

The Use of a Full Mission Bridge Simulator Ensuring Navigational Safety during the Klaipeda Seaport Development

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ABSTRACT: Full Mission Bridge simulating became a valuable tool to assess the conditions for safe navigation during seaport development. The article presents an overview of the works carried out at the Lithuanian Maritime Academy. The specialists of the Academy together with the pilots of Klaipeda State Seaport performed a number of trainings and tests using Full Mission Bridge simulator, related to navigational safety assessment. Overlooked works concern a wide range of directions: development of the harbour navigation channel, introduction of two-way traffic of ships, ships sailing with tugboats, coordination with vessel traffic service, emergency response of the LNG vessel in case of various scenarios, extremely big ships accessibility studies, the boundary weather conditions assessment and so on.

1 INTRODUCTION

During couple of past decades, application of maritime simulators became an ordinary part of maritime education and training. Simulators are using for bridge and engine room students studies, for seafarers' knowledge and skills upgrading, for assessment of competence.

The key features to a ship simulator are real operational controls and a system that allows the instructors operating the simulator to put the simulator students into realistic situations (Use..., 2015). One can develop situations on-board simulators, which are much more complex and grave when compared with real operations and are difficult to create (Malik & Zafar, 2015).

Recent tendency in training simulators development occurs in integration of ship simulators to the "whole ship" control simulating system, following a major trend in ship control - to interface all vital ship's systems on board to one integrated

system. As well as development of interactive training simulators, when several crew members of one ship or operators of different objects (ship-ship, or ship-shore) can practice in operating of equipment and performing procedures together, improving their teamwork and leadership skills (Sencila & Valioniene, 2016).

Full Mission Bridge simulators (FMBS) as well became a valuable tool for special training with new crafts, new ship equipment or a new navigation area, for providing of applied scientific research or case studies, related to safety of navigation.

Methods for safety evidence producing, arranged in realism and specificity growing, distribute in the following order: analysis of documented earlier experience; analytical methods; numerical methods; experimental methods, covering model testing, simulator testing and field-testing (*Safety...*, 2017).

Simulation models allow to analyse the possible modernisation variants taking into account the

variability of elementary parameters (Gucma et al., 2017; Paulauskas, 2013).

Main criterion of navigational safety analysis usually is a meeting the goal of inclusion of manoeuvring area within the safe area, what is based on the idea of ships' movement path analysis (Tomczak & Zalewski, 2007).

The navigational safety can also be expressed in terms of the probability of accident because manoeuvring area dimensions always meet the safe area dimensions at some confidence level equal one minus value of the probability of accident. The logging possibility of ships movement parameters during ship's simulation trails gave an opportunity to collect the set of data, required for statistical analysis and probabilistic safety assessments (Tomczak & Zalewski, 2007; Paulauskas & Paulauskas, 2013).

The bottlenecks of ships accessibility in most ports are the narrow port entrances and small turning basins. Full mission simulation creates the environment of real navigational and working conditions including collaboration between ship master, pilot, tug master and vessel traffic services and is the best tool for the operational safety and reliability studies of ship manoeuvring in restricted waters. (Abramowicz-Gerigk & Burciu, 2016).

Vessels are becoming larger. To extend the pier and to determine the appropriate channel depth, deterministic (PIANC approach determining minimum channel width) and semiprobabilistic methods for designing a channel. Each simulation trial was processed statistically in order to obtain the probability density function of ships' maximum distances from the centre of the waterway and the accident probability calculation in the given conditions were applied Perkovic study (Perkovic et al., 2013).

The article presents an overview of the works related to navigational safety training and tests using FMB simulator carried out at the Lithuanian Maritime Academy (LMA). Overlooked works concern a wide range of directions: development of the harbour navigation channel, introduction of two-way traffic of ships, ships sailing with tugboats, coordination with vessel traffic service, emergency response of the LNG vessel in case of various scenarios, extremely big ships accessibility studies, the boundary weather conditions assessment and so on.

