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USING THE SOFTWARE OF NAVI-TRAINER PRO 5000 SIMULATOR FOR ASSESSMENT OF THE DESIGNED NAVIGATIONAL INFRASTRUCTURE

ABSTRACT

The paper presents the possibility of using the navigational and maneuvering simulators software, for the verification of designed elements of navigational infrastructure. The article describes how to use the Navi-Trainer PRO 5000 simulator manufactured by Transas Marine to modeling sea waters. The Article is based on a scientific research project performed at the Institute of Navigation and Hydrography of Naval Academy of Gdynia. Project was aimed to check the possibility cut through the Vistula Spit and artificial connection the Gulf of Gdansk and Vistula Lagoon. The paper presents a description of creating a virtual basin with planned navigational infrastructure. There will by also presented the maneuvering tests for the assumed maximum ship model and few construction variants. Each of the project variants was tested in different hydro-meteorological conditions.

The result of simulation tests are proposals that demonstrate the feasibility of the project and proposed possible changes affecting the level of safety.

Keywords:
navigation infrastructure, modelling.

INTRODUCTION

Development of transport by sea implies a necessity of building ships of still increasing tonnage and dimensions. To comply with their requirements, construction of new ports and reconstruction of the existing ones appeared to be a fundamental challenge. The key problem in designing and modernizing harbour infrastructure is safety of navigation. Such designs are expensive and labour consuming; therefore they have to be error-free. To minimize any risk of error at the stage of designing,

the most advanced technologies, also the research and designing methods should be applied. And that is an opportunity where using simulators proves to be really beneficial.

The broadly understood expression 'Simulator' may refer to the both — simulation equipment — as well as the additional software, applied to enable modelling elements of virtual reality. Simulation tests have been now-a-days an essential element in the process of verification of the designs in progress. The methods of simulation applied in ships traffic engineering are operated basing on complex mathematic models, describing movement of a ship and an influence of external conditions (hydro--meteorological) on her goings-on. Even if the traditional methods are reliable, applying simulation allows generation of numerous diversified initial conditions, offering a broader range of research potentialities. Experiences in simulation processes produce the following opportunities:

— repeatability of any situation;
— full control over external factors;
— simulation of any potential navigational situation;
— surveying with high accuracy the traffic parameters;
— immediate correction and elimination of errors.

An example for using the simulator for creation of navigational infrastructure is the design of the Vistula Spit Cross-cut. Three variants of the planned Cross-cut structure have been designed.

CHARACTERIZATION OF THE PROJECT

The Project 'Construction of the Channel for Navigation across the Vistula Spit' has covered the scope of works, resulting in construction of the following structures:

— lock: 200 m long, 25 m wide and 5m deep, with gates at its both sides;
— channel: the main section of the channel is 1100 m long, H = 60 m wide and 5 m deep, with banks lining and revetments of the bank slopes;
— breakwaters: to protect the port and the channel entrance against impact of sea waves;
— natural dumper of waves in the port to be situated at the sea side;

— new fairway for approaching the navigation channel from the sea — 5,5 m deep and 60 m wide, also the fairway at the Vistula Lagoon at the distance between the channel and ELB10 buoy, 60 m wide and 4 m deep under construction at the first stage (the fairway depth was approved by the Maritime Office in Gdynia);
— berths in the channel and port at the sea side;
— mooring dolphin at the Vistula Lagoon side to enable ships waiting;
— two low drawbridges with access roads;
— technical infrastructure (service roads, mechanisms for opening and closing the lock gates and the drawbridges) necessary to enable proper operation of the navigation channel;
— fairways for approaching the Vistula Lagoon ports [6].

The Table below presents the scope of works and connected therewith navigational infrastructure.

