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SYSTEM OF AUTOMATIC GENERATION OF SHIP MANEUVER DOCUMENTATION

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Abstract:

According to the definition in the resolution International Maritime Organization no A.860 (IMO 1997) navigation is the process of planning, recording, and controlling the movement of a craft from one place to another. When navigating in special conditions, for example, when approaching a port or in restricted areas, it is immensely important to know the vessel's maneuverability. Therefore, identifiable information must be available on each vessel. Each watch officer is required to have the necessary knowledge of both the equipment and maneuverability of his own vessel. The description and scope of the documentation containing this data are provided in IMO Resolution A.601 (IMO, 1987). The maneuver documents that must be available on the navigation bridge are Pilot Card and Wheelhouse Poster also Maneuvering Booklet. The timeliness of the data contained in the maneuver documentation significantly influences the safety of navigation. At present, the maneuver documentation is not created in an automated manner. Automation of registration and data processing process will increase the knowledge of the behavior of the own vessel. In addition, it allows to obtain maneuvering data that exceeds the parameters necessary to prepare ship documentation. Especially research carried out in various hydrometeorological conditions, enabling the assessment of the movement of the ship on the waves. These data can be used to carry out research projects related to the subject of vessel behavior analysis. That is why the authors have made an attempt to automate the registration and processing of data necessary to create documents and their continuous generation in electronic form. In this article the authors present a proprietary computer application that enables the achievement of the assumed goals along with checking the application's functionality on a selected type of a vessel. The correct operation of the system has been verified based on real study and simulation tests.

Keywords: *maritime navigation, automation of navigation, ship maneuvering parameters*

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1. Introduction

The safety of navigation is a very crucial aspect of every sea voyage, which is stipulated in the definition of navigation in the 1997 resolution IMO A.860, which is: Navigation is the process of planning, recording and controlling the movement of a craft from one place to another (IMO 1997). One of the most important navigational tasks performed continuously during a sea voyage is determining the own position of the ship with the use of available navigation systems, eg (Czaplewski, Zwolan 2019, Gucma 2016). The methods and ways of determining the position are widely described in the subject-related literature, eg (Naus, Wąż 2011; Weintrit 2016; Jurdziński 2020). However, when navigating in "special conditions", for example, when approaching a port or in restricted areas, e.g. by surface or depth (Gucma S. 2001, 2004), it is very important to know the maneuverability of the ship. Therefore, information on maneuvering parameters must be available in a conspicuous place on the bridge on each watercraft. It is imperative for every watch officer to be familiar with the maneuvering characteristics of his own vessel. The description and scope of the documentation containing these data are provided in IMO Resolution A.601 (IMO, 1987). The maneuver documents that must be available on each ship are: Pilot Card, Wheelhouse Poster and Maneuvering Booklet (IMO, 1987; ABS 2006, 2017). "Pilot Card" is filled out by the ship's captain - this is to provide the necessary information for the pilot. This should include the current condition of the ship with regard to its loading, maneuvering and propulsion machinery and other relevant equipment. The content is available for use without special maneuvering tests. The Wheelhouse Poster must be kept available on the bridge at all times and of a size for ease of use. It should contain general data and detailed information on the maneuvering characteristics of the ship. The "Maneuvering Booklet" should also be on the bridge and should contain data on the maneuvering characteristics of the vessel (general description of the vessel, maneuvering characteristics in deep water, characteristics of stopping in deep water, maneuvering characteristics in shallow water, changes in maneuvering characteristics under wind, maneuvering characteristics at reduced speeds, supplementary information). Each of the above-mentioned documents is indispensable for safe and effective shipping, to be able to properly conduct navigation maneuvers, e.g. to avoid collision or to save human life or at least to properly execute the scheduled return in accordance with the Voyage Plan. The maneuver documents package is also essential for harbor pilots when entering ships into port, as they are usually unfamiliar with its maneuverability. At the time of accepting the pilot on the ship, the captain is obliged to provide information, among other things, about the length, width, displacement, year of construction, length of anchor chains and the efficiency of the necessary devices needed to conduct navigation, as well as the draught, type and condition of propulsion, propeller, and above all, they are obliged to present the ship's maneuver documentation (Jurdziński, 2020), which is most often presented in the form of posters placed on the sheets (on the walls).