2 NAVIGATIONAL FEATURES OF THE KLAIPEDA SEAPORT

Klaipeda seaport is the most northern ice-free port of the eastern Baltic Sea. A multimodal, universal, deep-water seaport can accommodate vessels of up to 400 m in length and 60 m in width. The port accepts up to 8300 vessels annually, cargo-handling turnover reaches up to 46 m t per year, and annual cargo handling capacity is up to 65 m t.

Klaipeda port does not have any natural shelter from the seaside except breakwaters due to its geographical position. As westerly winds and transverse coastal current prevail in the port of

Klaipeda, the navigation conditions for vessels entering the port are quite complicated. The most complex places in terms of navigation are the approach canal, port gates, internal navigation canal between Buoys No. 5 and 9 as well as *Maluku Bay*.

The approach canal starts 0.7 nautical miles from the port gates at the buoy No.2 and continues up to the port gates, it is 150 metres wide and 15.5 metres deep. Vessels are affected by the wind, swell and transverse current the direction of which depends on the wind. It is an especially dangerous place for the outbound vessels, as a vessel performing the turn of 23° at the port gates encounters two additional external forces: swell and transverse current.

The port gates are the most hazardous place in terms of navigation. Here the proceeding vessels have the highest drift, as the navigation canal turns at 23°, the current attains 1.5 times greater rate due to the decreased cross section of the canal and despite the fact that the distance between the heads of the port gate is 235 metres, the canal itself stays only 150 metres wide.



Figure 1. Klaipeda seaport entrance

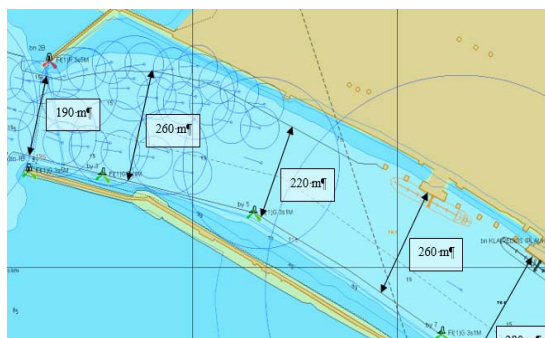


Figure 2. Klaipeda sea port channel from Buoy No. 5 to No. 7

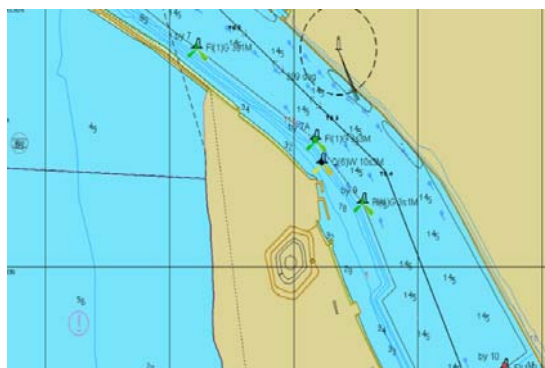


Figure 3. Klaipeda sea port channel from Buoy No.7 to No. 9

The internal canal from Buoy No. 5 to Buoy No. 9 extends 1 nautical mile and is 250 metres wide and 15 metres deep. The greatest danger for ships is the lateral wind, limited speed, 25° turn at the Buoy No. 9 and the impact of the proceeding vessels on the tankers berthed at the quays.

The navigation in the *Maliku Bay* is a challenge for safety due to the narrow 90 metre wide and a very compact internal basin where safe manoeuvring of vessels is very complicated.

