger prints are displayed. Note that the engine rating from the physical model is in radians per second of the axis. This must not be confused with the speed of the propeller axis as the gearbox is in between.

The power on which the optimisation is performed is currently the output power of the engine to the outgoing shaft. In the future this will probably be replaced by fuel power flow (burning energy x fuel flow) to avoid much debated fuel consumption curves of the engine to fully dominate the advice. Note, however, that this can be changed easily so that the fuel power flow is used after all.
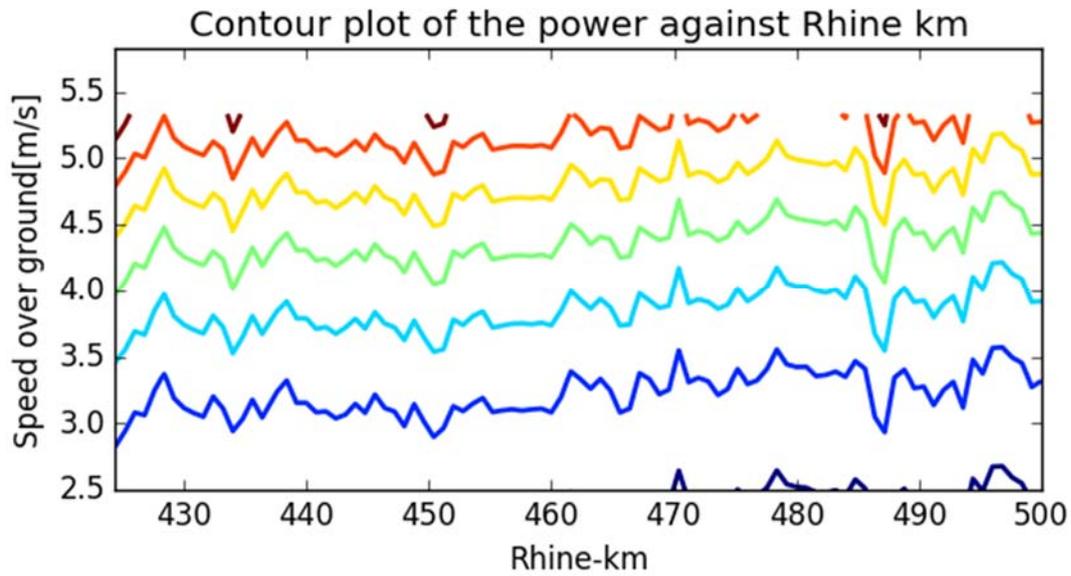
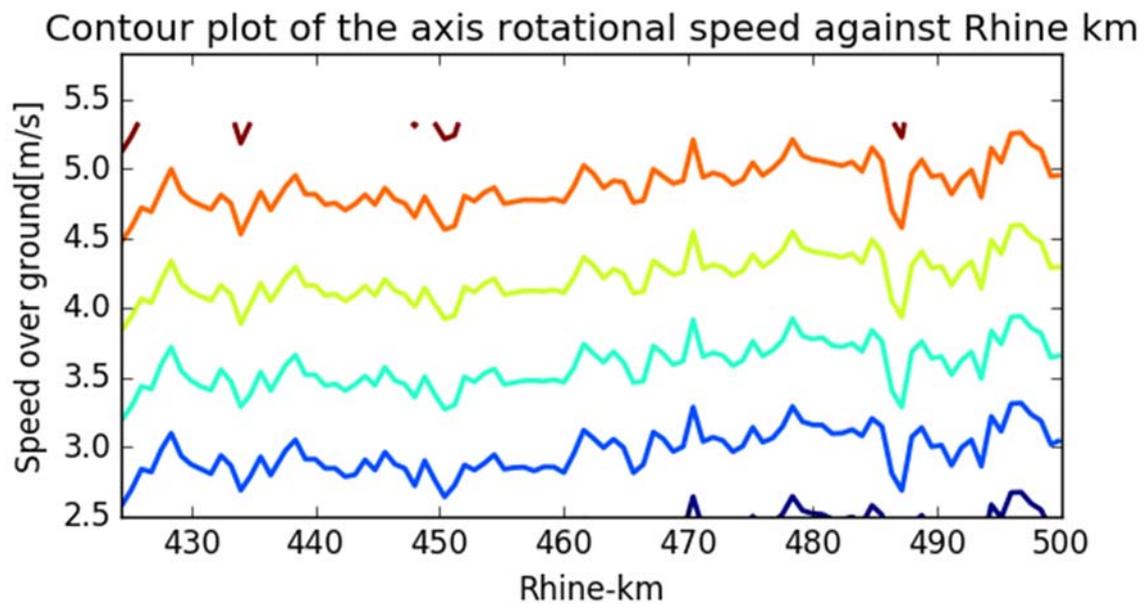Figure 9: Rhine-km against speed over ground, contours of constant power.