Table 1. Specification of the design elements [2]

Item	Specification	Length [m]	Width [m]	Depth [m]
1	Main channel	1.100	60	5
2	Main channel quays	2.200	7	5
3	Lock	200	25	5
4	Breakwaters	950	Bases — 7	5
5	Fairways at the Lagoon	7.000	60	4
6	Mooring dolphin	200	40	5
7	Low drawbridge	60	13	–
8	Low drawbridge	60	13	–
9	Main access road	500	7	–
10	Alternative access road	500	7	–

For investigation purpose, for each of the variants the virtual model of the navigation region has been created. Next, the trial runs of manoeuvrings were carried out, applying the assumed maximal vessel, admitted for manoeuvring within this water area. The above simulations have been performed in diversified meteorological conditions. The weather zones, created for the simulations purpose, have included the both — perfect weather conditions as well as these, occurring the most often in the area. The manoeuvring trials were carried out in two stages. At the first stage, the simulations were based on using a tool for automatic watercraft manoeuvring. Then, the simulation results were compared with courses of the trial runs conducted by watch officers. It enabled determination of the excellent route for passing and

indication of crucial points, affecting safety of navigation. In compliance with the described above method of research, we can divide the research works into two principal stages:

— creation of the virtual model of the Cross-cut variants in the simulator environment;
— simulation researches and working out the results.

Fig. 1. Visualization of the suggested variants of the Cross-cut structure [2]

For this research purpose there has been used the simulator, operated basing on Navi-Trainer Professional 5000 software, created by Transas Marine. The software meets all the requirements of STCW convention — chapters A-II/1 i A-II/2. It offers trainees and the Simulator staff a very broad range of potentialities.

According to the instructions of the Maritime Board Office in Gdynia and the data, included in the feasibility study, the maximal length of vessels, assumed to be manoeuvring within the Cross-cut, is 100m. Due to the available depth of the water area, a draught of such vessels is 4m. In conclusion of analyzing all the available watercrafts included in the simulator data base, there has been selected the River/Sea Ship. Her total length is 95 m, with 3.7 m of draught suit perfectly to the accepted assumptions. It is a twin screw vessel, equipped with a bow thruster. Her wide range of manoeuvring capabilities opens an extensive scope of occasions in the researches.

PROCESS OF CREATING THE CROSS-CUT MODEL
IN THE SIMULATOR ENVIRONMENT

For carrying out the simulation trials it is necessary to generate in the simulator's environment a new training water area, covering an area of the future Cross-cut. To reach this goal, using the 'Model Wizard' software, the new training area has been built from the very beginning. The software is an autonomous system, cooperating with environment of the NT PRO 5000 simulator. It is equipped with the built-in library of three-dimensional objects (3D) and elements of navigational signing. It gives a possibility of creating new water areas and objects using no additional programs. An exception is creation of new unique 3D objects (buildings, vessels); then it is necessary to use additional software for 3D designing. A prerequisite for the created object is to have 3D upgrade, as only the files with the above upgrade can be imported to the Model Wizard program. An example of such programs is AutoCAD, 3D studio max, Google SketchUp in its upgraded version. This tool opens a capability of automated creation of new training water areas, basing on import of ENC charts and bathymetric information. The Model Wizard software is consisted of three autonomous integral programs:

— S c e n e   E d i t o r — a program, allowing to create new water areas for training purpose and to modify the existing ones. Especially useful is the second function, as it makes possible to implement immediate changes in navigational aids or bathymetric configuration in a specified water area [3];

— M o d e l   E d i t o r — a software to enable creation of new vessels and to modify manoeuvring parameters of the existing models [3];

— P r o t o t y p e   E d i t o r — for creation of the new and modification of the existing objects (port infrastructure, buildings, vessel targets, helicopters, rescue elements) [3].

Creation of a new training water area, acceptable for environment of NT 5000 simulator with a use of 'Model Wizard' software is a complex and labour consuming process. It requires preparing a lot of necessary data and specialized software literacy. A time we need to create a new training water area depends on degree of complicacy of a coastline and a number of additional objects, requisite for creation thereof. The works connected with construction of water area of the Vistula Spit Cross-cut took about 2 months. The process proceeded according to the following algorithm.