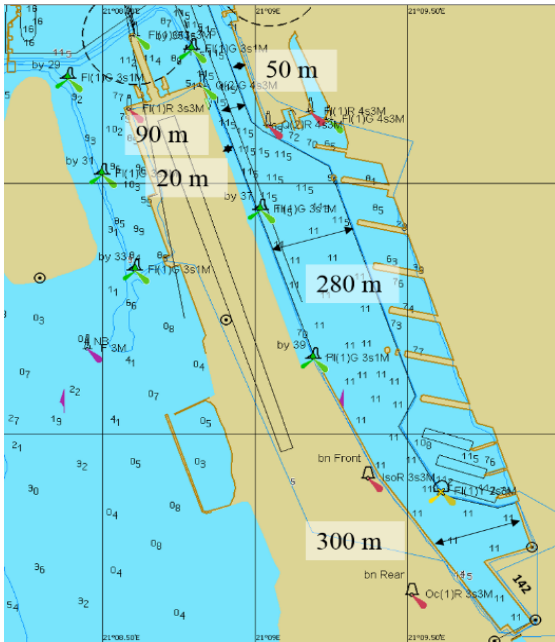


Figure 4. Klaipeda sea port *Maliku Bay*

Since 2012, in order to accommodate the vessels with maximum parameters in the port and to stay competitive in the cargo handling area in the Eastern Baltic Sea region, the Klaipeda seaport authority has implemented the projects of the navigation canal development. During development, the port was deepened to 15.5 m, and the navigation canal was widened to 150 m in the narrowest places. The Authority actively cooperated with LMA, using Full Mission Bridge simulators for the purpose of the assurance of the safety and security of the port as well as for training the personnel in the fields of pilotage and vessel traffic organization.

3 APPARATUS AND METHODOLOGY

3.1 *The navigation simulator description*

Real time simulation tests have been carried out on the six bridges Full Mission Bridge Simulator Transas NTPro 5000, installed at the LMA.

Two Instructor workplaces were equipped each with control and monitoring station, briefing/debriefing station, selective radar station, selective visualisation station and camera control station.

Two bridges No. 1 and No. 6 were equipped each with full mission bridge conning station, ARPA/Radar, ECDIS, GMDSS stations, navigation aids (GPS, log, echo sounder, UAIS) and full set of

real ship controls. The bridge No. 1 was equipped with 150° horizon 5-channel monitor visualization, bridge No. 6 – with 200° horizon 5-channel screen visualization. Four bridges (from No. 2 to No. 5) were equipped with 3-channels 120° horizon visualization.



Figure 5. Navigation simulator lay out: (1) bridge No. 1, (2-5) bridges No. 2 to No. 5, (6) bridge No. 6, (7) instructor workplace, (8) instructor workplace and debriefing room.



Figure 6. Bridge No. 6 with 200° horizon visualization



Figure 7. Bridge No. 1 with 150° horizon visualization



Figure 8. Bridges from No. 2 to No. 5 with 3-channels 120° horizon visualisation

3.2 Methods for producing navigational safety evidence

Experimental methods, to whom the ship handling simulation belongs, are evaluating as most realistic.

As was mentioned by Tomczak & Zalewski (2007), main criterion of navigational safety analysis in general is a meeting the goal of inclusion of manoeuvring area within the safe area, what is based on the idea of ships' movement path analysis.

During conducting of navigational safety assessment tests at the LMA, sailing area design, application of various meteorological conditions and maps of the water flow structure, testing of various ship models, planning of different tests scenarios, setting of boundary meteorological and vessel parameters, carrying out large-scale testing performed by highly qualified specialists and expert assessments of their performance were used.

During the tests, usually the following expert assessment methodology was used. The pilots conducted only real-time simulation. Three or four pilots on different bridges conducted planned number of trails of the same exercise from preliminary prepared scenario. After every scenario exercise conduction by pilots, common discussion, aimed to evaluate maneuvers was hold, assessing the feasibility and the risky of the exercise, focusing passing distance to the most critical points. After the all scenario exercises was carried out, final discussion was hold, aimed to formulate common navigational

safety recommendations and restrictions for the whole scenario.