The timeliness of the data contained in the maneuver documentation significantly affects not only the safety of the vessel that performs the maneuvers, but also has a significant impact on the safety of navigation in the entire area (Gucma 2022). Therefore, the ship's maneuver documents must not only be properly prepared at the beginning of its use (during shipbuilding tests) or after each subsequent shipbuilding repair, but according to the authors, they must be constantly updated during the normal daily operation of the ship. Nowadays, it is possible with the use of integrated measurement platforms, for example the measurement platform, which was developed by the authors of the article and which was described, for example, in (Świerczyński, Zwolan 2014; Czaplewski, Zwolan 2016). Obtaining maneuver information requires the registration of a data stream from specific navigation devices, which is sent in an automated manner to the central unit of the platform, e.g. using the NMEA protocol. The standard of communication on board ships using this protocol is described, inter alia, in (Luft et al 2002; Sivkov, 2018). The obtained data should be processed and the necessary information filtered in order to present it in graphic and text form. At present, the process of creating maneuver documentation is most often carried out in a traditional way. There is no uniform system that would enable it to be generated automatically or partially automatically (without the ship's design data). This article presents the proprietary platform enabling the automation of the

registration, processing and presentation of maneuvering data in the form of ready-made ship documents. The main components of the measurement platform are the maneuvering data acquisition module and the application that enables automatic generation of the ship's maneuver documentation together with data visualization.
The authors have attempted to create a platform that enables the processing of registered data in an automated manner and enables the creation of electronic ship maneuver documentation in an automated manner. Similar ideas for integrating in one place on the navigation bridge of Command, Control, Communication and Information (C3I) Systems information were already formulated in the late nineties of the last century, but only now take on a new impetus and meaning. The paper consists of three main parts:

- Ship maneuvering data acquisition module - this section describes the construction and principle of operation of the author's device for recording and analyzing ship maneuvering data;
- Application for generating ship maneuver documentation - this part contains the algorithm and method of operation of the application to automate the process of generating maneuvering documents developed by the authors;
- Tests verifying the correct operation of the application - the last part presents validation tests of the system based on simulation studies.

2. Ship maneuvering data acquisition module

Contemporary vessels are equipped with a large number of navigation devices and systems (Banachowicz et al, 1996). Their main purpose is to provide navigational information. Some of these devices provide us with the information necessary to prepare the ship's maneuver documentation. In order to determine the diameter of the ship's circulation, the characteristics of stops (free, forced) and the hose test, data from the following devices should be recorded:

- log,
- gyrocompass,
- anemometer,
- GNSS receiver.

Additionally, knowledge of the detailed navigational equipment of the vessel is essential in order to complete the maneuver documentation. The ship maneuvering data acquisition module developed by the authors is the receiving part of the measurement system. Its components make it possible to receive and record information from sensors such as: log, anemometer, GNSS receiver, Navtex, compass, AIS, satellite compass, inclinometer, etc. This module allows you to connect selected navigation devices and record NMEA messages through RS 232, RS422 connectors, USB. The device also has a multiplexer for data transmission via WiFi network, with which we can provide a signal to the computer network. This configuration enables the system to be used in a multidirectional manner, depending on the devices owned by the users. The additional equipment of the system is a recording device (e.g. a computer). This equipment facilitates the introduction of configuration changes and secures the task of data storage and its constant monitoring. An important task of the module is also to fuse signals from all connected sensors. The constructed maneuver data acquisition module includes the necessary components for integration with all navigation devices. The configuration of the measurement set consists of devices inside the mobile measurement platform and external sensors connected depending on the measurement task (Fig. 1).
The permanent elements of the measurement platform set are:

- GNSS system receiver,
- AIS receiver,
- Wi-Fi router transmitting the recorded parameters via radio to the measurement computer,
- NMEA NDC-4 multiplexer for collecting information from 4 sources and sending them to a measurement computer via a USB port. The need to use a multiplexer result from the lack of serial ports in current laptops and a limited number of USB ports,
- InSight Radar 2 - Black Box (IR-BB),
- Actisense NGW-1, NMEA 2000 TO NMEA 183 converter,
- Actisense NGT-1-USB, NMEA 2000 TO PC (USB) converter,
- charger.