SELECTION THE MAP COVERING THE AREA OF ISSUE

Intending to create a water area of high degree in specificity of details and possibly the most accurate location thereof in the space, it is necessary to use official charts for its generation. Thus; the base for creating the Vistula Spit Cross-cut water area was ENC pl4map41 map cell in S-57 format, produced by the Hydrographic Office of the Polish Navy. For comparison and verification of the coast line the satellite photographs overlaid on the topographic map can be used. When the applicable map cell is selected, it is to be imported to the program. After implementation of S-57 cell, it is transformed to TX97 format, applied in the Model Wizard program. While replacement of the formats takes place, the program is automatically importing the existing coast line together with the basic navigational marking, bathymetry and altitudes.
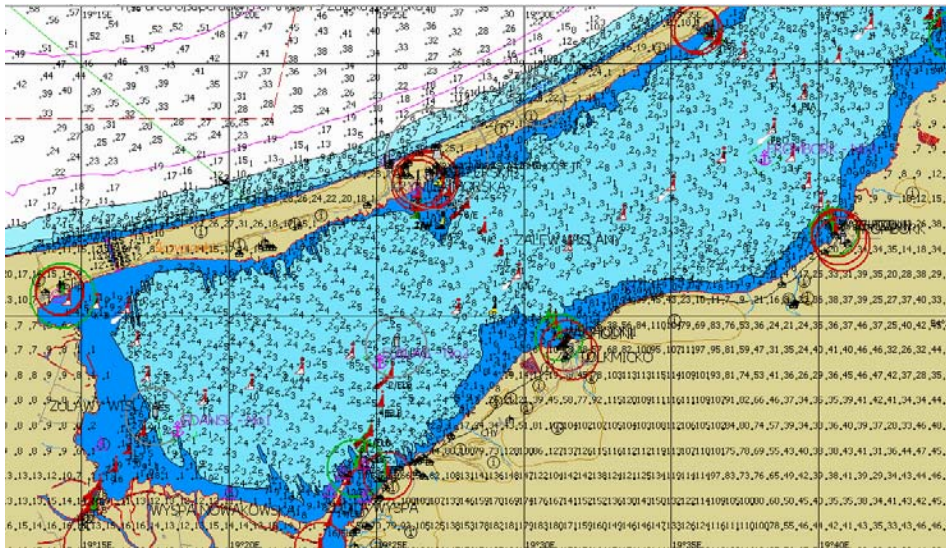

Fig. 2. The cell of map ENC pl4map41 after conversion to TX97 format [own study]

**EDITION OF THE EXISTING COASTLINE
AND CREATION OF THE NEW ONE**

After the basic coastline is generated, a process of its edition takes place. While the coastline is under transformation, three parameters are subject to edition:

— height above sea level;
— type of coastline (e.g. assigned for mooring);
— material the coastline is built of (e.g. sand, stone).

Thus, apart from correction of the existing coastline there is a possibility to create a new one. Drawing the new coastline is necessary in designing of harbour quays. To draw up a water area of our interest precisely, there is an eventuality to overlay a raster map or any bit map as a base map. To create three variants of the virtual model of the Cross-cut entrance there were used bit maps included in the Feasibility Study. The decision about arrangement of the quays has been made in consultation with the Director of the Maritime Board Office in Gdynia. Next, in compliance with the dimensions specified in the Feasibility Study, the Cross-cut has been created. Accurate projection of the coastline would enable to generate in future the electronic navigational chart (map) of the area under creation.
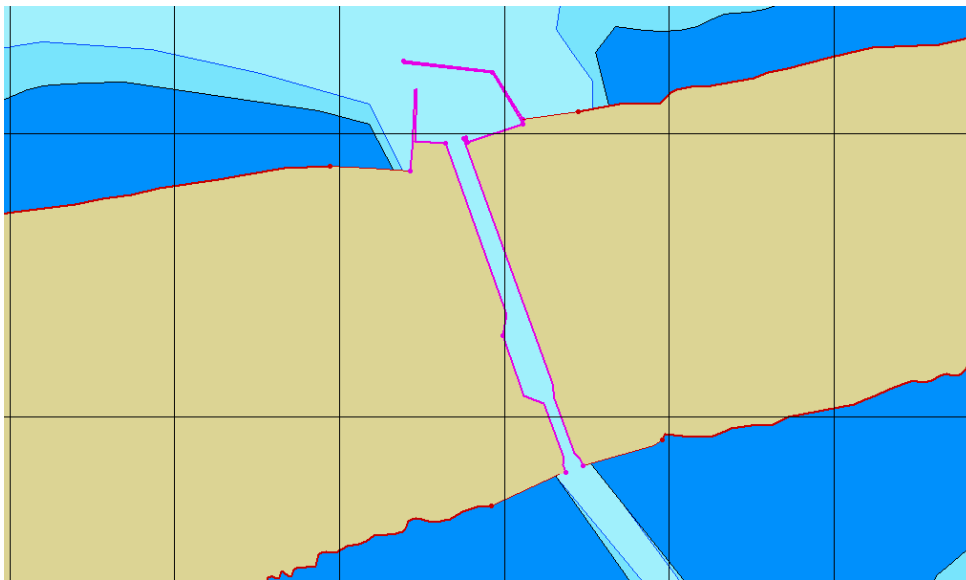

