D3.1 Implementation of EconomyPlanner

Creation Date: 2013 - 09- 06
Revision Date:
Project: MoveIT!
WP: 3

Responsible: Autena Marine – Mr. Savelkoul

Document Properties

Document Name:	D3.1 Implementation of EconomyPlanner
Document Author(s)	Arno Bons
Document Editor(s)	Arno Bons
Date of delivery	2013-04-29
Nature of Deliverable	☐ Report ☒ Prototype ☐ Demonstrator ☐ Other
Circulation	
Security Status	
Document Status	☐ Draft ☒ Final ☐ Approved by SG Steering (or SP meeting type-D) ☐ Approved by reviewer ☐ Acknowledged by MOVEIT! Steering ☒ Issued to EC
Keywords	EC Planner – Implementation
Related MoVeIT! Reports	D1 - D3.2 - D3.3 Economy Planner Interface Overview Economy Planner Use Case Overview

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Document history

Version	Date of delivery	Changes	Author(s) Editor(s)	Reviewed by
1.1	06-09-2013		Mr.Bons	Mr. Savelkoul
1.2	09-27-2013		Mr. Bons	Mr. Thill

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1 Executive Summary

1.1 Problem Definition

The objective of deliverable 3.1 is to equip 4 selected ships from the shipping companies CFT, Helogistics, Plimsoll and ThyssenKrupp Veerhaven with the EC Planner as developed in Work Package 3.

1.2 Technical approach

First the system architecture of the EC Planner is developed. The EC Planner consists of several mathematical prediction modules developed by MARIN, Autena Marine and Deltares, which are described in chapter 2. The different modules require input from on board measurements. Therefore the 4 selected ships are equipped with several sensors by Autena Marine. The set up of the measurements are described in Work Package 1 State of the art and measurements. Finally the software of the EC Planner will be installed on computers and implemented on board of each selected ship.

1.3 Results and Achievements

- The system architecture of the EC Planner is developed.
- The description of the design overview of the EC Planner, including description of interfaces between the different modules of the EC Planner is completed in "Economy Planner Interface Overview" [1].
- An overview of all the use cases for the EC Planner, which is described in "Economy Planner Use Case Overview" [2].
- The EC Planner 1.0 (beta version) is running on a demonstration laptop, see Figure 1.
- Implementation of EconomyPlanner v1.0 on ThyssenKrupp Veerhaven pushbarge is done.

Although initially planned so, starting with the installation of 4 EC Planners at this moment is not cost- and time efficient. At this moment a basic version of the EC Planner 1.0 is available on a demonstration laptop and installed on a pushbarge of ThyssenKrupp Veerhaven. A first installation is needed to test and learn, and thereby to provide input for further development. For this phase in the project it is not beneficial to have a "beta-version" running on 4 ships all over Europe. Therefore a revised planning was submitted to Brussels for approval.

This change in the planning of Work Package 3 is essential as it provides a better opportunity to learn from reality by first installing 1 EC Planner version 1.0 on the Veerhaven ship only, which will be used as a "guinea pig". Subsequently a second version 2.0 will be developed in which these lessons have been implemented. Finally a working stable version of the EC Planner 2.0 will be installed on the 4 participating ships. The benefit of this option is that the version of the EC Planner finally to be installed in this project will be much more proven and also incorporates more of the recent developments, thus adding functionalities.
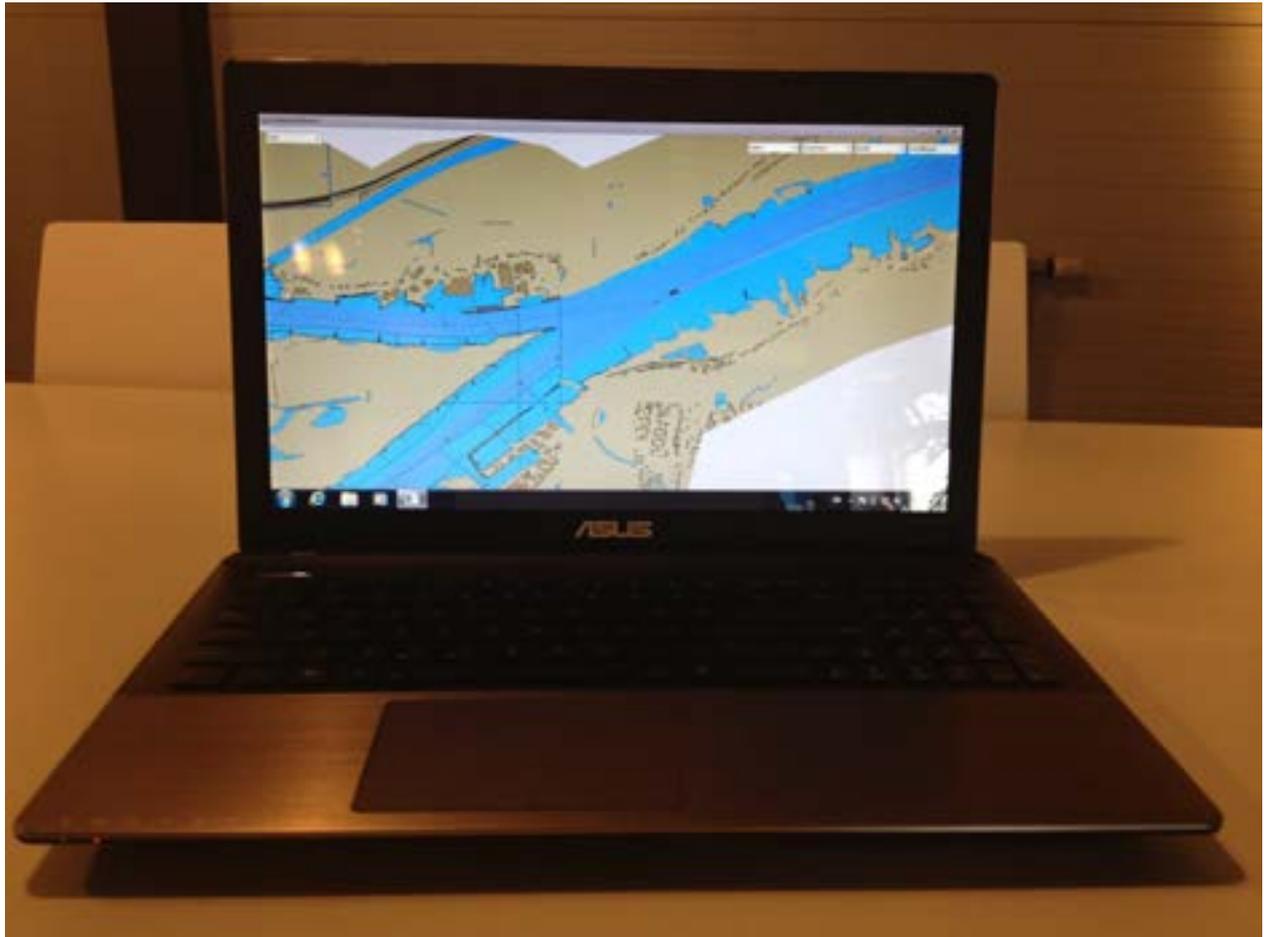
Figure 1: Beta version 1.0 of EC Planner on laptop

1.4 Contribution to MoVeIT! objectives

The objective of this work package is to reduce fuel consumption by energy efficient ship operation, by developing the EC Planner. This will be done by implementing the following measures in the EC Planner; installing the EC Planner on board of the 4 selected ships of shipping companies involved, developing a system to share the actual and local water depth information with other ships, determination of the optimal track on the river and development of an optimal autopilot following the track at the least fuel consumption.

Based on the shared actual and local water depth information over a certain relation the voyage planner of the EC Planner determines the optimal track for this relation. Furthermore, by knowing the actual water depth, the skipper is able to determine the expected maximum allowable loading draft for his voyage. The aim of energy efficient ship operation is to decrease the fuel consumption taking into account the effects of the restrictions of the fairway. The virtual ship of the EC Planner prevents that an avoidable surplus of energy is used when restrictions occur. The skipper is advised to decrease the number of revolutions to an optimised value.

1.5 Exploitation and Implementation

Technically, all inland ships from the EU community can be equipped with an EC Planner. In order to generate an accurate actual water depth map it is even essential

that sufficient ships will participating with sharing water depth information. What "sufficient" is, should be researched.

2 Implementation of EcomomyPlanner

Figure 1 visualizes the system architecture of the EC Planner. The grey boxes represent on shore services and the blue boxes represent all equipment and software of the EC Planner that is installed on board. The arrows show the data flow between the different modules of the EC Planner. As delivery of Work Package 3, the document "Economy Planner Interface Overview" [1] describes the file formats of the data that have to be exchanged between the different modules of the EC Planner. The interface model describes all the top level EC Planner components and the relationships between them. Commonly used in system design is to describe a system using the concept of interfaces. Interfaces are model elements that define sets of operations that other model elements must implement. An implementing model element realizes an interface by overriding each of the operations that the interface declares. To build the actual EC Planner system all the interfaces have to be implemented.

Two main workflows can be distinguished in this system architecture. The first workflow describes the creation of an actual map by sharing water depth information, as presented by arrows 1 until 5. This method is explained in Deliverable D3.2 Integration Of Communication. The second workflow describes the determination of the optimal track based on this actual map, as presented by the arrows 6 and 8, which is explained in Deliverable D3.3 Optimal Track.