4 NAVIGATIONAL SAFETY RELATED WORKS CARRIED OUT AT THE LMA

Navigational safety related works carried out at the LMA using Full Mission Bridge simulator could be divided into three main directions, sometimes using all three during one job realization:

- Development and evaluation of the port's passage;
- Improvement of vessel traffic organization;
- Personnel training to improve safety of navigation.

The list of works related Klaipeda seaport navigational safety assessment carried out at the LMA using Full Mission Bridge simulator presented in the Table 1.

5 KLAIPEDA SEAPORT EXERCISE AREA CREATION AND DEVELOPMENT

LMA and Transas specialists created the Klaipeda seaport exercise area with 3D visualization in the end of 2012. Created area size was 36.2 x 54.0 nautical miles within the rectangle with the following coordinates: NE corner 56°08,00N 21°31,00E and SW corner 55°14,00N 20°26,00E.

Table 1. Works related to navigational safety carried out at the LMA using Full Mission Bridge simulator

Year	Work topic
2012	The Klaipeda seaport electronic exercise area with 3D visualisation creation.
2012	The pilot training on the introduction of two-way vessel traffic in the port of Klaipeda and the evaluation of hydro-meteorological conditions ensuring safe two-way traffic after the completion of channel deepening and widening project.
2012	Trials of navigation conditions evaluation for entering/leaving a Panamax size bulker (L=225 m, B=32 m) in ballasted condition and laden to maximum allowable draft at Klaipeda container terminal quay..
2013	Trials of navigation conditions evaluation for entering/leaving a Panamax size bulker (L=225 m, B=32 m) in ballasted condition and laden to maximum allowable draft at the quay of the stevedoring company Malku ilankos terminalas located in the Malku Bay.
2013	Training for Butinge oil terminal Cargo masters of Aframax and Suecmax type tankers mooring to Butinge's SMP (single mooring point) buoy.
2013	The seaport pilots and VTS operators training on LNG vessels pilotage in the port under different hydro-meteorological conditions, the organization of vessel traffic during vessels pilotage, the order and possibilities of tug use, the management and evaluation of extreme situations during pilotage (attended by 24 pilots and 8 VTS operators).
2014	Navigational trials and evaluation of Klaipeda seaport approach channel turning and widening.
2014	Trials of ship mooring at stevedoring company Bega quay, the evaluation and estimation of maximum vessel parameters, the basin required for safe mooring and safe hydro-meteorological conditions. The evaluation of mooring possibilities for Panamax size vessels.
2015	Trials of navigational vessels pilotage in order to evaluate navigational and hydro-meteorological conditions, changing channel parameters, creating new port entrance elements by three alternatives of development project of Klaipeda seaport.
2014 – 2018	Joint training of FSRU "Independence" crews together with Klaipeda seaport pilots using the navigational model of the Independence terminal in order to ensure navigational safety and emergency response of the LNG vessel in case of various scenarios. At all 18 Masters and Chief Officers of Hoegh LNG AS (Norway) trained.
2014 – 2018	Joint training of LNG supply vessels crews together with Klaipeda seaport pilots using navigational models of vessels in order to ensure navigational safety and emergency response of the LNG vessel in case of various scenarios. At all 18 Masters and Chief Officers of 9 crews from such companies as C/O DYNAGAS LTD, Greece; GasLog LNG LTD, Monaco; K LTD, UK were trained.
2018	Navigational trials of entering an extremely big 400 meters long and nearly 60 meters wide container ship MSC Ingy to Klaipeda seaport.



Figure 9. The whole Klaipeda exercise area



Figure 10. Klaipeda exercise area high detailed zone

Klaipeda seaport shipping area was developed using the Wizard application, which serves for the generation of spatial, 3D models of a geographical area (scene), based on electronic chart data, satellite data on the earth terrain, and provide real-time operation of the simulator visualisation system. It should be noted that chart accuracy is 0.2 – 0.5 mm on its original scale. For example, for a 1:5000 chart it is 1 – 2.5 m, while for 1:50000 charts it is 10 to 25 m, respectively. Therefore, the ship navigation training can be carried out in conditions closely approximating the real ones.