Figure 10: Rhine-km against speed over ground and engine speed in radians per second.

ii. Constant power and sections

The algorithm is currently based on constant engine power. As shown by results derived by DST, the ship sails close to its highest efficiency when the power delivered by the engine is constant over the distance of the trip.

"Sections" are the parts of the trip in which the engine rpm is kept constant. The borders are at fixed Rhine-kms, by default 10 km, but longer if the trip is longer. For now, this is needed to reduce computational time (and avoid potential browser time-out). Speed over ground is abbreviated as SOG, and it is given in meters per second.

Because the flow velocities and water depth differ during the trip quite frequently, constant power may yield too frequently varying recommended engine rpm. This is not preferred as it is impractical to the user and may cause him to ignore the advice. Therefore, the trip is split into sections on which a constant rpm is advised. This rpm may be equal in successive sections, but it will differ most of the times (depending on rounding to a certain step size).

iii.   Constant rpm and sections

In the previous section, the information needed to construct the concrete advice to the user was given. Even though the algorithm is based on constant power, the advice needs to be displayed to the user as a corresponding rpm (engine speed): the engine speed in rpm the user needs to apply when sailing on certain Rhine sections (Rhine-kms). This on its turn leads to some power and SOG variation within the sections, caused by the changing waterway conditions there (Figure 11 and Figure 12).
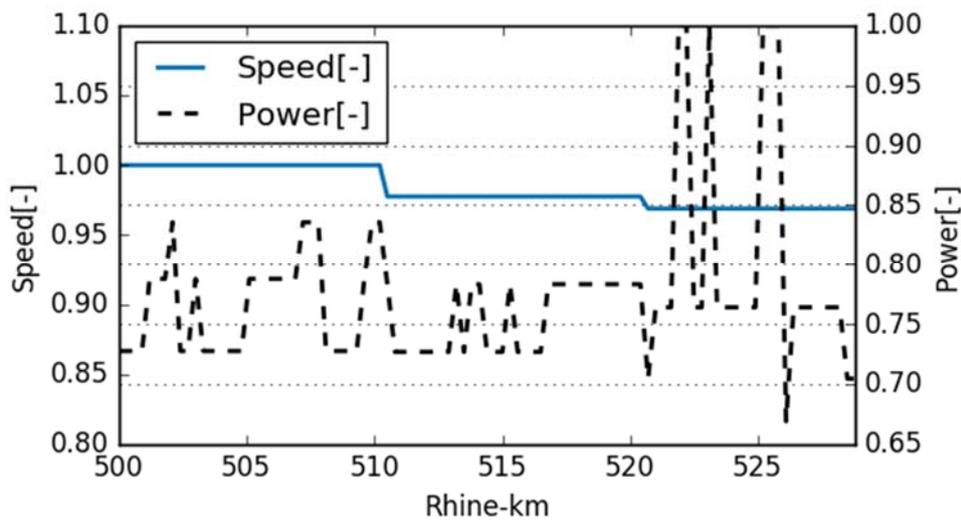