In general, the EC Planner integrates both static and dynamic information of both current and upcoming situation in order to provide the best possible voyage information and planning in terms of economy, environment, efficiency and logistics. However, taking into account the upcoming situation is out of the scope of the MoVeIT! project, it can benefit from the hydrological forecasting system as developed by Deltares for another relevant Dutch joint industry project as IDVV and SAVE, which is explained in D3.2. The future traffic center as presented in Figure 2 is out of the scope of MoveIT!.
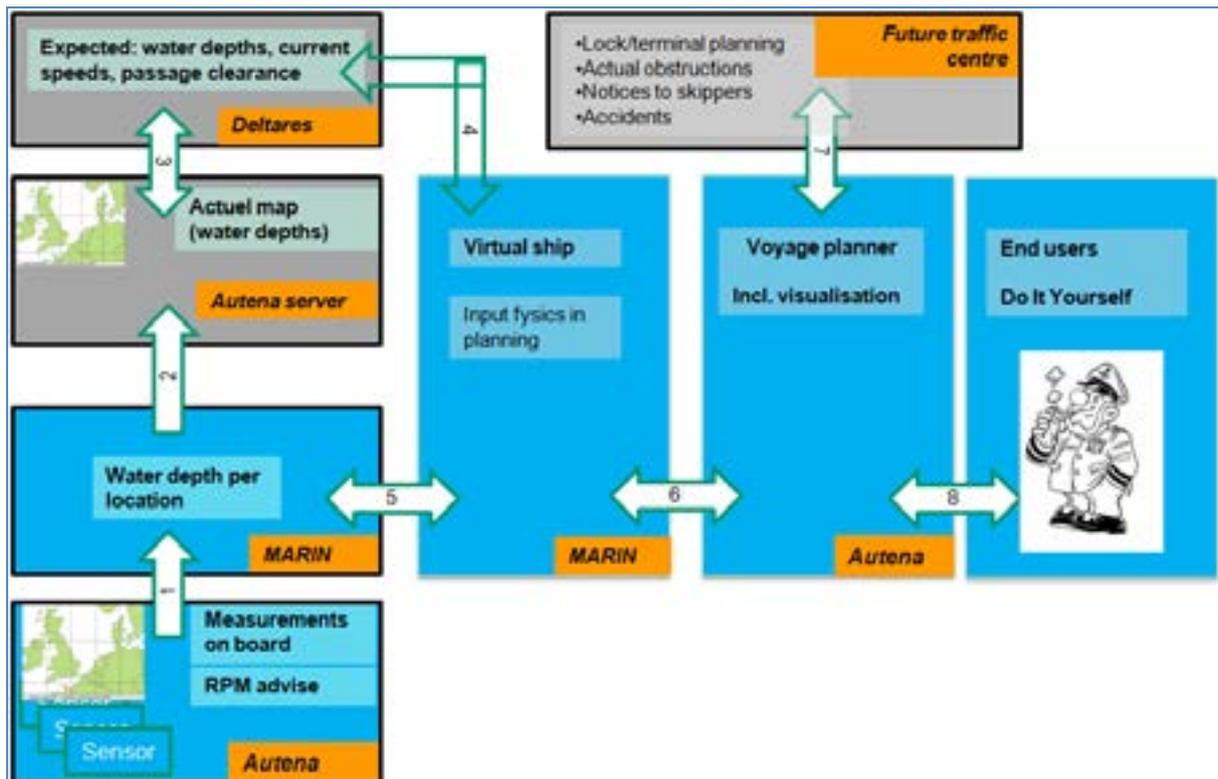
Figure 2: System architecture of EC Planner

The developed EC Planner is able to:
- Generate an actual electronic chart, in terms of real actual local water depth
- Determine the optimal track based on the actual electronic chart
- Determine the maximum allowable loading condition for the journey
- Generate accurate ETA's, voyage plan
- Follow the track with minimized resistance
- Advice skippers on optimal RPM during the trip

The software of the EC Planner will be installed on Nexcom NISE 3600E Industrial fanless computer and will be implemented in the wheelhouses of the 4 selected ships from the shipping companies CFT, Helogistics, Plimsoll and ThyssenKrupp Veerhaven. The computers have to be connected with Red Lion Communication Controller to obtain measurement data that will be required as input for the mathematical models of the EC Planner. During the installation of the computers on board, some main particulars of the ship have to be given. Please note, these parameters have to be set once during the installation of the EC planner. The user interface of the EC planner will be shown on a Olorin 22" fully dimmable LCD touch -monitor. For the communication with the server on shore, there is installed an UMTS/HSDPA –router which provides the connection with internet.

Figure 3 gives a schematic overview of all the required hardware to be installed aboard in order to have a complete working EC Planner including all functionalities as listed above. The exact required measuring equipment depends on the propulsion configuration of each ship. Figure 3 gives an example of a ship with two propulsion engines. A detailed description of the set up of the measurements are documented in Work Package 1.
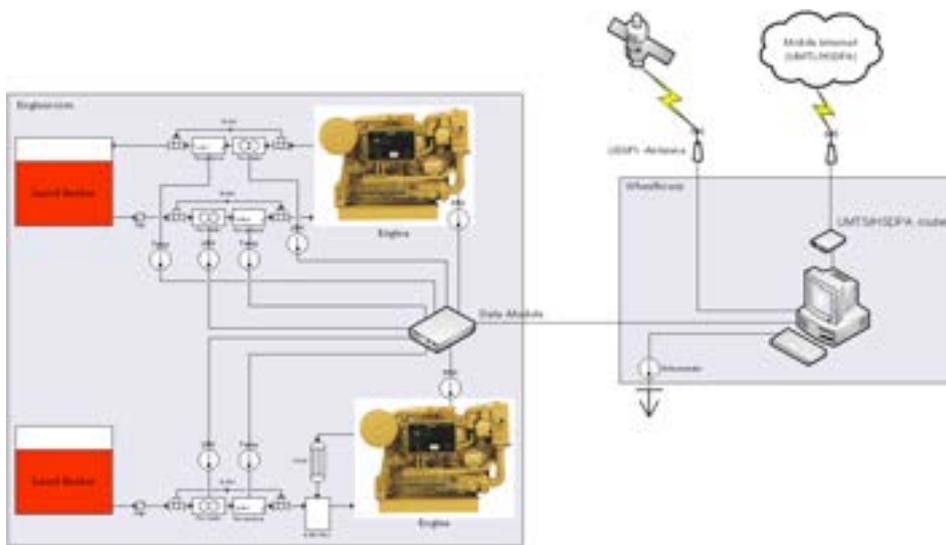
Figure 3: Schematic overview of the required hardware for the EC Planner

3 Bibliography and References

1. Molenmaker Kor, MARIN, Economy Planner Interface Overview, September 2013
2. Molenmaker Kor, MARIN, Economy Planner Use Case Overview, September 2013

4 Indexes

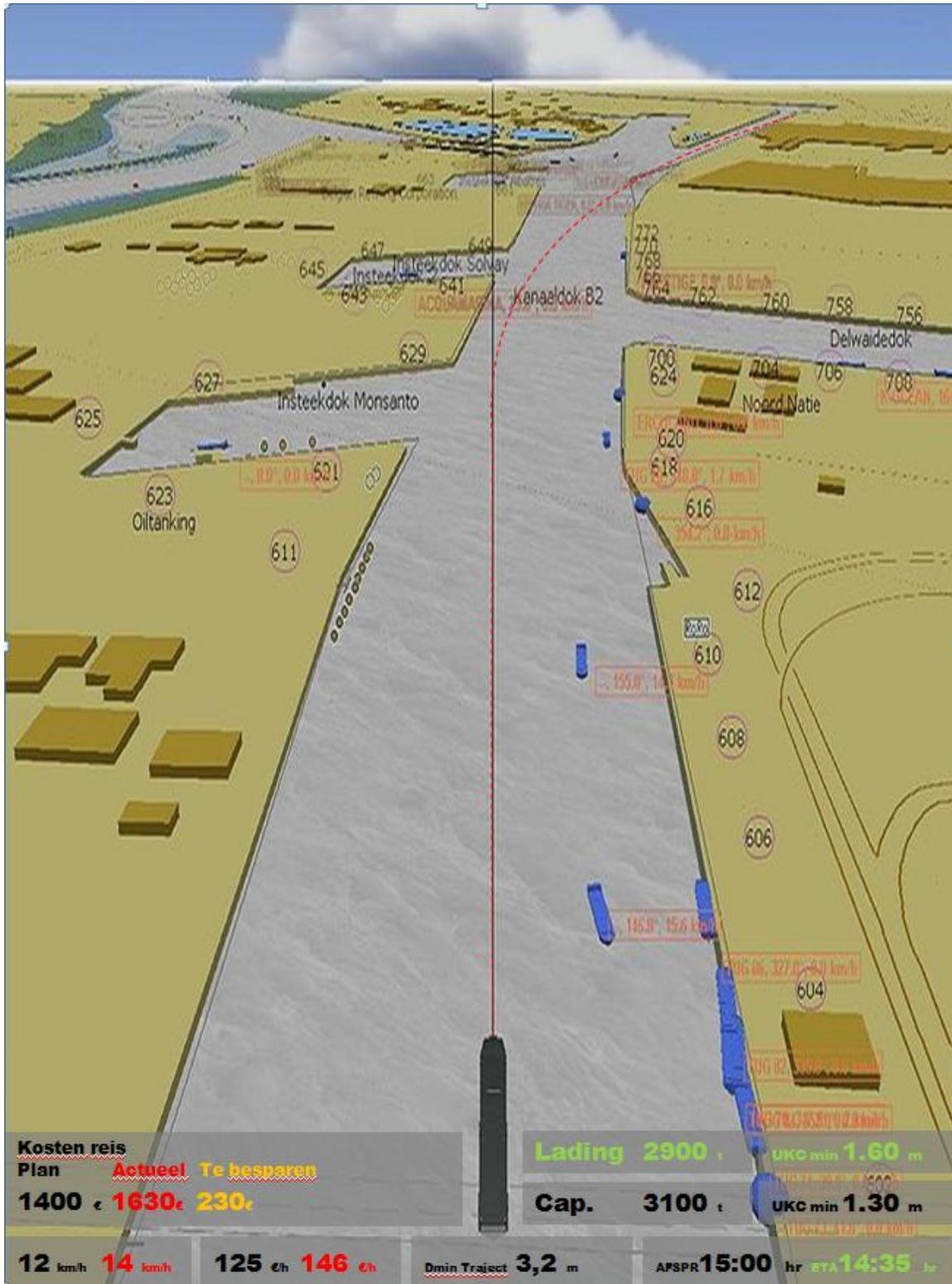## 4.1 Index of Figures

4.2 List of Abbreviations

EC Planner   EconomyPlanner

Appendix A: Economy Planner Interface Overview

Economy Planner Interface Overview

5 Purpose

The interface model describes all the top level Economy Planner components and the relationships between them. Commonly used in system design is to describe a system using the concept of interfaces. Interfaces are model elements that define sets of operations that other model elements must implement. An implementing model element realizes an interface by overriding each of the operations that the interface declares. To build the actual Economy Planner system all the interfaces have to be implemented.