Depending on the needs of the seaport, the following major changes of the exercise area for further navigation tests were used:

- Changing the depth, water area parameters and installing moving dock at Bega terminal pier;
- Changing the depth at Klaipeda container terminal pier and Malku Bay terminal;

- Creating FSRU Independence terminal piers;
- Changing the direction, depth and width of navigation channel;
- Changing channel parameters, creating new port entrance elements by three alternatives for the development project of Klaipeda seaport.

The directions and rates of water currents, depending on the water outflowing to the sea or inflowing to the lagoon debits, entered into the simulation conditions, were prepared by Lithuanian Energy Institute.

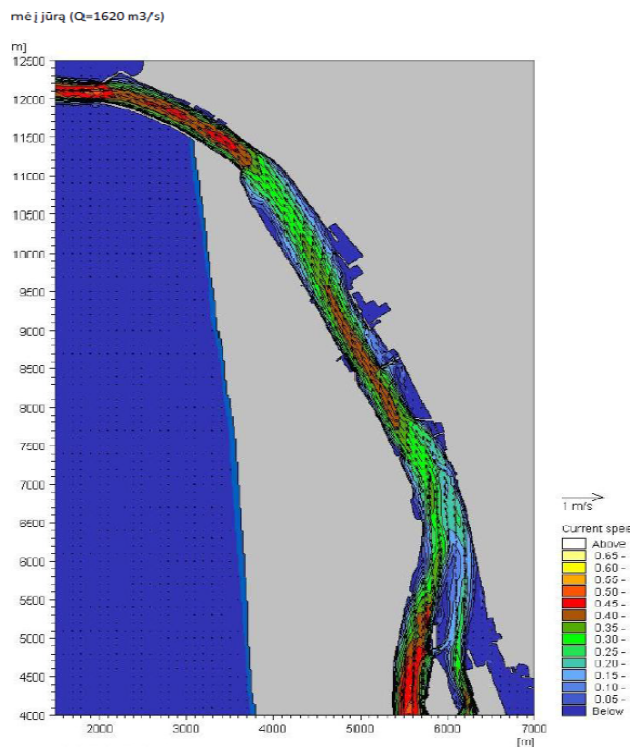


Figure 11. Structure of the flow with 1620 m³/s debit from the lagoon to the sea

6 SHORT PRESENTATION OF PORT DEVELOPMENT WORKS

6.1 Navigation conditions evaluation for Panamax size bulker entering/leaving the Malku Bay

One of the challenges to Klaipeda Seaport was entering of Panamax size ships to the southern, most distant part of the port. Trials and assessment of alternatives with the following objectives were carried out in 2013:

- To evaluate the possibility to enter 230 m long and 32 m wide Panamax size bulk carrier in ballast and laden to maximum draught with a possibility to around in the internal basin;
- To ascertain marginal hydro-meteorological conditions;
- To determine the possibilities of tug use, the amount of tugs necessary for safe berthing of the ship.

Models DISP 44081 t and 64062 t of bulk carriers were used for trials. 30 scenarios for different hydro-meteorological conditions were modelled on the basis of bathymetric data and environmental conditions,

provided by hydrographic department of Klaipeda State Seaport Authority and with regard to the navigational conditions of the sea area.

