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Investigations for Inland Waterway Design in Shiphandling Simulator and Computer-based Assessment of the Results

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ABSTRACT

Some German inland waterways need enlargements to give access for seagoing vessels to inland ports up the river. The waterway authority has therefore raised some projects to use the Maritime Simulation Centre Warnemuende for investigations to estimate the profile and shape of the river contour necessary for the special ships.
Two types of ships (a 110 m coaster and a 185 m inland cargo vessel) were modelled as own ships for the Shiphandling Simulator.
The ECDIS data sets were digitised according to the new design of the waterway and the Data files for the radar presentation and the visual systems were prepared. Specials emphasis was laid to some regions with narrow bends where the encounters of the ship were seen complicated.
The tests of the ship models and the river models and the trails for the real investigations were made by experienced ship operators, both for inland and seagoing vessels.

The assessment of the trail data were made by a specific computer program to screen through the results. From recorded data the ships dimension and contour were set into relation to the fairway dimensions and the radius of the ships track was calculated.
These parameters achieved by using a sophisticated simulator environment were used as background for investigations in order to verify more simplified design methods to be applied for further design projects of other waterways.
Additional emphasis was put on recommendations for the layout of aids to navigation within the waterway and the navigation equipment on board of the vessels in order to allow for a safe and efficient passage of the complicated waterway sections.

INVESTIGATIONS FOR INLAND WATERWAY DESIGN IN SHIPHANDLING SIMULATOR AND COMPUTER-BASED ASSESSMENT OF THE RESULTS

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Abstract: Some German inland waterways need to be expanded in order to give better access for seagoing vessels to inland ports up the rivers. The waterway authorities have therefore introduced some projects whereby the Maritime Simulation Centre Warnemunde is to examine the profile and shape of the river contour necessary for the special ships. Two types of ships (a 110 m coaster and a 185 m inland cargo vessel) were modelled as appropriate ships for the Ship handling Simulator. The ECDIS data sets were digitalized according to the new design of the waterway and the Data files for the radar presentation and the visual systems were prepared. Special emphasis was paid to some regions with narrow bends where the encounters of the ship were seen to be complicated. The tests of the ship models and the river models and the tracks for the actual investigations were made by experienced ship operators, both for inland and seagoing vessels.

The assessment of the recorded data was carried out by a specific computer program which screened through the results. From recorded data the ships' dimension and contour were brought into relation with the fairway dimensions and the radius of the ships track was calculated.

These parameters were achieved by using a sophisticated simulator environment and used as background for investigations in order to verify more simplified design methods to be applied for further design projects of other waterways.

Additional emphasis was put on recommendations for the layout of aids to navigation within the waterway and the navigation equipment on board the vessels in order to allow for a safe and efficient passage through the complicated waterway sections.

1. Introduction

The use of simulators plays a very important role in investigating the layout of inland waterways for the design process when adapting these transport lanes to accommodate new demands. The ship handling simulator is one of the core elements of the Wismar Universities Maritime Simulation Centre which was originally intended for training and research purposes for seagoing vessels. Now it has been expanded to develop various simulation models of inland vessels and waterways and to investigate specific scenarios in order to guarantee a risk free and economic layout of the waterway and safe operation of the ships.

For assessment of the trail data a specific computer program was created to screen through the simulation results. From recorded data the ships dimension, contour and track radius were set in relation to the fairway dimension. These parameters were achieved by using a sophisticated simulator environment and used as a basis for later considerations in conjunction with the final fairway design.

The Maritime Simulation Centre Warnemunde at Wismar University, Department of Maritime Studies in Rostock-Warnemunde accommodates six simulators embracing a common network and comprising four ship-handling bridge systems with differing levels of equipment, a ship's engine system and a VTS facility (see Fig. 1).

The ship handling simulator of the MSCW consists of 4 ships bridges characterized by different levels of navigational equipment and various facilities for enhanced visual simulation.