1   Interface Model

The interface model describes all the top level Economy Planner components and the relationships between them. Commonly used in system design is to describe a system using the concept of interfaces. Interfaces are model elements that define sets of operations that other model elements, such as classes, or components must implement. An implementing model element realizes an interface by overriding each of the operations that the interface declares. To build the actual Economy Planner system all the interfaces have to be implemented.

You can use interfaces in class diagrams and component diagrams to specify a contract between the interface and the classifier that realizes the interface. Each interface specifies a well-defined set of operations that have public visibility. The operation signatures tell the implementing classifiers what kind of behavior to invoke, but not how they should invoke that behavior. Many classifiers can implement a single interface, each one providing a unique implementation.

Classes or components that realize the interfaces by implementing this behavior simplify the development of applications because developers who write client code need to know only about the interfaces, not about the details of the implementation. If you replace classes, or components that implement interfaces, in your model, you do not need to redesign your application if the new model elements implement the same interfaces.

For example this implementation of the Economy Planner uses ASCII files between the VoyagePlanner and the VirtualShip. However another implementation could use webservices instead. The interfaces do not change (what of the system) only the implemenation is different (the how of the system).

<u>System Overview Economy Planner</u> – *(Component diagram)*
Each ship gathers hydrological environment data at their current GPS location. The local water depth is corrected for trim and squat. This local environment data is stored locally on the ship and uploaded to the MeasurementServer. All this data on the measurement server will be processed and uploaded to the EnvironmentServer. This Environment-Server processes the data and creates new forecast data. This forecast data can be downloaded to ship and used in the Economyplanner onboard. The VirtualShip uses this forecast data to generate the most optimal track on the river.
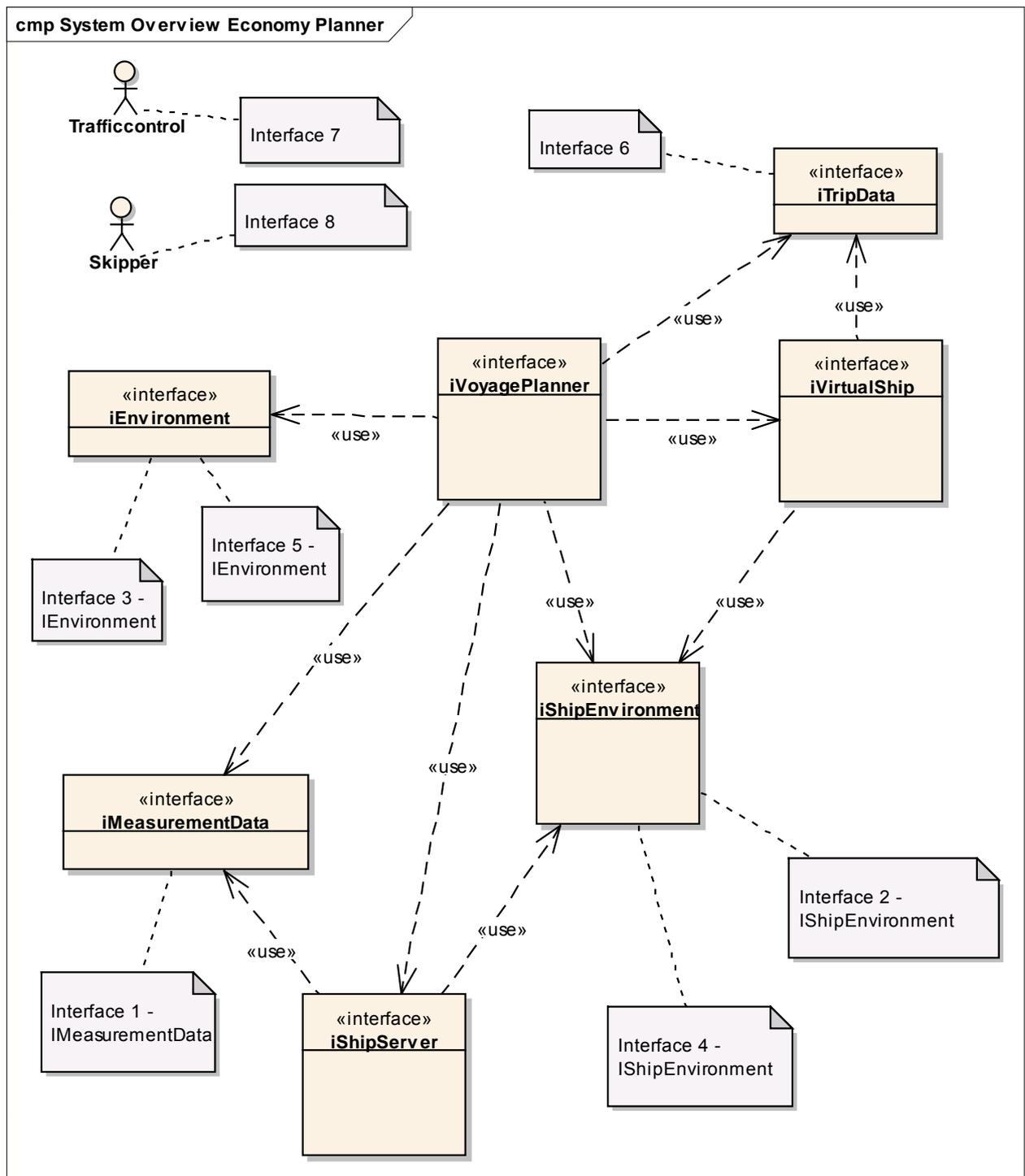
Figure: 1

System Overview Actual Map – *(Component diagram)*

One of the main goals of the Economyplanner is to create a map with actual water depths. This will be achieved by gathering local water depths as measured by individual inland ships using the European inland waterways. Ships equipped with the Economy-planner will broadcast their local water depth for a certain GPS position to an onshore server. The local water depths can be determined on basis of the echo sounder signals. Since, echo sounders are not measuring the water depth, but under keel clearance, it

has to be corrected for initial draft and squat. Squat is an important issue for ships navigating with limited under keel clearance in restricted waterways such as channels and canals. Squat is defined as the reduction of under keel clearance resulting from bodily sinkage and change of trim, which occurs when a ship moves through the water.

Figure: 2

1.1   Interface 1

Interface 1 - IMeasurementData

1.2   OnboardMeasurements

The ship server takes care of gathering all the measurement data of the ship, the communication between the applications running on the ship and the communication with the server located onshore. It is the heart of the ship data gathering and communication.

MeasurementService – *(Logical diagram)*

All elements and components used for measuring the ship, engine and hydrological data aboard. It is important that all of this data is set or measured automatically. It is recommended not to rely on manual entering of these values, because there is no way that these values can be checked if they are entered correctly. Automatic measured values increase the overall quality of the calculations and results.

Figure: 3

1.2.1 iEngine

The iEngine interface describes the operational engine characteristics, like RPM and fuel flow. These characteristics provide valuable information about the load and fuel consumption of the engine.
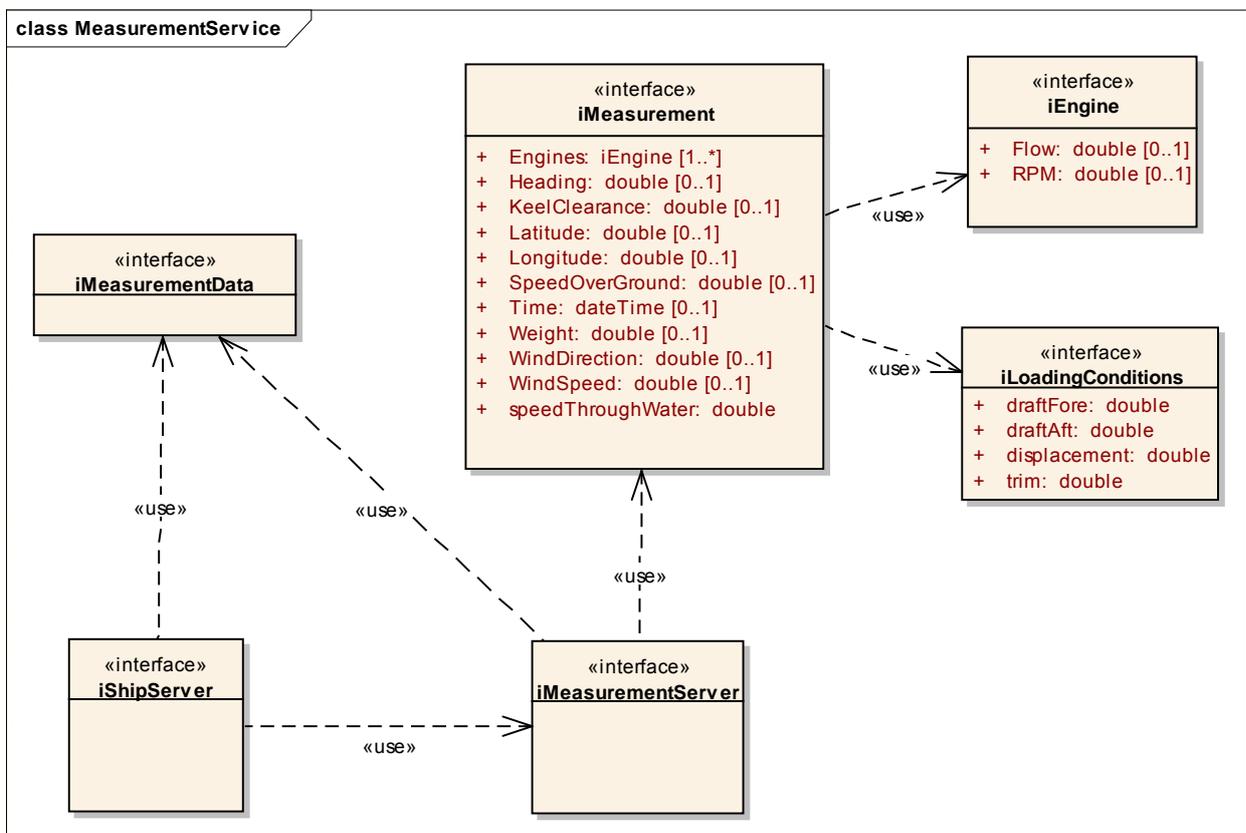
Attribute	Notes
Flow double	
RPM double	

1.2.2 iMeasurement

The iMeasurement interface describes the operational ship characteristics, like heading and GPS location. These characteristics provide valuable information about the ship and its environment at a certain GPS location. These values are measured (almost) real-time.