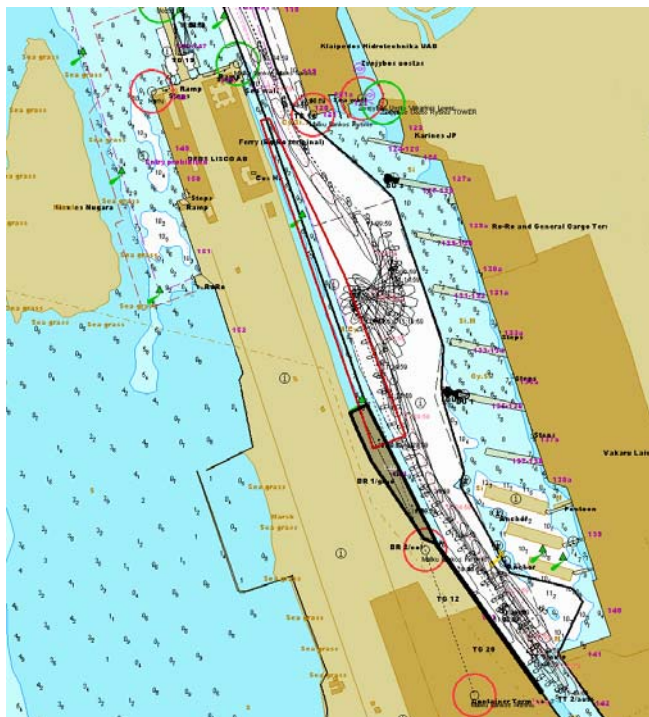


Figure 12. Turning the Panamax DISP 44081 t vessel around in the *Malku Bay*

More than 120 trials were carried out together with the pilots and safe entering conditions were formulated.

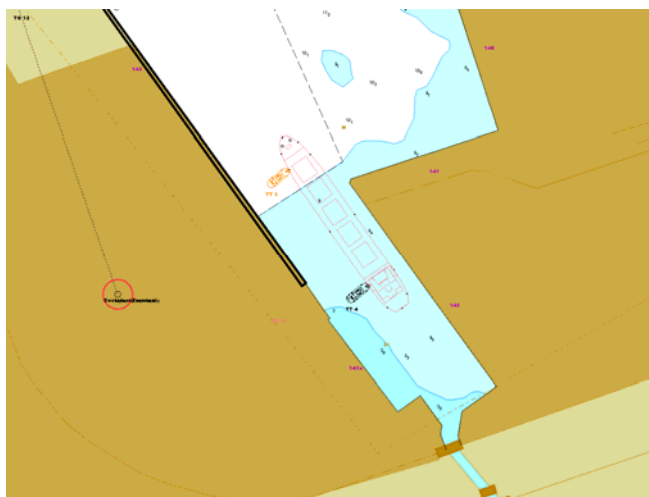


Figure 13. Panamax size vessel towing to *Malku Bay*

From the moment of first navigational testing more than 50 Panamax vessels were entered safely to the *Malku Bay* – the southern, most distant part of the Klaipeda seaport. After the possibility to enter vessels of higher tonnage to the *Malku Bay* became a reality, the terminals located in the *Malku Bay* acquired wider chances of cargo handling and their competitiveness increased.

6.2 *Klaipeda port approach channel widening, deepening and change of its direction*

In 2015 seaport Authority ordered the conducting of navigational trials regarding turning the bend of the approach channel 10.5° to the North, its deepening to 15.5 m and widening to 15 m in the simulator of LMA.

In 2017 seaport Authority ordered navigational pilotage trials of 3 approach channel alternatives to estimate the optimum direction and width of Klaipeda port approach channel in case the navigation channel would be deepened to 17 m. Now the port administration is carrying out the port approach channel reconstruction designing works on the basis of LMA tests report.

The aim of trials:

- To analyse the behaviour of different vessels of up to 400 m long and 60 m wide while entering and leaving the port after the change of the port approach channel direction;
- To evaluate marginal hydro-meteorological conditions;
- To determine the width of manoeuvring lane for vessels with maximum parameters.
- To ascertain a safe manoeuvring speed for tugs and vessels with maximum parameters.

Conducting trials duration was 20 days, in 2015 and 2017:

- 14 vessel models were used bulk carriers DISP 44081 t, 64062 t, 69580 t, 142600 t, 248000 t, container ships DISP 86900 t, 132540 t, 211405 t, a gas carrier DISP 109623 t, oil tankers DISP 81306 t, 82078 t, 122961 t, 189406 t;
- 3 new port approach channels were modelled with the new configurations of the port gate;
- 300 different scenarios of hydro-meteorological conditions were modelled and executed together with pilots.