All the elements were placed in one case. In addition to the devices located in the case, it is possible to connect external sensors, which can be:

- Inertial system for measuring the vessel's movement in 6 degrees of freedom and position thanks to the attached GNSS receiver. The obtained measurement results are transmitted via

NMEA2000 and 0183 connectors to the computer. It is possible to use an additional sensor of the inertial system, which, after placing it on the bow of the vessel, will enable the determination of the drift angle after comparing the readings from the two sensors;
- A measurement computer that collects information from all sensors and data on the height and direction of the sea wave from meteorological buoys located along the route of the vessel;
- A weather station that allows measuring the direction and speed of real and relative wind, air temperature, and atmospheric pressure,
- Gyrocompass,
- Satellite compass,
- Navtex,
- Radar,
- ECDIS,
- Echo-sounder.

Eight devices can be connected to the measurement platform at the same time. They can work in parallel and transmit data at the same time. Thanks to the multiplexer, the received signals are fused and transmitted into one data stream. External sensors, mounted on vessels, constitute a set of detachable components used during research works.

3. Application for generating ship maneuver documentation

In order to automate the process of generating the maneuver documentation, a dedicated computer application was developed (Tarnicka 2021). It was created in the C ++ Builder environment. The application presents actual information obtained on board. The program module was implemented on the basis of three documents. Two of them reflect the maneuver documentation in the form of the "Pilot Card" and "Wheelhouse Poster". The third document "IMO Criteria" presents a detailed verification of the maneuver parameters of the vessels in terms of the requirements that are predefined for all performed maneuvers, and the dependencies are described in "Explanatory Notes to the Standards for Ship Maneuverability".