Attribute	Notes
Engines iEngine	
Heading double	
KeelClearance double	
Latitude double	
Longitude double	
SpeedOverGround double	
Time dateTime	
Weight double	
WindDirection double	
WindSpeed double	
speedThroughWater double	

1.2.3 iLoadingConditions

The iLoadingConditions interface contains the properties of the present loading conditions.

Attribute	Notes
draftFore double	Draft of baseline at fore perpendicular
draftAft double	Draft of baseline at aft perpendicular
displacement double	Displacement
trim double	

1.2.4 iMeasurementData

The iMeasurementData interface describes the operational ship characteristics, like heading and GPS location. These characteristics provide valuable information about the ship and its environment at a certain GPS location. These values are measured (almost) real time and are specific for each ship.
The frequency (the heartbeat) of the data request is the responsibility of the caller of the interface/service. The onboard measurement is done with a frequency of 1 Hz (1 sample each second).

Interface 1
ShipID
DateTime stamp
GPS location (lat and lon)
Heading
Speed Over Ground (SOG)
Speed through Water (V_s)
Keel clearance
Draft
DraftAft
DraftFore
Fuel consumption
Actual RPM
Actual Loading depth
Actual trim
Wind speed
Wind direction

1.2.5 iMeasurementServer

The iMeasurementServer takes care of gathering all the measurements on board of the ship. All measurement data will be available through the interface 1 definition.

1.2.6 iShipServer

The ship server takes care of gathering all the operational ship data; the communication between the applications running on the ship and the communication with the server located onshore. It is the heart of the ship data gathering and communication. All ship data will be available through the interface 4B definition. Data is stored locally if the server onshore is not available.

1.3   Forecasts

The Forecast takes care of processing the hydrological data and calculating predictions for water depth, current and free height values.

Forecasts – *(Logical diagram)*

All elements and components used for providing hydrological environment values for a given GPS location and forecast values for a maximum of 3 days. This hydrological environment is based on actual hydrological data gather by all participating ships, data provided by the authorities and mathematical calculations for the forecasts.
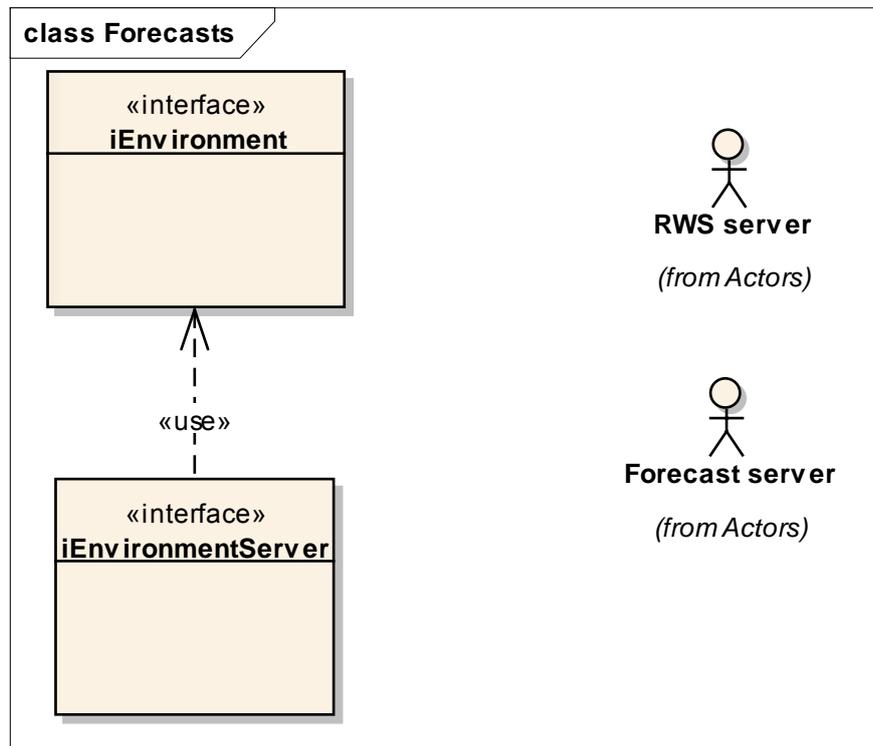

Figure: 4

1.3.1 iEnvironment

The iEnvironment interface describes the hydrological environment at a given GPS location.

Interface 3
DateTime stamp
GPS location
default actual waterdepth
default actual current
dataset for several prediction intervals with:
expected waterdepth
expected current

The default actual waterdepth is the waterdepth provided by authorities. This value is available through public measurements.

1.3.2 iEnvironmentServer

The iEnvironmentServer takes care of gathering all the hydrological environment values. These values will be available through the interface 3 definition. The forecasts for the waterdepths, watervelocity and direction, free height and bed levels. The forecast is for a maximum of 3 days.

1.4   VoyagePlanner

The voyage planner keeps track of the route and its legs. The voyager planner creates all the legs for a given route. For each leg additional information will be added based on the expectations for the water depth, current speed and other environmental conditions. The voyage planner relies on the virtual ship to do the calculation for the entire route to find the most optimal RPM and fuel consumption setting.

VoyagePlanner – *(Logical diagram)*
All elements and components used to calculate the track for the ship based on the given start and end location and the hydrological environment.
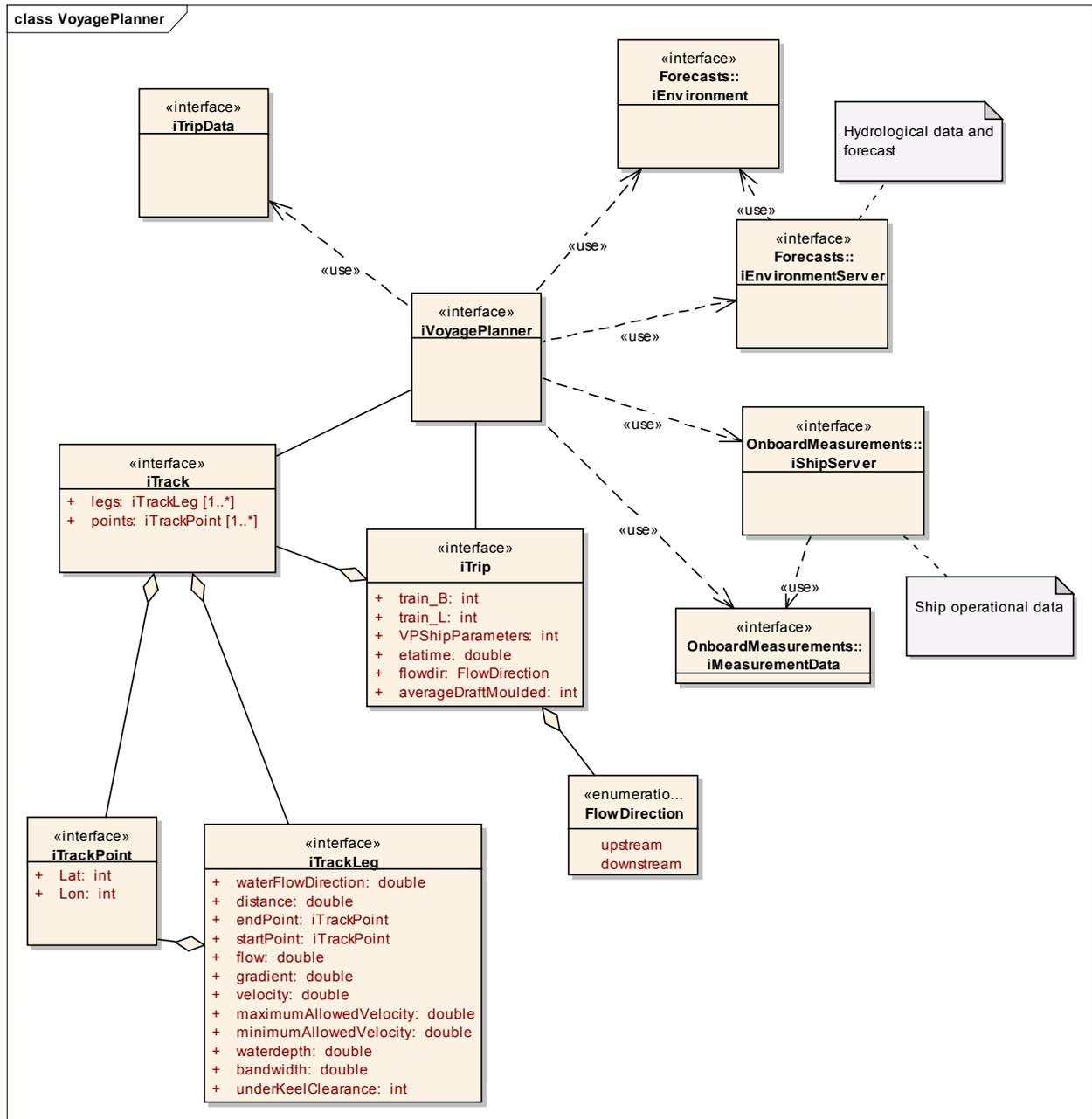
Figure: 5

1.4.1 FlowDirection

Attribute	Notes
upstream	Flow against sailing direction, equals −1
downstream	Flow in sailing direction, equals 1

1.4.2 iTrip

The iTrip interface describes all elements and atrributes which define the trip. A trip is a single track with one or more legs, a start and end location and several trip environmental conditions, like upstream or downstream, requested time of arrival, departure time.

Attribute	Notes
train_B int	Number of barges in width direction of the train. Plain ship train_B=0
train_L int	Number of barges in length direction of the train. Plain ship train_L=0
VPShipParameters int	Set of ship parameters for SHIPTYPE = 0
etatime double	Total sailing time
flowdir FlowDirection	Flowdirection
averageDraftMoulded int	Average draft moulded, TOPER, [m]

1.4.3 iShipEnvironment

This interfaces describes the hydrological environment at the ships' GPS location. The environment local to the ship.

interface 4A
ShipID
DateTime stamp
GPS location (lat and long)
default actual waterdepth
default actual current
local waterdepth

The default actual water depth is the water depth provided by authorities. This value is available through public measurements.