According to the recommendations of PIANC (2014), the width of one-way channel shall be from 3.6 to 6 times the calculated vessel width. The vessel models used for the trials were 366 metres long and 56 metres wide. While calculating a lane for ship proceeding, a drift of $5 - 10^\circ$ was taken into account that can occur due to transverse currents and wind. Thus, a vessel of 366 metres takes the lane of 120 metres.

The results of the pilot trials showed that the largest drift with the wind of S, SW directions and its speed 12 – 18 m/s was determined for gas carriers, it exceeded 10° and even reached up to 15° . Comparing the result with other ship models used in the trials (bulk carrier DISP 69580 t, container ship DISP 132540 t and 86900, oil tankers 82078 t and 122961 t) ship's drift in critical positions of the channel (gates and channel bends) fluctuated from 3° to 7° , as a result the width of the manoeuvring lane increased to 2B. Therefore even taking into account the unexpectedly worsened hydro-meteorological conditions, human error or technical problem, there is sufficient room left for the manoeuvring in the channel.

After the reconstruction of the approach channel, it would be possible to safely accommodate vessels of up to 400 metres long and 60 – 65 metres wide.

During the trials empirical diagrams were used for the estimation of ship parameters (Drift angle, Yaw angle, Roll angle, Ship bank interaction, Wind effect), as it is shown in Figure 14.

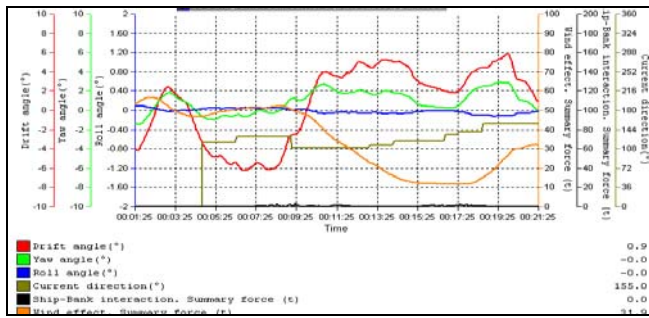


Figure 14. Empirical diagram of DISP 142600 t bulk carrier entrance to the port

The red colour curve shows the change of the vessel drift angle (up to 6°) while a bulk carrier of 142600 t displacement is entering the port of Klaipeda, when the wind is NW 14 m/s and current from the sea of 1 knot.

Exploring approach channel alternatives, a special attention was paid to the vessels moored at company *Klaipėdos nafta* quays No. 1 and No. 2 while vessels enter or leave the port. According to PIANC recommendations, a safe distance between a moored tanker and a passing vessel shall be not less than 60 metres and this condition was adhered to during the trials.

First alternative – the direction of the port approach turned 10.5° to the North. The width of the port approach channel in the outer part of the port constitutes 250 metres, 180 metres at the port gate and approximately 250 metres in the middle of the channel, the depth – 17.5 metres.

Second alternative envisions the construction of a new southern mole with an additional protective mole, situated to the North from the port entrance channel, bending the port entrance channel by 110° – 290°, the width of the designed port entrance channel – 250 metres in the outer part and at the port gate.

Third alternative envisages the construction of the southern mole of different structure with additional moles, situated to the North and to the South of the port entrance channel, thus bending the port entrance channel by 110° – 290°. In this case, the width of the port entrance channel would constitute 250 metres and the basin for the turning around of ships with diameter of 450 metres would be designed.