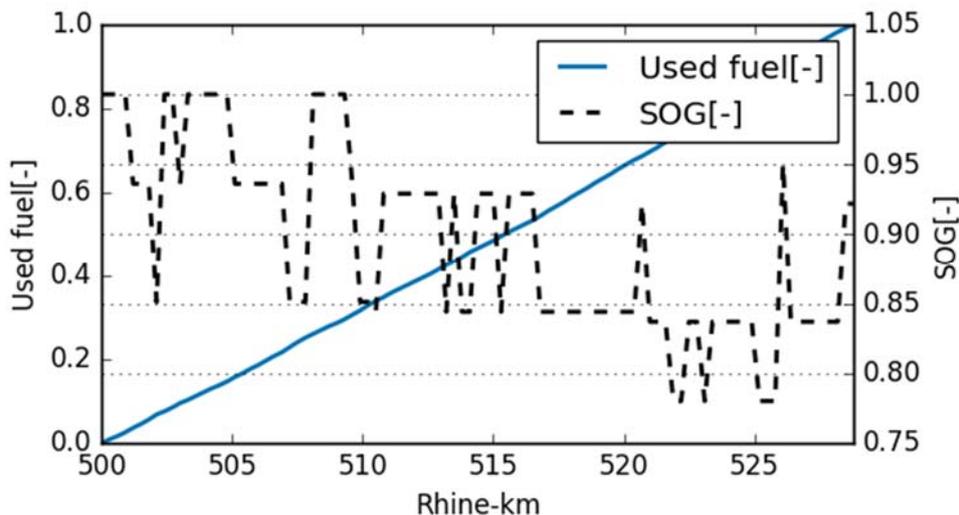Figure 11: Result of the ENAT: non-dimensional engine power and rpm against Rhine km of the trip.

Figure 12: Non-dimensional SOG and cumulative fuel consumption over the trip.

6. Summary and outlook

In Work Package 2 of the H2020 EU project PROMINENT, the system for energy-efficient navigation was initially specified, complemented by an economic analysis of its implementation. Based on the specification, further developments were carried out, and the necessary information on the navigation conditions of the pilot stretches was processed and compiled for the purpose of usage in PROMINENT.

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- evaluation and optimisation of fuel consumption associated with different sailing strategies;
- evaluation of vessel performance and efficiency (e.g. fuel consumption) compared with other vessels (e.g. with different dimensions).

The core of the report was made up of a comprehensive description of the system for energy-efficient navigation which can be applied as land based tool, too: the Efficient Navigation Tool (ENAT), comprising the following issues: provision of a valid advice to the user, system configuration (hardware, data models), set up of servers, security and privacy considerations, description of the graphical user interface, and description of the optimisation algorithm including all input requested. The advice given to the user is visualised on a screen (e.g. tablet). It comprises sectional recommendations on the engine rpm to be set and speed over ground of the vessel. In order to allow for high-quality estimation of the ship performance of the Rhine vessels involved in PROMINENT (Task 5.4), comprehensive model tests were carried out for the three vessels under consideration, in addition to the numerical ship performance modelling carried out.

The real-time use of on-board measurements to be carried out in PROMIENT may be used to check and complement the water level measurements performed by the authorities. As the models get better, on-board measurements may be used in real time to fit and correct model parameters. Ship-performance models may also be improved by using real-life tests. In the latter, the vessel needs to sail at different speeds in calm water without current, in both a deep and shallow section. This will provide valuable information about the speed-power curve of the vessel in real life, which is very rare for inland waterway vessels. The tool might also allow the vessel owner / operator to retrieve a 1-2-3 days look-back of the engine performance data with relation to the fairway data measured by the vessel. This can be topped up with the corresponding air emission measurement / estimation data.

Another extension worth to be considered comprises the inclusion of more waterways in the database. Taking this into account, respective data of the Upper Danube were already compiled and provided to TNO for further use. When routes become more complicated, further development efforts are demanded regarding some form of route planning.