The local water depth is based on the trim and squat for this ship at the GPS location. The local water depths can be determined on basis of the echo sounder signals. Since, echo sounders are not measuring the water depth, but under keel clearance, it has to be corrected for initial draft and squat. Squat is an important issue for ships navigating with limited under keel clearance in restricted waterways such as channels and canals. Squat is defined as the reduction of under keel clearance resulting from bodily sinkage and change of trim, which occurs when a ship moves through the water.

The frequency (the heartbeat) of the data request is the responsibility of the caller of the interface/service.

1.4.4 iTrack

The interface for a general "track". A track is an alternation of waypoints and "legs" leading from one waypoint to another. A track always starts and ends with waypoints. A specific track will have specific waypoints and legs, hence this interface is generic and requires the actual TrackPoint and TrackLeg types as instantiation parameters.

Attribute	Notes
legs iTrackLeg	
points iTrackPoint	

1.4.5 iTrackLeg

This interfaces describes all the attributes and elements for one singe track leg.

Attribute	Notes
waterFlowDirection double	Compass direction of flow, [deg]
distance double	Sailed distance along track, [km]
endPoint iTrackPoint	End location of the route leg
startPoint iTrackPoint	Start location of the route leg
flow double	Water flow velocity in the leg [m/s]
gradient double	River gradient [m/km]
velocity double	current velocity in the leg, VLEG [km/h]
maximumAllowedVelocity double	Maximum allowed velocity on channel leg, [km/h]
minimumAllowedVelocity double	Minimum allowed velocityon channel leg, [km/h]
waterdepth double	Water depth of the waterway, [m]
bandwidth double	Width of the navigable channel, [m]
underKeelClearance int	Under keel clearence for the ship in this leg

1.4.6 iTrackPoint

This interface describes all atributes and operations for one single track point.

Attribute	Notes
Lat int	Latitude
Lon int	Longitude

1.4.7 iTripData

The iTripData interface describes the operational trip characteristics as defined in interface 6.

Direction =>direction to travel(input)
Distance =>total distance travelled (input)
Flow =>speed of the current in the river (input)
Gradient => River gradient in m/km (input)
Lat => Lattitude (input)
Lon => Longitude (input)
VLEGMAX => Maximumallowed speed on this leg, or0 (input)
VLEGMIN => Minimum allowed speed on this leg, or 0 (input)
WWAYADEPTH => Average water depth of the waterway (input)
WWAYWIDTH => Width of the navigable channel (input)
VLEG => Velocity in the leg(input)
This prognosis database is a plain text file. The location of the file is passed on through the PlannerService interface."Direction" "Distance" " Flow" "Gradient" "Lat" "Lon" "VLEGMAX" "VLEGMIN" "WWAYADEPTH" "WWAYWIDTH" "VLEG"

Interface 6A
LEGST=> leg distance travelled (output)
LEGST_TOTAL=> total distance travelled (output)
NLEC=> adviced RPM for this leg
PDLEG=> fuel consumption for this leg
LEC=> velocity for this leg

1.4.8 iVoyagePlanner

The voyage planner keeps track of the route and its legs. The voyager planner creates all the legs for a given route. For each leg additional information will be added based on the expectations for the water depth, current speed and other environmental conditions. The voyage planner relies on the virtual ship to do the calculation for the entire route to find the most optimal RPM and fuel consumption setting.

1.5   VirtualShip

The virtual ship is a mathematical model that represents the ship on a PC on the bridge. The results of the measurements are required to calibrate the virtual ship, being the basis of the Economy Planner.

VirtualShip – (Logical diagram)
All elements and components used to calculate the ship's behaviour. This calculation is based on the ship geometry and its characteristics, the hydrological environment and the trip.
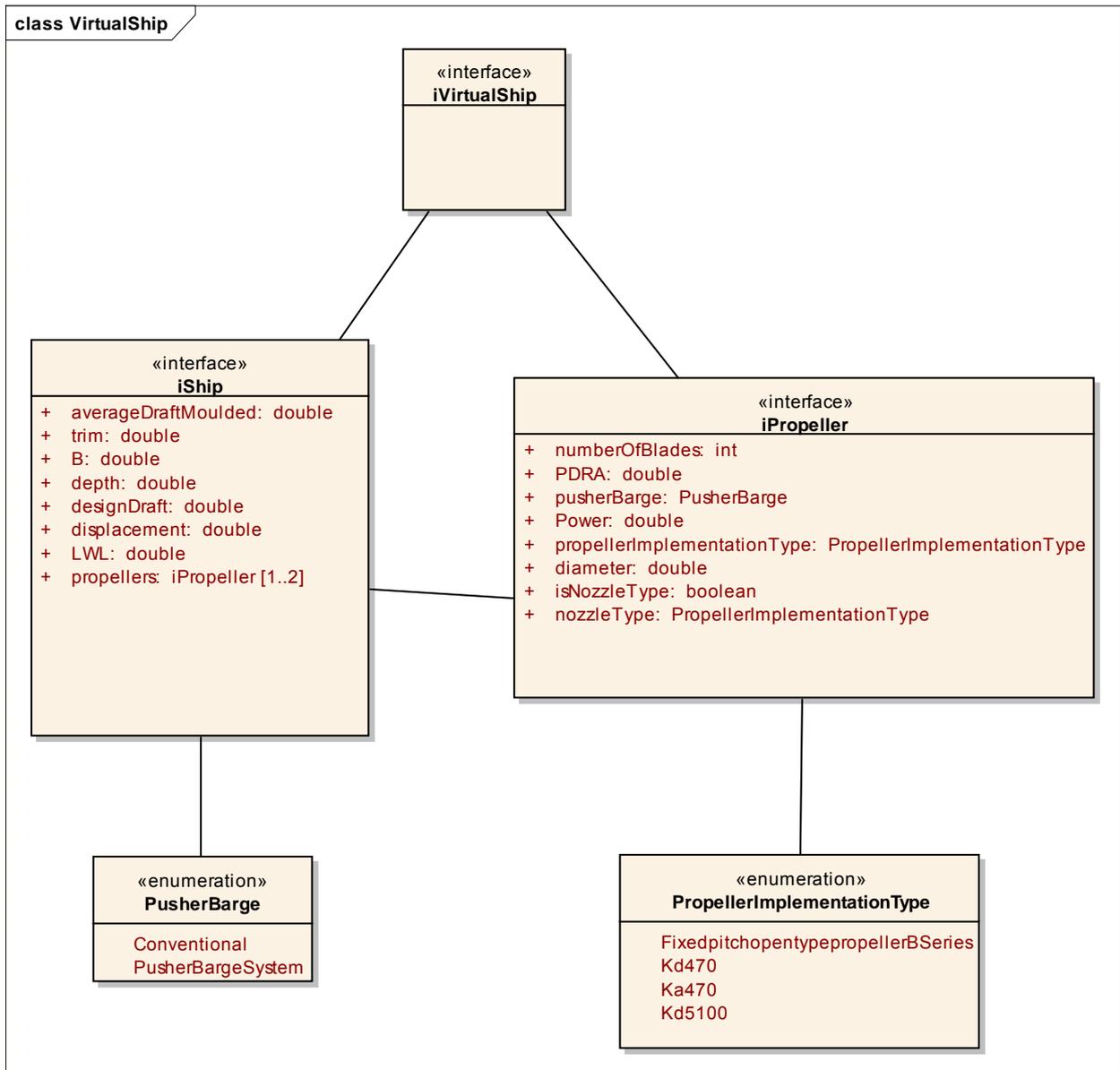
Figure: 6

1.5.1 PropellerImplementationType

Attribute	Notes
Fixedpitchopentypepropeller BSeries	Fixed pitch open type propeller (B–Series)
Kd470	Fixed pitch propeller with 19A, 22 or 24 nozzle -> Kd 4–70
Ka470	Fixed pitch propeller with type 37 nozzle -> Ka

Attribute	Notes
	4-70
Kd5100	Fixed pitch propeller with type 33 nozzle -> Kd 5-100

1.5.2 PusherBarge

Attribute	Notes
Conventional	
PusherBargeSystem	

1.5.3 iPropeller

This interface describes the characteristics of a ship propeller.

Attribute	Notes
numberOfBlades int	Number of blades per propeller
PDRA double	Pitch/diameter ratio of propeller at 0.7 R [-]
pusherBarge PusherBarge	
Power double	Installed propulsion power [kW]
propellerImplementationType PropellerImplementationType	
diameter double	Diameter of the propeller [m]
isNozzleType boolean	Is this propeller a normal propeller or a nozzle type propeller?
nozzleType PropellerImplementationType	

1.5.4 iShip

This interface describes the characteristics of the ship and its geometry.

Attribute	Notes
averageDraftMoulded double	Average draft moulded, TOPER
trim double	Ships trim, average of fore and aft trim
B double	Beam moulded [m]
depth double	Moulded depth of ship [m]

Attribute	Notes
	For inland vessels, this is generally equal to the maximum draft. Maximale diepgang.
designDraft double	The design (maximum) draft of the ship [m]
displacement double	Total displacement including shell and appendages [t]
LWL double	Length on the waterline [m]
propellers iPropeller	

1.5.5 iVirtualShip

The virtual ship is a mathematical model that represents the ship on a PC on the bridge. The results of the measurements are required to calibrate the virtual ship, being the basis of the Economy Planner.

Part of the Virtual Ship is the calculation of the squat and trim to determine the local water depth. This calculation is based on the environment values at the ships' GPS location and ship characteristics.

1.6 TrafficControl

Traffic control is an external stakeholder for the Economy Planner. Based on data shared from each Economy Planner on a variety of ships, Traffic Control can determine bottlenecks for locks and passages. This information can be used to plan the waterways much more efficient.