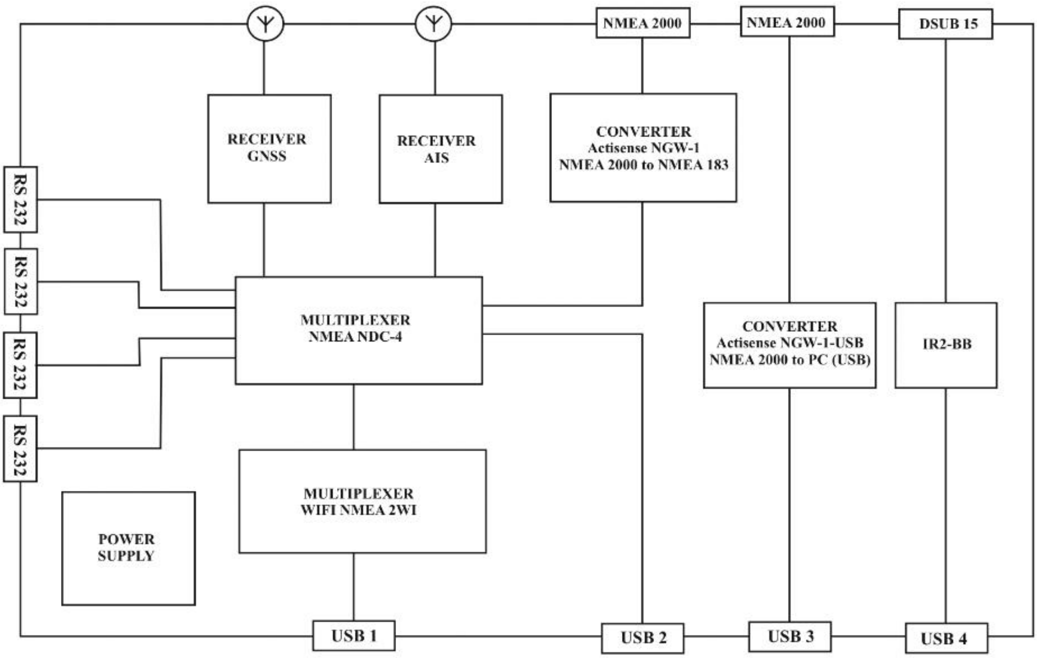


Fig.1. Block diagram of the mobile measurement YYY platform (source: own study)

The process of creating documentation is preceded by maneuvering tests in order to obtain information about the maneuvering capabilities of the ship. The data to be recorded during the actual tests are:

- time,
- ship's position,
- course,
- speed over ground.

Fig. 2 shows a simplified application operation algorithm.

After starting the application, the title page is displayed with links to the selection of documents:

- PILOT CARD,
- WHEELHOUSE POSTER,
- IMO CRITERIA.

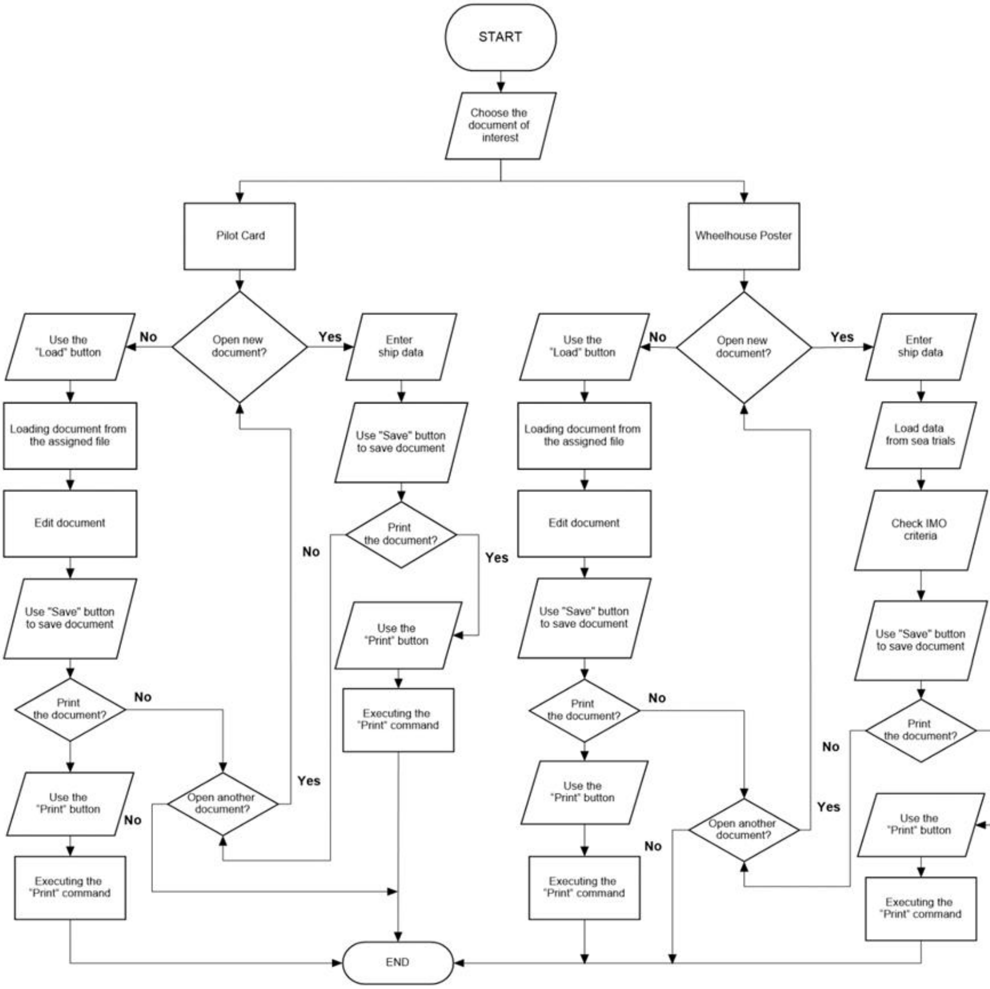


Fig. 2 Algorithm for producing the ship's maneuver documentation (source: own study)