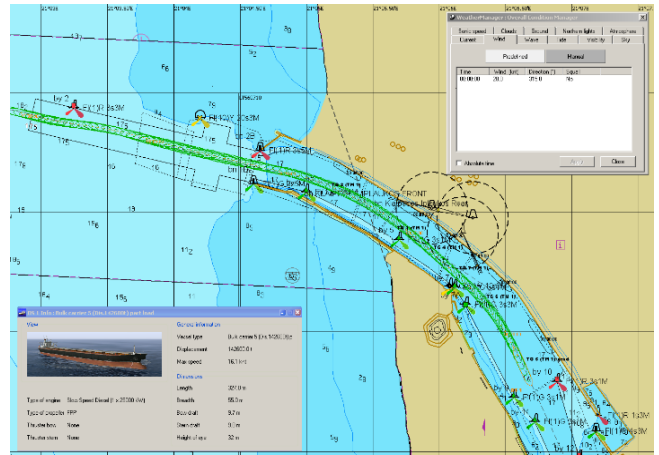


Figure 15. Entrance of DISP 142600 t bulk carrier, first alternative

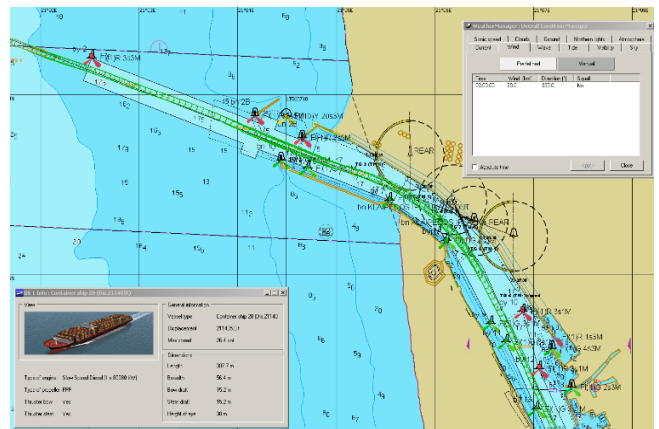


Figure 16. Container ship DISP 211405 t entrance, second alternative

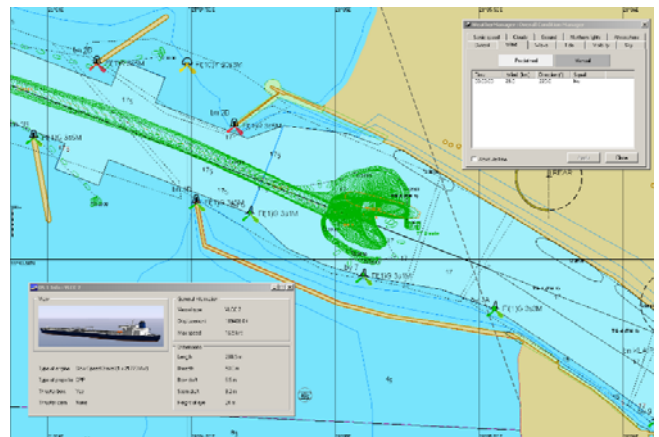


Figure 17. VLCC DISP 189406 t entrance with turning around, using tug assistance, third alternative

Comparing all three seaport approach channel alternatives, the third one was chosen as safest for navigation because:

- An opportunity to connect tugs before the port entrance;
- An opportunity to use the additionally formed manoeuvring area at the port entrance for turning ships of maximum parameters;
- In the case of two-way traffic, the situation at the port entrance and in the port inner canal for ships up to 300 m is significantly better.

7 CONCLUSIONS

Presented in the article Klaipeda seaport navigational safety related works, carried out at the Lithuanian Maritime Academy using the Full Mission Bridge simulator, could be divided into three interconnected directions: development and evaluation of the port's passage; improvement of vessel traffic organization; personnel training to improve safety of navigation.

During the navigational safety assessments, the following methods were effectively used: sailing area design, application of various meteorological conditions and the maps of water flow structure, testing of various ship models, planning of different test scenarios, setting of boundary meteorological and vessel parameters, carrying out large-scale testing performed by highly qualified specialists and expert assessments of their performance.

Full Mission Bridge simulating became a valuable tool for the navigational safety assurance during seaport development.

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