Appendix B: Economy Planner Use Case Overview

Economy Planner Use Case Overview
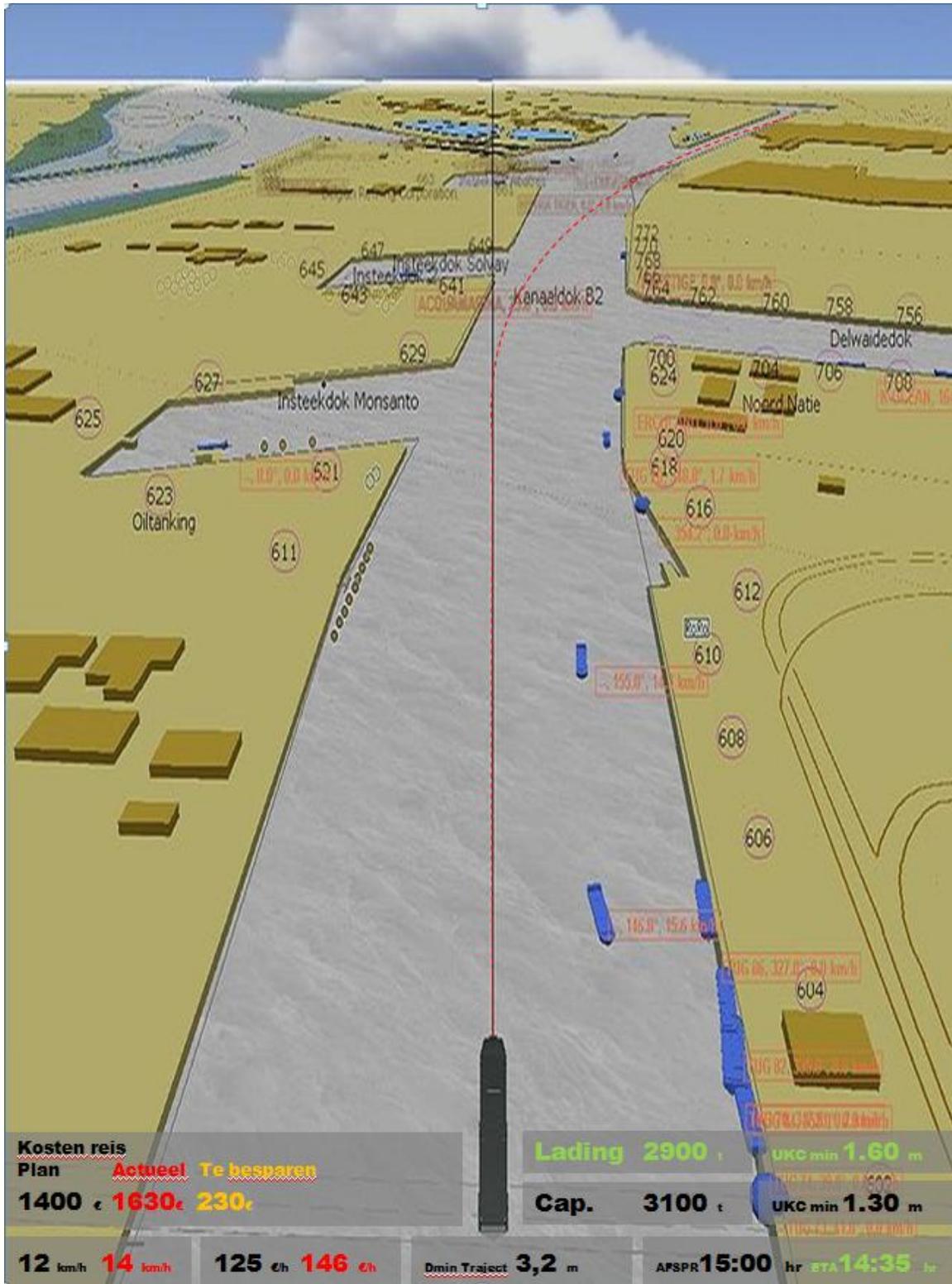
6 Purpose

This document provides a overview of all the Use Cases for the Economy Planner and consists of the following sections:

- Use Case view: Use cases describing the functionality.
- Vision.
- Conceptual view. A top level overview describing the main components.
- All stakeholders.

2   Architecture

The Use Case view describes the Economy Planner primary (architectural significant) use cases and the actors of the Economy Planner. Use Case Diagrams are used to describe the functionality of the Economy Planner from the customer's perspective. If you had to find a single word, a use case is synonymous with, it would be like a scenario. But it's much more than that. It is the particular scenario that it made up out of activities.

Use Case diagrams have only 4 major elements: The **actors** that the system you are describing interacts with, the **system** itself, the **use cases**, that the system knows how to perform, and the lines that represent **relationships** between these elements.

Use Case diagrams are used to represent the functionality of your system from a top-down perspective (that is, at a glance the system's functionality is obvious, but all descriptions are at a very high level. Further detail can later be added to the diagram to elucidate interesting points in the system's behavior.)

<u>Primary Use Cases And Actors</u> - *(Use Case diagram)*
The objective of the Economy Planner is to reduce fuel consumption by energy efficient ship operation. This will be done by implementing the following measures in the Economy planner, installing the Economy planner on ships, developing a system to share depth information with other ships (relation in this respect with RIS), determination of the optimal track on the river, the track with the least amount of fuel consumption. The target is a fuel consumption of at least 10%.

The Economy Planner must operate standalone on a ship. Standalone means that it must be able to calculate the optimal route and track on the base of the last available ENC maps, with or without actual expectations. For an update of the ENC maps with actual data an online connection to the internet is required.
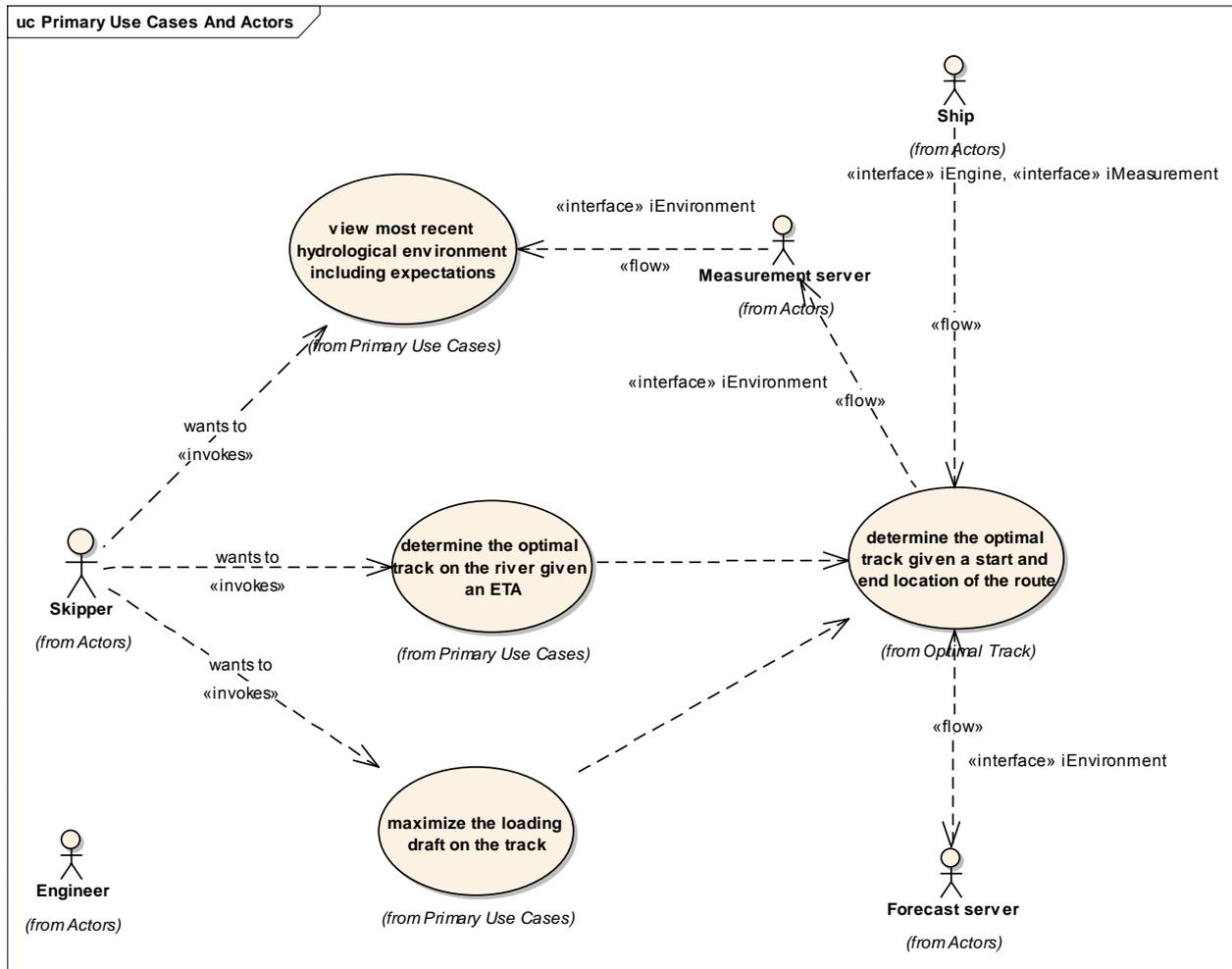
Figure: 1

View most recent hydrological environment - *(Use Case diagram)*
Each ship is equiped with a keel clearance and trim measurement devices. The measured value is used, together with ship characteristics and environmental values, to calculated the actual waterdepth at the ship's GPS location. This value and other ship measurements are uploaded to a ship measurement server which is onshore.

This ship measurement data is used to provide the skipper more information about the environmental conditions along the route. The skipper selects the start and end destination and a route is generated on the graphical user interface. The skipper can also add ship measurement data for a give time frame and include the forecast data as well. This way the skipper can easily determine the environmental conditions along the route for a give time and forecast.

For validation purposes reference data from RWS is available. This data can also be included in the route graphical user interface. This data is presented in such a way that the differences are clearly identifiable.

Each ship equipped with the Economy Planner can benefit from each other's experience. Actual information on the bottom topography becomes available on board via the route and presented in the ECDIS (Electronic Chart Display Information System). This will be achieved by gathering local water depths as measured by individual inland ships using the European inland waterways. Ships equipped with the Economy Planner will broadcast their local water depth for a certain GPS position to an onshore server. The local water depths can be determined on basis of the echo sounder signals. Since, echo sounders are not measuring the water depth, but under keel clearance, it has to be corrected for initial draft and squat. Squat is an important issue for ships navigating with limited under keel clearance in restricted waterways such as channels and canals. Squat is defined as the reduction of under keel clearance resulting from bodily sinkage and change of trim, which occurs when a ship moves through the water.