Fig. 3. Edition of the generated coastline [own study]

PROVIDING DETAILS OF BATHYMETRIC INFORMATION

It often happens that bathymetric information imported from a map is inaccurate or out of date. To correct depths and bottom configuration it is necessary to change

routes of isobaths or to add the new ones. There is also a possibility to map-in each point of depth and height above sea level. In case of working on the Cross-cut model it was necessary to create a new grid of depths for the worked up area. After the required corrections of bathymetry, it has to be verified. In the Model Wizard program, a function of generating preview of the area configuration is available (Sensor Viewer function). While analyzing 3D visualization, generated by Sensor Viewer, it is possible to observe accidental singular points of improper depths. The three-dimensional model of the Cross-cut bottom area is presented below.
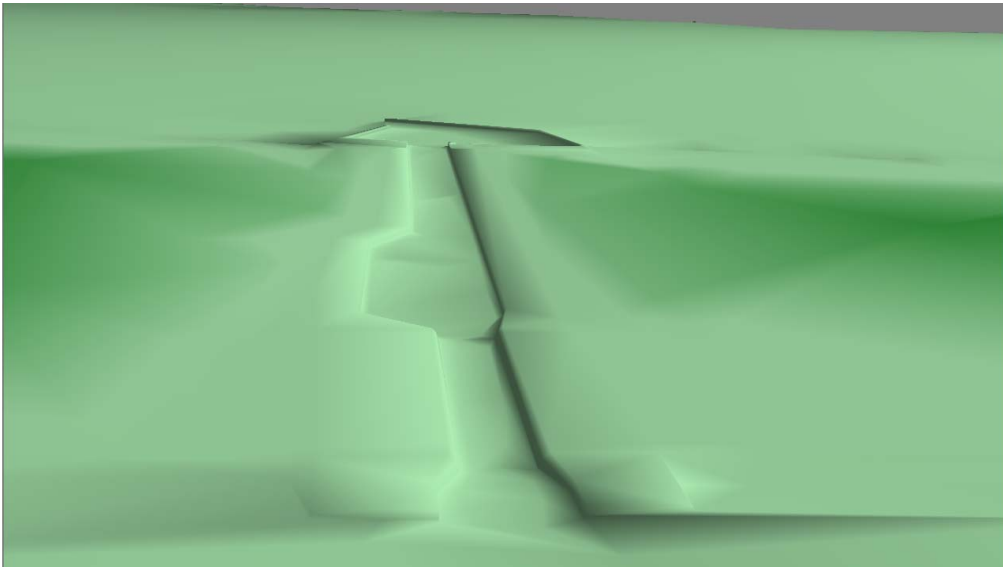

Fig. 4. Picture generated using Sensor Viewer program [own study]

THE AREA SURFACE CONFIGURATION

A relief of the Vistula Spit area, situated in direct proximity of the Cross-cut, is not very differentiated. It is mainly covered with trees, sand and grass. In creation of the area coverage, the library of the objects, attached to the program, may be used. Flat layers adjacent to the channel and the port entrance are created by over-laying respective layers lying at various heights above water level. These layers were covered with materials of differentiated structure.

Fig. 5. Edition of the generated area relief [own study]

CREATION OF NAVIGATIONAL INFRASTRUCTURE PROVIDED WITH NAVIGATIONAL AIDS

After configuration of the area and creation of the precise coastline with the port basin and navigation channel, a process of creating navigational infrastructure is set up. To create the Vistula Spit Cross-cut water area there have been used the both — the navigational markings elements and port infrastructure included in the library of the program objects, as well as the newly generated objects. An example of such a new object is the lock. Thus the markings, in conformity with IALA [5], have been situated at the pointed out places.