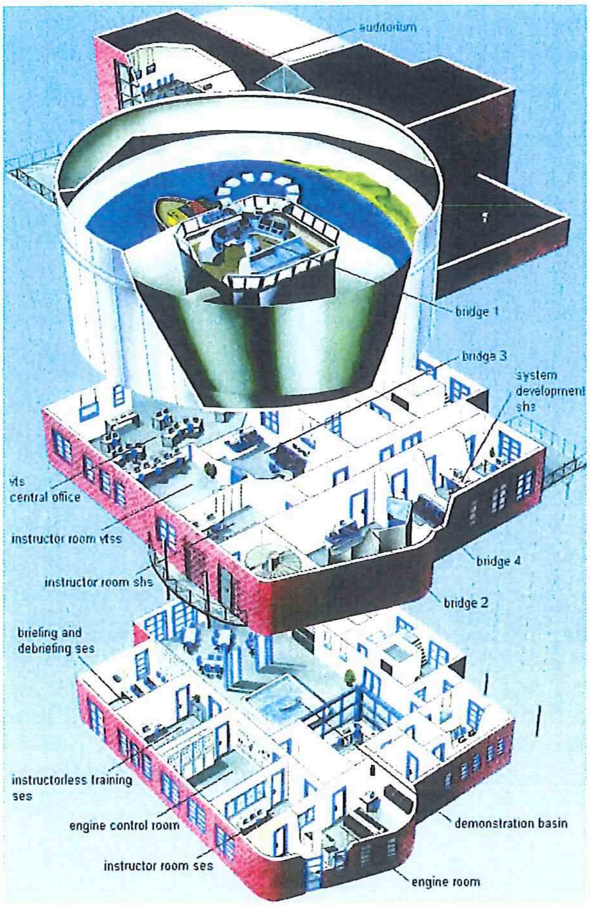

Fig. 1: Maritime Simulation Centre Warnemunde - Overview -

Located on the first and second floors of the Centre, all four ship bridge systems are able to simulate steering and manoeuvring characteristics of differing types and sizes of vessels.

- The largest of the four, Bridge 1 is capable of simulating a full range of ship handling operations; essentially it consists of a fully integrated replica bridge assembly.
- Bridge 2 has a similar projector-based 257° visual display system which can be specifically used for manoeuvring a ship from bridge wing during going-along-side or tow-boat operations.
- The remaining two units Bridge 3 and 4 are used mainly as radar cabins, each being additionally equipped with 120° visual display screens.

All bridges and instructor stations are connected through GMDSS communication facilities. An additional feature of the system is a facility for computer-based instructor-less training, for which there are four separate exercise stations, equipped with handles for rudder and engine telegraph. These provide trainees with pre-programmed ship handling scenarios and with a secondary screen posing multiple-choice questions for assessment by a special scoring method.

Additionally, Bridge 1, is capable of simulating an entire range of ship operations via networking the SHS with the companion ship engine simulator SES and is therefore equipped with an engine monitoring and control system.

More detailed information on the MSCW and the different simulation bridges may be gained on the homepage in the World Wide Web at http://www.sf.hs-wismar.de/mscw/.

2. Preparation for Simulation experiments

2.1. *Modelling of inland vessels*

At the MSCW all facilities and tools are available to prepare simulator ship models as well as sea areas and waterways, also for inland navigation. In this chapter the main steps necessary to prepare for the simulation of ships and navigation areas will be briefly explained.

For the simulation studies in the field of inland navigation the following ship types were realized summarized in table 1.

Table 1: Data of inland navigation vessels

	Inland Cargo ship	Cargo-ship with barge system	Coaster (ballast con-dition)	Coaster (loaded)
Length	105	185	110	110
Breadth	11	11	12,5	12,5
Draught forward	2,8	2,8	1,2	3,2
Draught aft	2,8	2,8	2	3,2

The necessary manoeuvring data and documentation are collected in order to model the specific ship, and for each loading condition an extra simulation model must be prepared.

The first step is to collect the data provided by the customers including the main dimensions of the ship and information on engine, propulsion and steering parameters. Furthermore photo images (for visual simulation), ship data sheets, sketches and ships planes are taken into consideration.

The development and modelling of a simulation vessel is subdivided into two steps:

- The modelling of the dynamic behaviour with respect to the hydrodynamic interactions and effects by external influences and
- The development of the visual ship model for ship handling simulation.