The initial draft of the ship is known at the beginning of the voyage and can be automatically retrieved from the loading computer of the ship. The virtual ship module calculates squat.
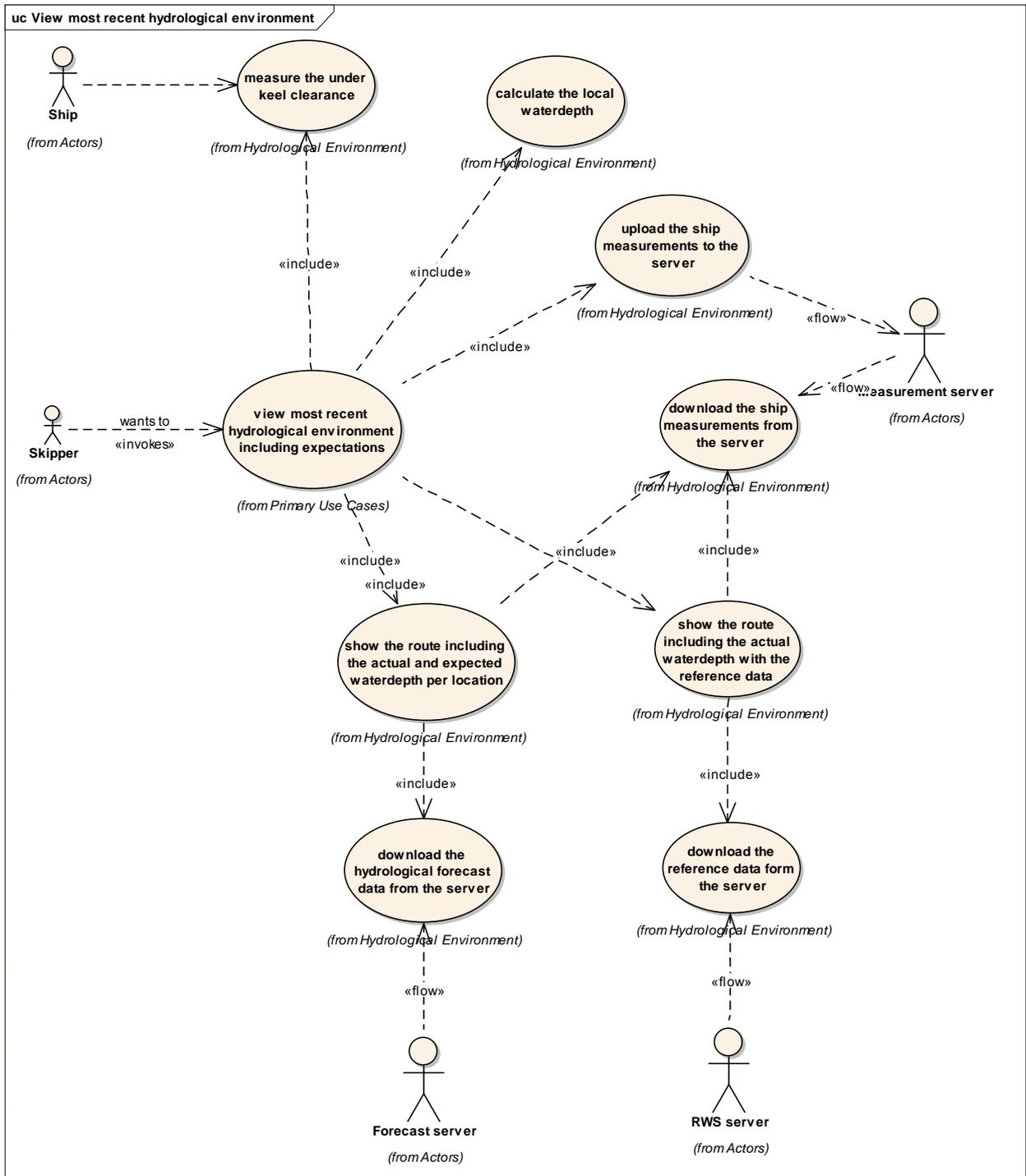
Figure: 2

Optimal Track Use Cases - *(Use Case diagram)*
Every ship has access to actual information on the bottom topography. This information can be used to select the optimal track given the draught of the ships. The optimal track will be developed, using optimization theories on basis of draught of the ship and available water depths.

The current water depths are used for the creation of the actual map, in terms of water depth, that will be presented on the ECDIS to the skipper. Both the current and expected (based on forecasts) water depths will be used by the virtual ship for the determination of the optimal track.

The restrictions in water depth (and width) are of eminent importance for the energy consumption. This is due to the fact that engines on board keep the selected number of revolutions during operation. When the water conditions get restricted the propellers have problems to get enough water and therefore they have to work harder and this costs more energy and subsequently fuel.

So, based on the given route, the EC planner will determine the optimal track by looking for the deepest parts on the river, taken into account the turning circle of the ship.
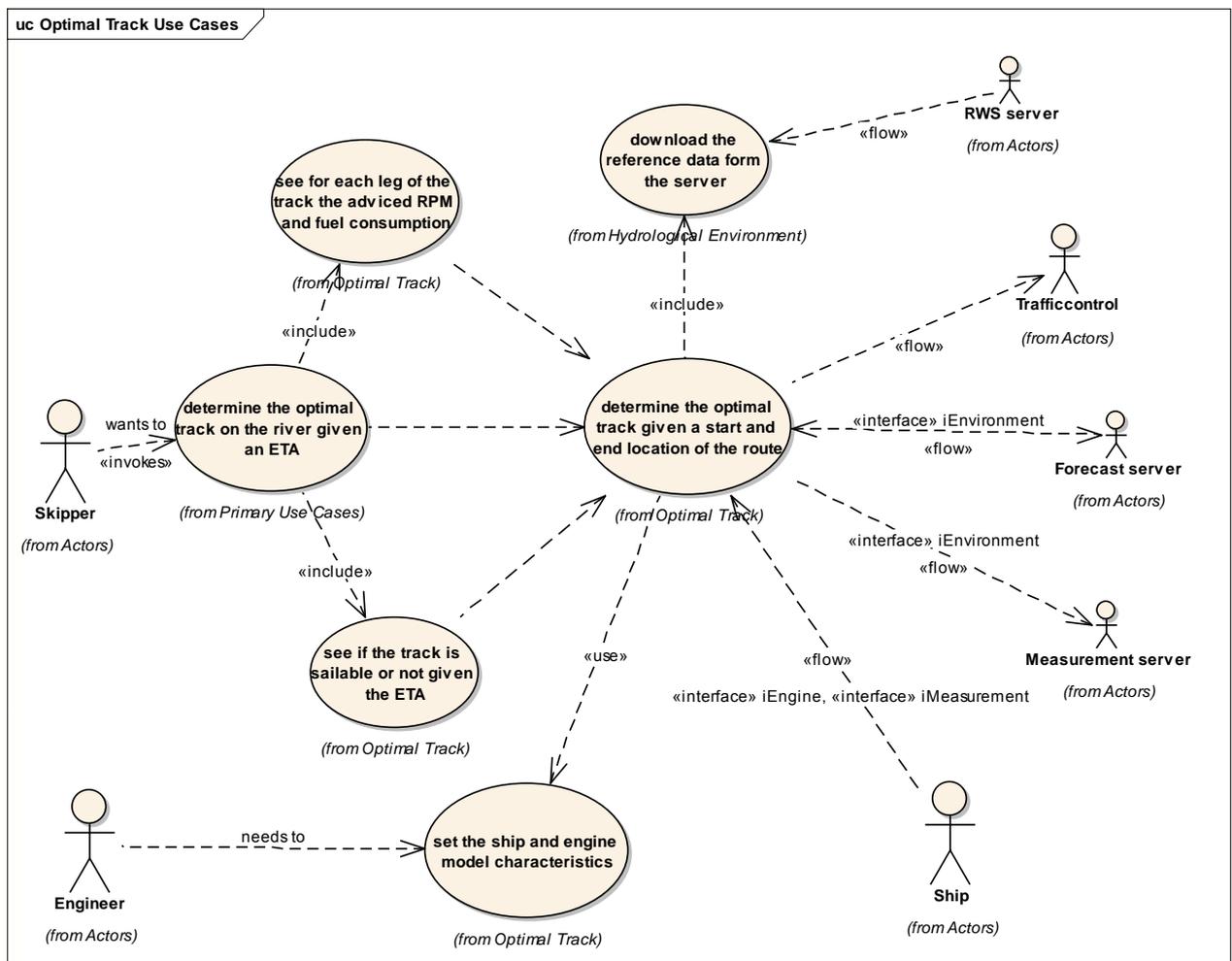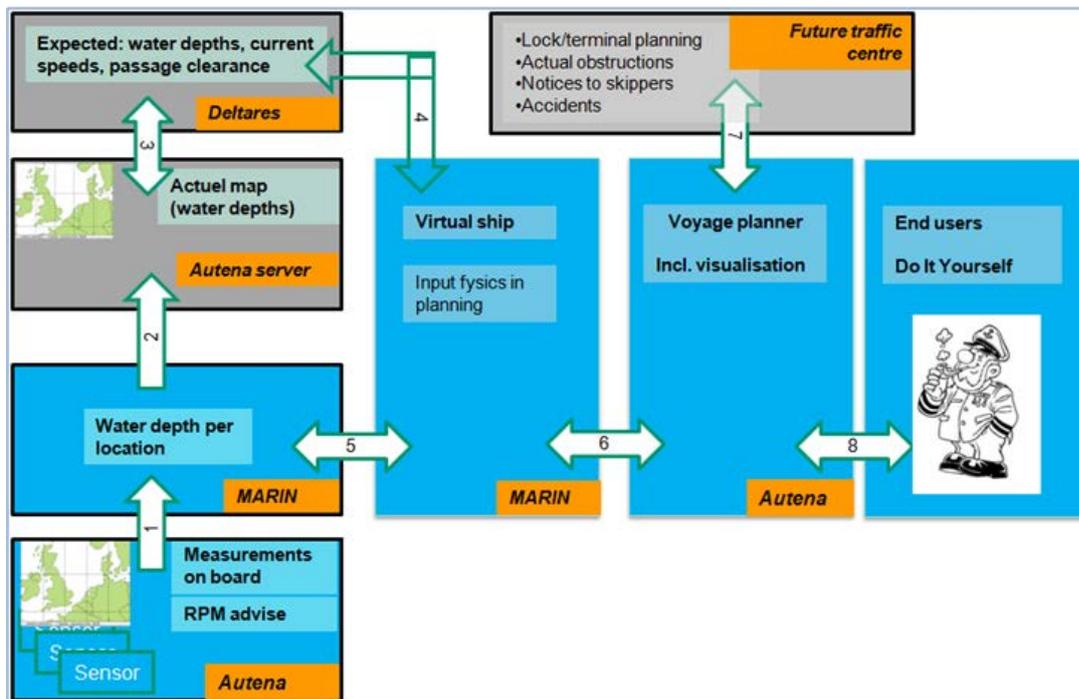

Figure: 3

2.1 Conceptual diagram for the Economy Planner

2.2 Vision for the Economy Planner

6.1 Description

The objective of this work package is to reduce fuel consumption by energy efficient ship operation, by developing the Economy Planner. This will be done by implementing the following measures in the Economy planner, installing the Economy planner on board of the 4 ships of shipping companies involved, developing a system to share depth information with other ships (relation in this respect with RIS), determination of the optimal track on the river and development of an optimal autopilot following the track at the least fuel consumption. The target is a fuel consumption of at least 10%.