IMPORT OF THE CREATED 3D OBJECTS AND SELECTION OF THE OBJECTS FROM THE PROGRAM DATA BASE

The succeeding stage of creating the water area for training consists of overlaying the last layer, it means the 3D objects. The new elements have to be imported to the 'Model Wizard' program whereas the existing we choose in the available objects library. To situate properly the objects existing in reality we can use a background, performed using a satellite photography of the area. The new structures, created for the Cross-cut purpose, are the lock and bridges, situated according to the design.
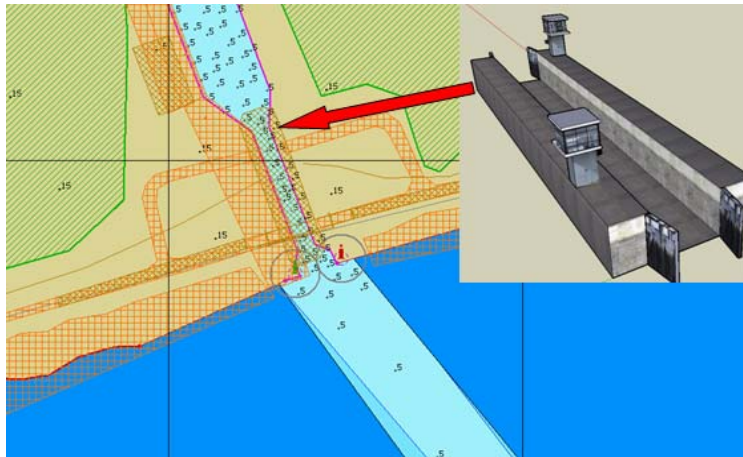
Fig. 6. Placing internal and imported 3D objects on the designed area [own study]

THE MODEL COHERENCY CHECKS
BY GENERATING 3D VISUALIZATION

After the water area had been designed, there was a possibility of checking correctness. In this stage it is necessary to apply the 'Visual Viewer' function. It generates 3D preview of the created water area and also gives a chance to preview the designed scenery in a way as it looks from any point, height and angle of view. The function enables to generate respective hydro-meteorological conditions and to verify their influence on the generated area. There is also a capability to get a preview of the situation as it is seen at night, to verify proper operating of navigational lights.
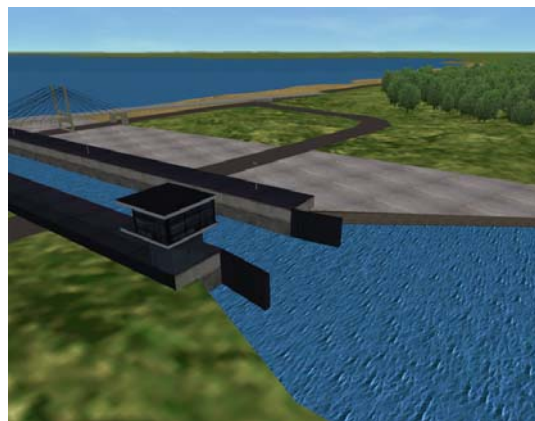

Fig. 7. Example of the picture generated by the Visual Viewer tool [own study]