For real life simulations it is imperative to use a simulation model which can be adapted to the specific prevailing conditions which must be taken into account. For this purpose a detailed mathematical model is required describing the dynamics of the ship by coefficients and parameters in order to adapt the simulator ship characteristics to the real ships' behaviour. Due to the complexity of the objects and the interaction that should be taken into account, high demands are made on the accuracy of the modelling process.

The software tools available at the simulator are based on the modelling of ships motion by means of differential equations, considering up to six degrees of freedom of ship motions. Additional equations describe the engine dynamics and external effects.

The special problem of the hydrodynamic modelling process is that very little data can be provided. Therefore a simplified method was used for the estimation of force and moment coefficients by means of "Clarke Estimation" in the first step.

During the second step the preliminary motion parameters were tested and adapted to the real behaviour with the assistance of well experienced captains and navigators. After the fine tuning process the manoeuvring parameters of the developed simulator ships were found to be sufficiently close to real ships of the same dimensions.

The modelling of the visuals for the ships was implemented using ships` plans and photos . The software tool "MultiGen" was used for that purpose. In the beginning the ships were drafted as "Wire frame models" and the modelled object areas were overlaid by textures images at a later stage. The three dimensional models consist of several triangle areas, which give a life-like quality together with the overlaid images.

One example for the sight model of a pusher tug-barge system which was implemented during the simulation studies for inland navigation is shown in Figure Fig. 2.

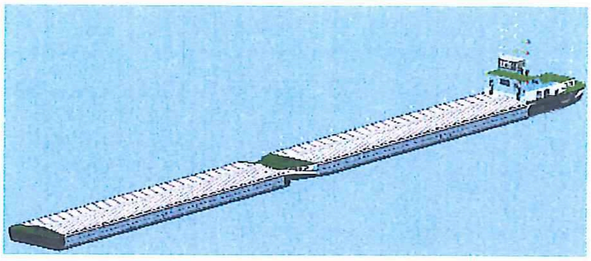

Fig. 2: Simulator Ship: barge system "pusher tug-barge system" – perspective view

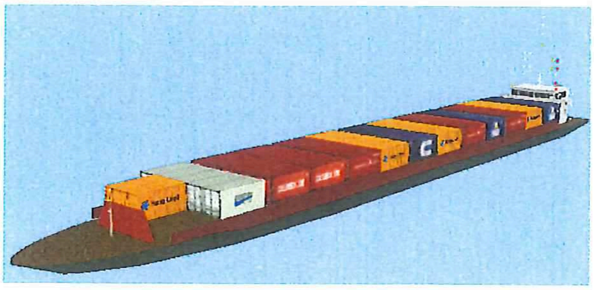

Fig. 3: Simulator ship: Coaster , loaded with containers – perspective view

2.2. *Modelling of Waterway for visual presentation and digital charts*

For the simulation of the vessel traffic in the designed shipping lane of the inland waterway segment Hohensaaten – Friedrichsthal of the river Oder a section of approximately three kilometres in length with a defined geometry and concrete dimensions was processed. The water depth was 4,5 m provided with a slope with a 1:3 ratio. Only a few buoys marking the fairway borders were planned as aids to navigation they were also integrated into the simulation environment. (Ongoing investigations e.g. concerning the potential influence of different configurations of aids to navigation could be realized with fewer efforts for modelling).

The work necessary to develop a simulation area can be subdivided into the following steps:

- digitalizing the charts provided
- development of the visual simulation (environmental objects)
- preparation of radar simulation and
- extension of the simulation system's database.

As a basis for the preparation of digital charts for the simulator, several maps and plans for waterways as well as other paper sources, Gauss - Krueger – Coordinates were used. For the development of the simulation area the data should be transferred, referenced and digitalized into geographic coordinates with the reference ellipsoid based on the world geodetic system (WGS84).

The end result of the digitalizing process is the Electronic Navigational Chart (ENC), which forms the basis for all other following work-steps necessary to prepare the simulation environment and the traffic simulations as well.

Besides the general modelling of the area special emphasis and great care must be paid to the modelling of the fairways in the ENC. All calculations during a simulation run as e.g. determining squat- and banking effects or the remaining water depth under keel, are based on these fundamental data.