6.2 Objectives per task

Task 3.1 Installing Economy Planner
The recently developed EC (Autena Marine and Marin, see Baseline, part B) has to be adapted to and installed on the 4 participating ships. The virtual ship is a mathematical model that represents the ship on a PC on the bridge. The results of the measurements are required to calibrate the virtual ship, being the basis of the Economy Planner, EC. Final developments to the virtual ship and calibration to simulate the real ship will be done.

Task 3.2 Integration of communication
The next important step is to create a system such that all ships equipped with the EC can benefit from each other's experience (comparable to the information on traffic jams put together on basis of all individual TomToms). For this relation with RIS (EU directive) is required and will be established. If this approach fails then MoVeIT! will use an own server to analyse, elaborate and broadcast the data on the bottom configuration. This

would be the first time that this system would work for inland ships. Research will be required to determine the local water depths on basis of echo sounder signals. These have to be corrected for squat and trim and these values will be calculated by the virtual ship. If this succeeds then actual information on the bottom topography becomes available on board via the route as described in the previous task and presented on the ECDIS.

Task 3.3 Optimal track
In this task a method will be developed that every ship has access to actual information on the bottom topography. This information can be used to select the optimal track given the draught of the ships. The optimal track will be developed, using optimization theories on basis of draught of the ship and available water depths.

2.3 Use Cases

A **use case diagram** at its simplest is a graphical representation of a user's interaction with the Economy Planner and depicting the specifications of a Use_Case. A use case diagram can portray the different types of users of the Economy Planner and the various ways that they interact with the Economy Planner.

2.3.1 Primary Use Cases

The Primary Use Cases are those Use Cases that are most likely going to occur when the Economy Planner is operational and everything went well.

2.3.1.1   view most recent hydrological environment including expectations

As skipper I want to see the most recent hydrological environment for my current route. I want to be able to see the expectations for several days ahead.

Every ship is equipped with measuring devices for keel clearance and (initial) loading trim settings. These values are used to calculate the water depth at the current GPS locations. This local water depth information or actual information on the bottom topography is uploaded to the measurement server. This information can that be shared among other participating ships.

The most recent hydrological environment, viewed on the ECN display, is made up out of available hydrological default data, these actual measurements from the measurement server and calculated expectation data for several days ahead.

2.3.1.2   determine the optimal track on the river given an ETA

As skipper I want to know the optimal track on the river. The track with the least amount of fuel demand in order to get to my target exactly on time.

The following step is that the EC planner determines and decides on the best track to be followed on basis of own ship and bottom configuration. First the skipper has to provide a DTA, ETA and a route in the user interface of the voyage planner. A route is just a sequence of waypoints to indicate the point of departure and arrival and which fairways have to be taken. Based on these provided input, the EC planner will download water depths and GPS positions from the Forecast server and will calculate the most optimal route.

2.3.1.3   maximize the loading draft on the track

As skipper I want to be able to iterate using the ETA, loading draft and expectations to figure out the most optimal ETA and loading draft. The Economy Planner is interactive and can assist the skipper in finding the most optimal settings for the route. Changing the ETA might indicate areas on the map with increasing water depth, or with decreasing water depths. Changing the ETA could mean taking on more load on the same trip, because the water depth increases. The Economy Planner supports the skipper to make decisions about ETA and loading draft.

2.3.1.4   Hydrological Environment

All Use Cases involved in making a map of real-time, actual hydrological data.

2.3.1.4.1   show the route including the actual and expected waterdepth per location

The skipper has entered the route he wants to sail. On his ENC the route is displayed between the start and destination location. Aditionally theh skipper can select:

•   to add the actual water depth for a specific history timeframe. The skipper can enter the value for this timeframe window. For example he wants to see all actual water depth measurements of the last 4 hours on his route.

•   to add the expectations for the actual water depth. The skipper can enter the value for the expectations timeframe window. For example he wants to see all values for current time + 3 hours.

2.3.1.4.2   show the route including the actual waterdepth with the reference data

The skipper has entered the route he wants to sail. On his ENC the route is displayed between the start and destination location. Aditionally theh skipper can select:

•   to add the available reference data for water depth.

2.3.1.4.3 measure the under keel clearance

Each ship is equipped with a under keel clearance measurement device.

2.3.1.4.4 calculate the local waterdepth

The local water depth at the current ships location is calculated using the underkeel clearance, the speed through the water and ship characteristics. The water deptn is corrected for squat and trim.

2.3.1.4.5 upload the ship measurements to the server

All ship measurements are collected and send over to the FTP server which is located onshore. All the ship measurements are collected and stored locally if the FTP server is not available. The local ship server should monitor if there is a connection with the on-shore server

2.3.1.4.6 download the ship measurements from the server

All ship measurements are collected on the measurement server which is located on-shore. If there is an online connection between the Economy Planner onboard and the onshore measurement server the most recent data is downloaded.

2.3.1.4.7 download the reference data form the server

This use case describes the hydrological reference system. The reference data is pubic available hydrological data with a low update rate. If there is an online connection between the Economy Planner onboard and the onshore reference data server the most recent data is downloaded. If not the available data set onboard is used.

2.3.1.4.8 download the hydrological forecast data from the server

Hydrological forecast data server. If there is an online connection between the Economy Planner onboard and the onshore forecast server the most recent data is downloaded. If no the most recent data onboard is used.

2.3.1.5 Optimal Track

All Use Cases involved in finding the most optimal track on a given route.

2.3.1.5.1 set the ship and engine model characteristics

This is the relation between the ship, the engine, RPM and fuel consumption. This relation is depending upon the ship and set during the installation of the Economy Planner. The following ship data is required by the installation of the EC planner.
- Main characteristics of the ship
- Main characteristics of the engine(s)
- Fuel consumption of the engines

2.3.1.5.2 determine the optimal track given a start and end location of the route

Based on a start and end location you need to calculate a track. You specify a route from port A to port B, the start and end location of your journey. The route is split up in 1 or more legs. All these legs make up the track of the route. Each legs comes with its own set of properties.
Properties of the leg are direction, distance, flow, gradient, begin and end GPS location, maximum and minimum speed for the leg, water depth, waterway width, velocity on the leg.

"Direction""Distance""
Flow""Gradient""Lat""Lon""VLEGMAX""VLEGMIN""WWAYADEPTH""WWAYWIDTH""VLEG"

2.3.1.5.3 see for each leg of the track the adviced RPM and fuel consumption

As skipper I want to see on each leg of my route the advised RPM setting and the corresponding fuel consumption.

Consider the case that the skipper has set the route from the current location to the destination. On the ENC map this route is displayed. The route is divided into several legs. For each leg the advised RPM and fuel consumption are calculated based on the requested ETA. The skipper can select a leg and see for this leg the required RPM and fuel consumption.

Based on his own judgement, the skipper can iterate using the Economy Planner to calculate the advised RPM and fuel consumption for the route.

2.3.1.5.4 see if the track is sailable or not given the ETA

As skipper I want to know if the route between departure and destination is possible given the ETA and the loading draft. I want to use the expectations for the selected route to see areas with limited water depth. I want to be able to iterate using the ETA, loading draft and expectations to figure out the most optimal ETA and loading draft.

2.4 Actors

A use case defines the interactions between external actors and the Economy Planner to accomplish a goal. Actors must be able to make decisions, but need not be human: "An actor might be a person, a company or organization, a computer program, or a computer system — hardware, software, or both."

Actors are always stakeholders, but many stakeholders are not actors, since they "never interact directly with the system, even though they have the right to care how the system behaves. Similarly, a person using a system may be represented as different actors because he is playing different roles.

2.4.1 Skipper

The Actor skipper is the main user of the Economy Planner. He will use the Economy Planner on a daily basis. He will plan his trips using the Economy Planner.

2.4.2 Engineer

The Actor engineer is the role of a qualified engineer who has indepth knowledge of the Economy Planner. He is capable of installing and configuring the Economy Planner. He is typically the engineer who installs the Economy Planner on board, configures it for use and instructs the skipper on how to use it. He will not use the Economy Planner on a daily basis, but more from a support point of view.

2.4.3 Ship

This is the actual ship the Economy Planner is installed. Parameters of the ship and engine(s) are used to configure the Economy Planner. The ship will be equipped with measurement equipment to support the Economy Planner.

2.4.4 Forecast server

This actor is the server which provides hydrological forecast data. The Economy Planner provides actual measurement data to this server as input. The server calculates the forecast and makes it available for download. The forecast data is used in the Economy Planner to calculate the optimal route and its settings.

2.4.5 Measurement server

This actor is the database server environment which is located onshore and collects all the measurement data from all the ships. The ships are equipped with the Economy Planner and upload their measurements to this server.

2.4.6 RWS server

For validation purposes the data in the RWS database can be used. This data includes the waterlevels and the 'bodemligging' wrt. NAP of the St Andriesbocht.

2.4.7 Trafficcontrol

Traffic control is an external stakeholder for the Economy Planner. Based on data shared from each Economy Planner on a variety of ships, Traffic Control can determine bottlenecks for locks and passages. This information can be used to plan the waterways much more efficient.