SIMULATION TEST RUNS

To verify the variants of the designed Vistula Spit Cross-cut structures, a series of simulation test runs were carried out. For each of the options the test runs were performed in variable meteorological conditions. Due to impossibility of modelling an influence of breakwaters on waves acting inside the channel, the tests included examination of wind force and direction, affecting navigation safety. Simulations of vessel's passing the Cross-cut channel were carried out assuming the winds blowing from four main directions: north, south, west and east. The velocities of the blowing winds represented forces of 4° B and 6° B. After simulations, the points of highest collision risk were determined.
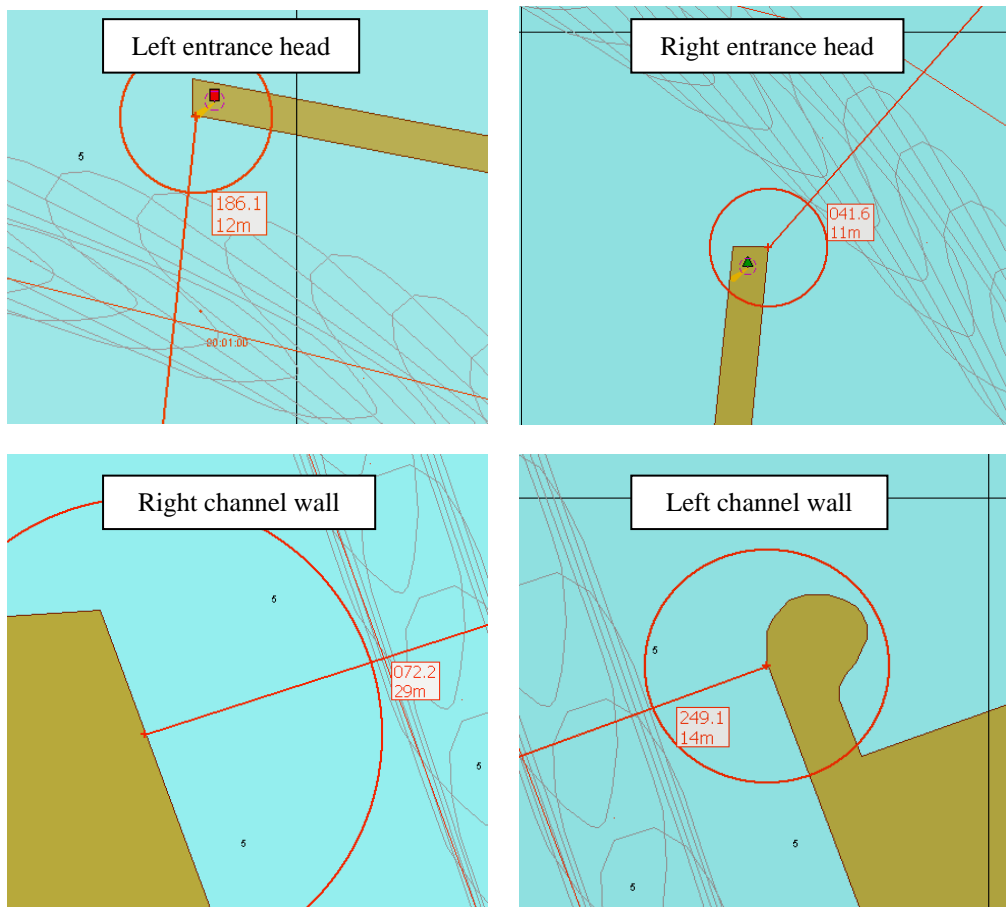

Fig. 8. Wake of the ship after the standard test run in the first variant [own study]

Next, an influence of wind force on its probability of occurrence was described. The boundary wind force, at which safe vessel manoeuvring becomes impossible, has also been determined. In addition, the test runs of vessel passing the lock after unmooring, at the appointed berth mooring post, were carried out as well.
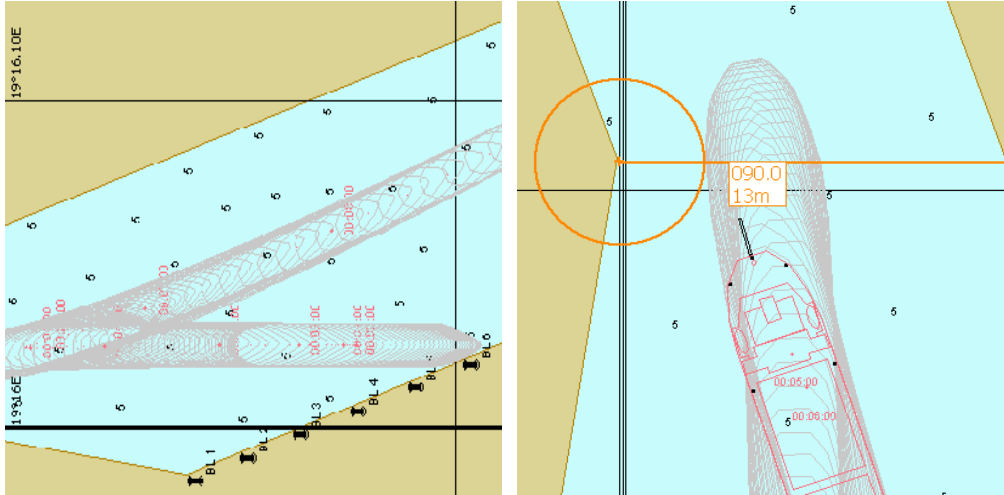

Fig. 9. Manoeuvre of vessel unmooring at the berth [own study]

The analysed variants differ only with the location of the Cross-cut entrance; in each of the options the channel structure is identical. Therefore there was no need to perform simulation of passing the lock for each of the options individually.