During the tasks performed between the start of the project and the elaboration of this report, the consortium has agreed on the basic outline of the PROMINENT consolidated database that receives inputs as geographical data, engine data and survey data. Consolidated also stands for the fact that it also collects and processes air emission monitoring data as derived from vessels that were equipped by TNO and MUL. The chart below shows in the green fields what has already been

accomplished. In yellow are the elements denoted that require further activities to be carried out in the second half of PROMINENT.
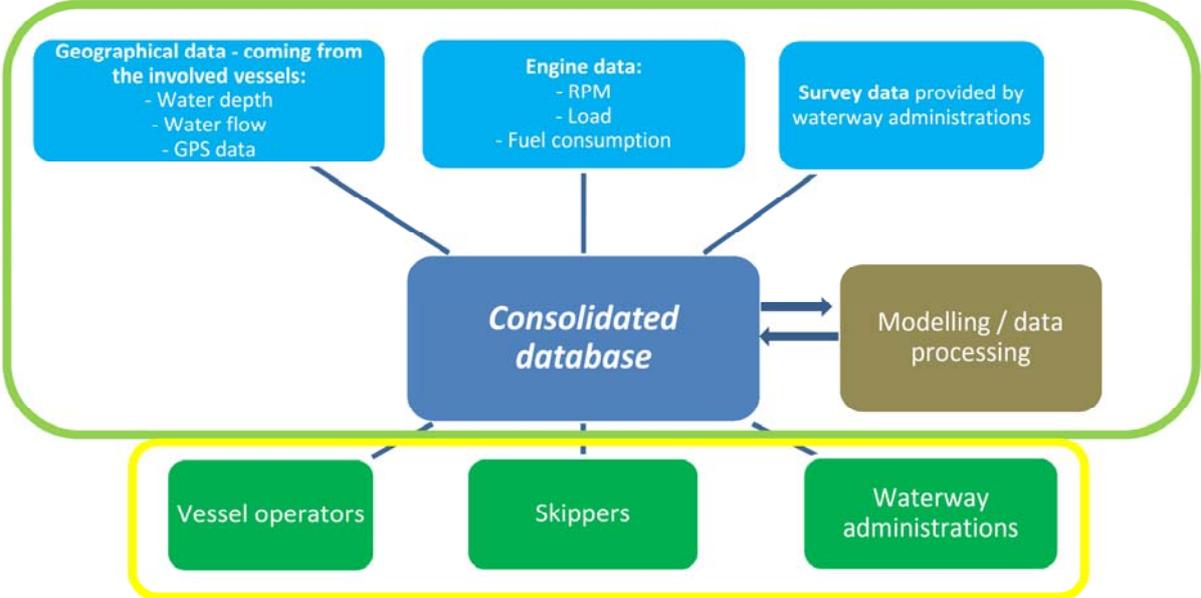

Figure 13: Set up of system for energy-efficient navigation.

References

Schweighofer, J. et al. (2015). D2.3 - Pilot Test Specification for Energy-Efficient Navigation. Technical report of the H2020 EU project PROMINENT, confidential.

Indexes

a. Figures

b. Tables

c. Abbreviations

API	application programming interface
BAW	Bundesanstalt für Wasserbau, Federal Waterways Engineering and Research Institute
cm	centimetre
DST	Entwicklungszentrum für Schiffstechnik und Transportsysteme e.V.
ENAT	Efficient NAvigation Tool
EU	European Union
FGS	Fahrgastschiff
GPS	global positioning system
GUI	graphical user interface
h	hour
HTTP	Hypertext Transfer Protocol

HTTPS	Hypertext Transfer Protocol Secure
H2020	Horizon 2020
km	kilometre
kW	kilowatt
l	litre
Lat	latitude
Lon	longitude
m	metre
Mmsi	maritime mobile service identity
MUL	Multronic N.V.
N/A	not applicable, not available
PRO	Pro Danube Management GmbH
PROMINENT	Promoting Innovation in the Inland Waterways Transport Sector
rkm, Rkm	river kilometre
rpm	revolutions per minute
s	second
SOG	speed over ground
TNO	NEDERLANDSE ORGANISATIE VOOR TOEGEPAST NATUURWETENSCHAPPELIJK ONDERZOEK
u	velocity
URL	Uniform Resource Locator
VIA	via donau – Österreichische Wasserstraßen-Gesellschaft mbH
V_S	ship speed
WP	Work Package
WSV	Wasserstraßen- und Schifffahrtsverwaltung des Bundes
1D	one-dimensional