For the purpose of displaying the navigation environment during simulation, the digitalized objects will be generalized and filtered. Objects on the water surface will be converted into 3D-data, to allow for the further processing of the data using the MultiGen-tools. Conversion of extracted surface objects is also necessary for simulation of the radar image, respectively the radar data processing. Examples of these final results are these objects which are visualized as part of the ENC, targets in the radar image and of course also as objects in the visual simulation (see also following figures).

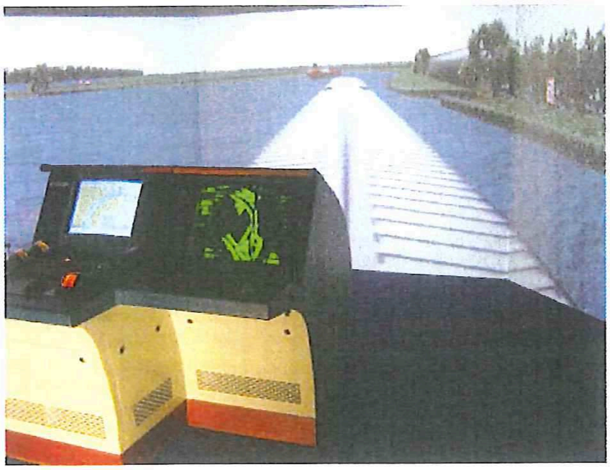

Fig. 4: View from Simulator Bridge 2 during a trail of the Pusher tug-barge system with control console containing ENC and radar image during an encounter situation with coaster

Fig. 5: View from Simulator Bridge 1 (loaded coaster) during an encounter situation with another pusher tug-barge system

3. Computer-based analysis of simulation runs

3.1. Analysis of manoeuvres in the simulation run

For analysis of the simulation runs and to aid the assessment and evaluation of fairway layouts, the images of ship tracks along the entire area are of special interest. The identification of shortcomings and recommendations regarding the final fairways design is only possible if the ship's positions are available at a specific time taking into consideration both the relevant manoeuvring parameters. By analyzing the data gained during all the different inland navigation projects it became clear, that this information is one of the special advantages of simulation based investigations.

The method of using time-related considerations of position- and motion data (as e.g. time history of speed, rudder, rate of turn as well as required navigable space and curve radius) as offered by a specific assessment software as an additional service is more sophisticated than the pure graphic presentation of ship's contours and other plots.

By means of recorded manoeuvring data of all the simulation trials it is possible to generate further detailed and proved statements and determine specific recommendations concerning special subjects of investigation.

As important basis for the graphic analysis of simulation runs the swept paths (tracks) of the ship's position and contours in continuous defined time steps during a fairway passage will be implemented.

The following figures contain two examples of analysed simulation runs of a coaster in loaded conditions. In Fig. 6 the swept path is shown as the continuous presentation of the ship shapes according to the pre-defined measurement times.

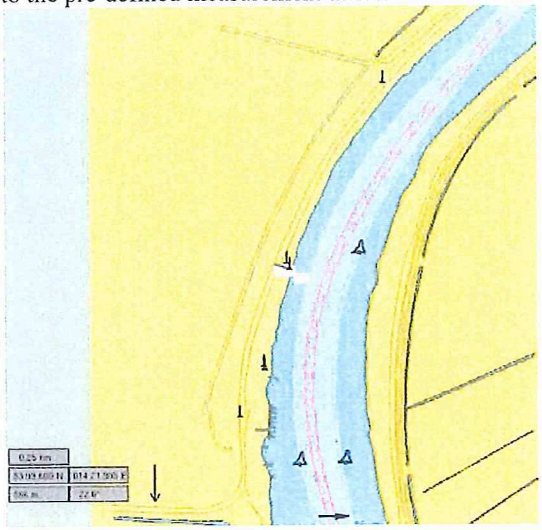

Fig. 6: Example of a swept path of the ships contour during simulation run

Fig. 7 gives an example of a detailed presentation of a manoeuvre entering a lock. For the purpose of more detailed analysis a special software SIMDAT was developed at the MSCW. It allows for lot of options and for quick and flexible reactions with regard to the specific subjects up for investigation.