A model of the proper watercraft used for the research purpose has been fitted with two propellers and the bow thruster [4]. Operation with rotary moments and using the thruster allows diminishing considerably the radius of circulation and even, in favourable conditions, ship's turning round at a standstill. However it has to be assumed that not all the ships are provided with such equipment, therefore in the test runs no thrusters were used and no moments were applied. The test runs were carried out with the program's automatic ship manoeuvring function engaged; the program is to determine the ideal ship passing trajectory, obtained in specific conditions. Results of the experiments have been compared with runs performed by watch officers having different degree in professional experience and described in the final conclusions.
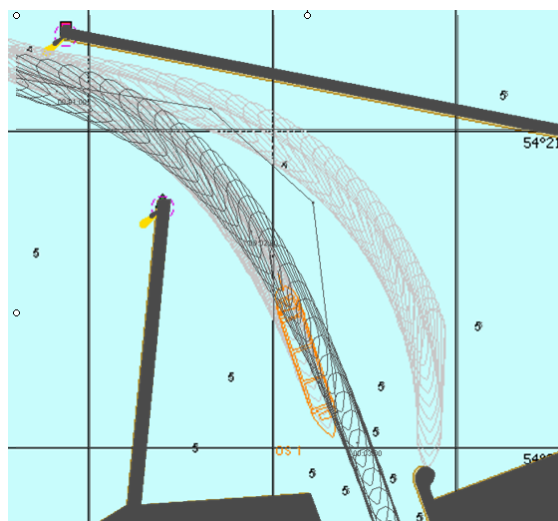
Fig. 10. Comparison of wakes [own study]

CONCLUSIONS

Investigations of the navigational restrictions for the designed Cross-cut of the Vistula Spit are very complicated. Safety of navigation depends on many factors. In our work we were focused only on wind impact on safety of manoeuvring, considering specific variants of the quays structures. However one should remember that apart from impact of wind there acts a range of elements, simulation of which is impossible. It is, let's say, a problem of bottom sediment transfer, silting up the channel and the Cross-cut entrance. This phenomenon affects the water depth, increasing it seriously. Taking the above into consideration a permanent checkout of the available depths was forced. This problem refers also to the fairway which will be constructed in the Vistula Lagoon water area. The depth at the direct proximity of the fairway route reach 1.5 m, thus there is a high risk of silting up the fairway all along.

The carried out researches were aimed at obtaining the data which allow to choose the more advantageous of the variants of structure or to identify one of components necessary in the process of making decision. Thus the conclusions resulting from this Work are focused only on assessment of the variants in respect of wind force and wind direction impact on safety of navigation.

As it was impossible to examine an influence of waves breaking in through the entrance in the third variant, examinations in this option was abandoned. For this

concept of structure an impact of wind on navigation safety while entering the Cross-cut is minor. It is not, however, the variant free from deficiencies, as eventuality of waves breaking in and bottom sediment transfer inside the port will cause situations which may induce a risk of collision.

Taking into consideration two of three variants we can state that the work's objective has been realized, as in effect of analysing the recorded simulation test runs it is possible with no problem, to indicate the better variant of the structure. The variant is the design with the entrance situated at the east side. It is not a perfect structure and one of the conclusions drawn from the carried out tests is a necessity of dislocation of the channel entrance to the right. As a result of the above change in the structure, the negative influence of wind blowing from the east and pushing the vessel would be eliminated as in effect her circulation radius gets increased. We also can state that the above mentioned change would cause rectification of the often occurring fault of ship tacking manoeuvre starting too late. According to the carried out experiments it has been proved that this fault is one of the most often occurring faults, when manoeuvring is performed by a man.

The obtained results have proved that the simulator at the Navy Academy disposal is a right tool, capable to support designing and verification of designs in sea traffic engineering. Thus we can state that now-a-days, when economical reasons are so important, an additional advantage is achieved when simulation equipment is available, as operating such equipment is relatively inexpensive if compared with experiments in reality.

REFERENCES

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