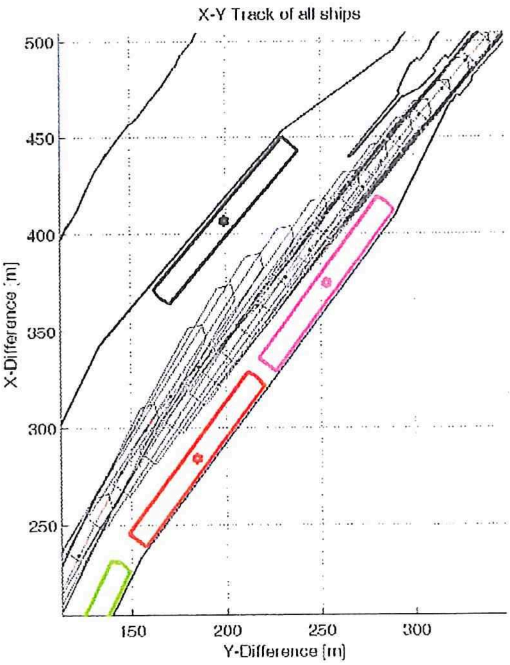

Fig. 7: Detailed analysis of a specific manoeuvring period passing berthed vessels during entering a lock

For the post-process analysis of the recorded raw simulation data the freely configurable software tool SIMDAT is to be adjusted accordingly. Among other things, it is not only possible to generate X-Y-Track diagrams but also a wide range of further graphs. Following basic analysis it is possible to generate more in depth time dependent graphs of e.g. fairway curve radiuses or extracts of the X-Y-Tracks for freely selectable sections of fairway bends. Such extracts are specifically used to determine the required navigable space at the fairway bend segments.

Further examples of the additionally generated detailed analysis of simulation runs are shown in the following figures and include plots of speed and rudder angle for a certain time span.

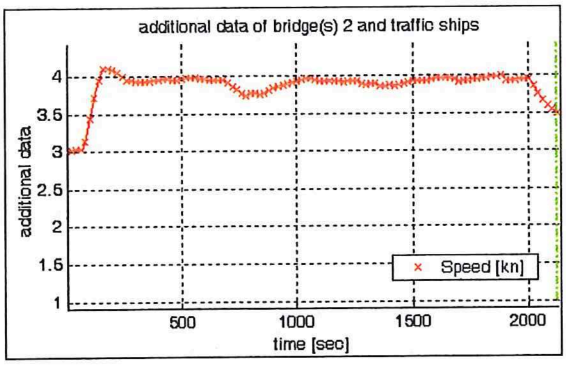

Fig. 8: Course of speed recorded during simulation run

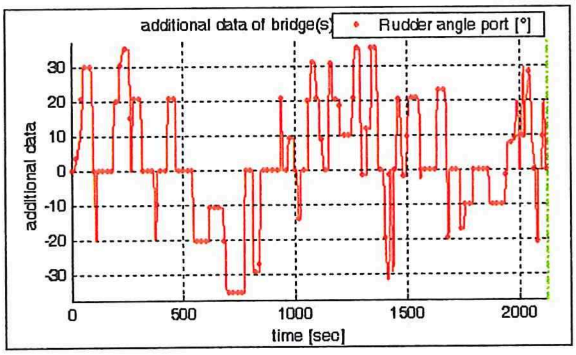

Fig. 9: Course of rudder angle recorded during simulation run

The plots of speed, rudder angle, rate of turn and other specific motion including steering parameter for the complete simulation period allows for detailed discussion of manoeuvring regimes and procedures at critical fairway sections.

3.2. Detailed analysis of motion and method for planning of other fairways

Specifically for the BAW some extra assessment and analysis were made in order to verify methods for fairway planning.

As a result of the simulation tests, the curve radii currently used by the vessels and the respective yaw angles (drift angles) were calculated from the lane courses. In Fig. 9 a coaster is shown in a certain fairway segment presented in fig. 10, where the full fairway section can be viewed and in addition the radius lines are presented.

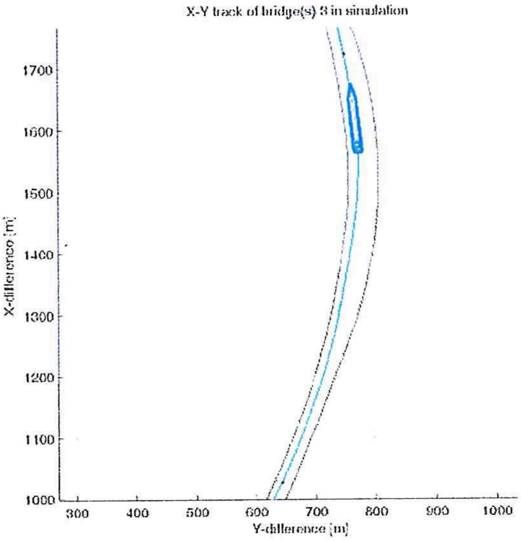

Fig. 10: Track of the coaster in one selected bend (red rectangle in Fig. 11) of the full fairway segment

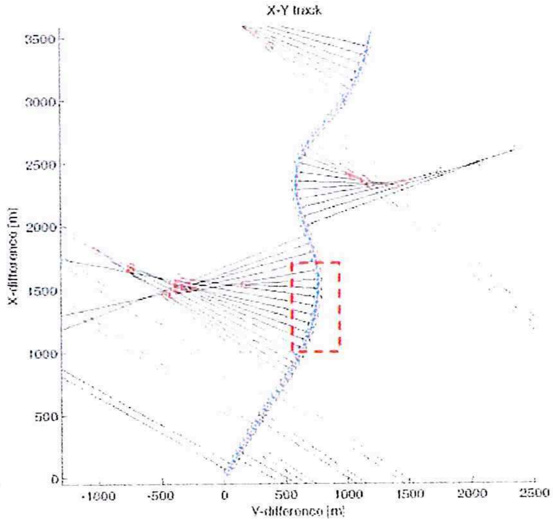

Fig. 11: Presentation of the full fairway segment with current radius lines at the related positions

The radius lines will be used for the respective measurement of radii distances which are shown in Fig. 11, completed by the drift angle effects to be seen in Fig. 12.

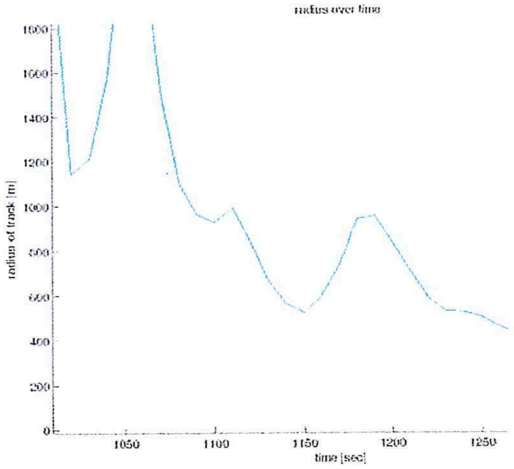

Fig. 12: Current radius of ships track at the related positions versus time

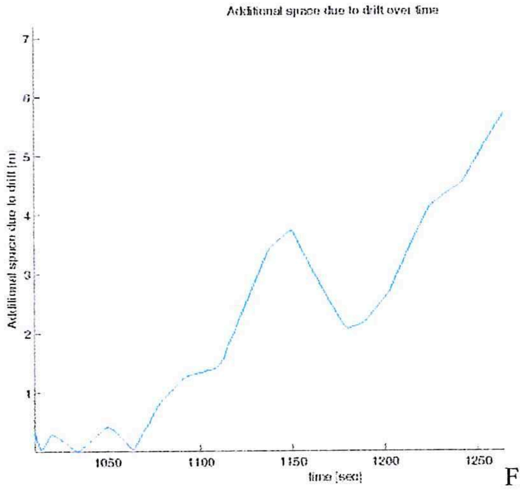

Fig. 13: Additional manoeuvring space needed by the ship due to drift angel versus time

These results were used to further verify and validate specific alignment procedures used by the German Federal Waterways Engineering and Research Institute BAW.

With these parameters the positions of the pivot point (the point at the vessel where the drift angle is zero) are calculated for the individual motion situations and the laws concerning the movement of the pivot points comprised within the alignment procedures are proven related to the ships motion.

If the position of the pivot point is known, minimum turning curves can be generated using the position of pivot point as fulcrum. They can be varied without large expenditure within the context of river development planning and fairway design procedures.

In order to do so, course axes are designed as a first step within a CAD environment along which the vessel should move. Using the position of the pivot point as fulcrum, ship contours can be generated solely by geometrical means along these course axes which add up into a minimum turning curve corresponding to a used lane with the required precision.

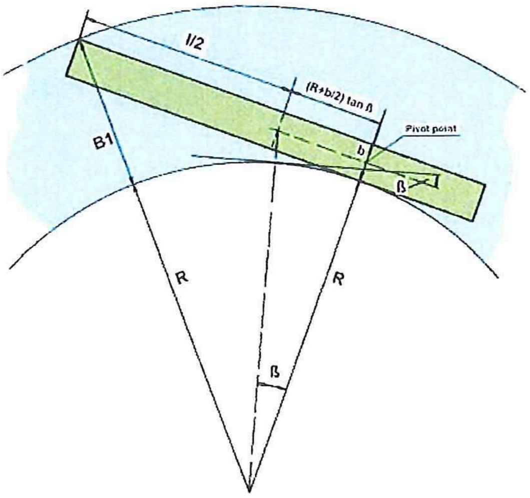

Fig. 14: Principle of geometrical relations using radius R and drift angle for fairway design

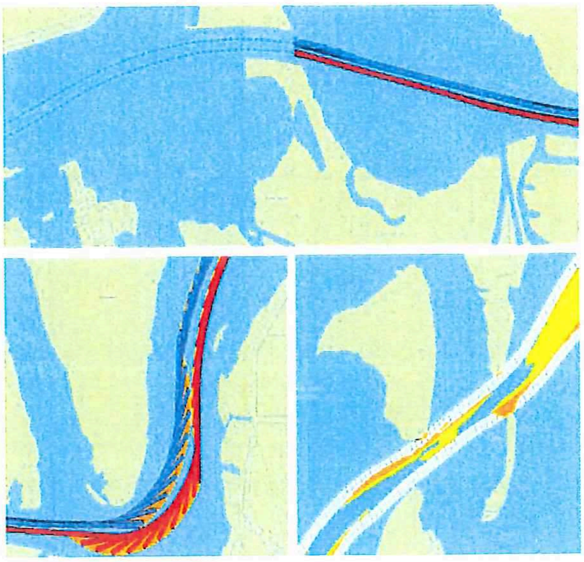

Fig. 15: Examples for simplified fairway design using geometrical relations for River Havel

4. Conclusions

The Maritime Simulation Centre Warnemunde which was originally planned for use in the field of deep-seagoing ship transport can also be used for inland navigation research by enlarging on existing simulation models. Precisely for this reason corresponding visual- and ship motion models were developed for inland navigation vessels and fairways.

The significant advantage of simulation based investigations in the field of inland waterway traffic becomes especially apparent when one considers the practicality of numerous repetition of test runs and the possibility of varying the simulation parameters as well as the designed layout of waterways. For different projects, dealing with the expansion of inland waterways, fundamental data were provided by simulations performed at this simulation centre.

At the same time some extra assessments and analyses were made in order to verify simplified geometric methods for fairway planning based on the knowledge of position of the pivot point during the passage.

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Author's Biography

Knud Benedict achieved his PhD's in Ship Dynamics and on Advisory Systems for Ship Operation. He is Professor/Senior Lecturer for Ship's theory and Vessel Traffic Technology and the Head of MSCW.

Michael Baldauf obtained his Ph.D. in Safety Engineering and is presently employed as chief coordinator for research. He is presently involved in several RD-projects dealing e.g. with Collision Avoidance and AIS.

Sven Herberg took his diploma in the field of Nautical Engineering. He is engaged on research projects dealing with problems of simulator modeling for ships and waterways including ECDIS and visualization.

Christoph Felsenstein worked as Captain and received his Ph.D. in Nautical Engineering. He is engaged on two research projects dealing with problems of maritime training and education.

Matthias Kirchhoff achieved his diploma in the field of automation and control engineering. He is working on the development of the computer-based evaluation tool.

Thorsten Dettmann took his diploma in the field of Naval Architecture. He is working on dynamic of inland navigation vessels and waterway design methods.

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