At the beginning, the user of the application may choose to develop new documentation or edit the existing one. In the case of generating a new document, after each maneuver attempt and registration of all parameters, a text file dedicated to a given vessel is created. Then it is saved to the folder that creates the database. After selecting an existing ship, it is possible to load the previous data and edit them again. The application allows you to run all documents at one time in order to compare the data contained in them. By selecting the "PILOT CARD" button in the main application window, the first page of the remote control card will be displayed (Fig. 3).

In this tab, you can find general information about the vessel and maneuver data that must be completed manually or automatically. It is also possible to implement the vessel data from the already available analyzed vessels.

From the "Pilot Card" level, it is possible to go directly to the next page of the document named "Steering". Figure 4 shows the program tab containing the template for making the second side of the pilot card.

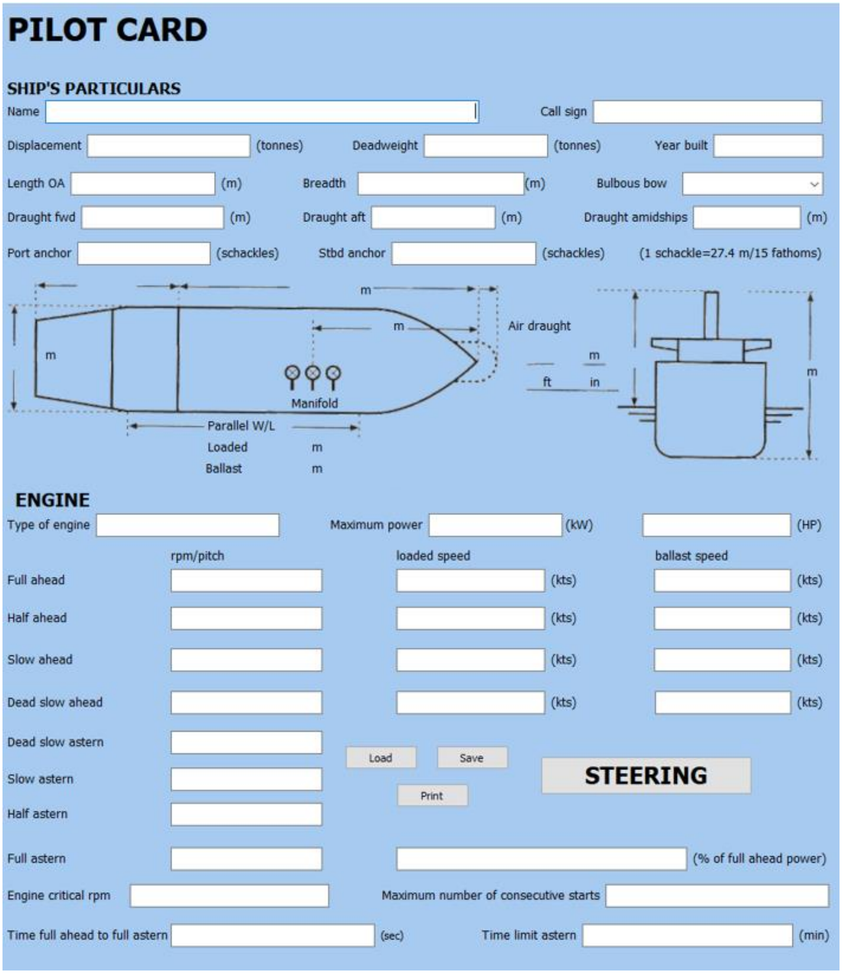


Fig.3. Pilot Card (source: own study)

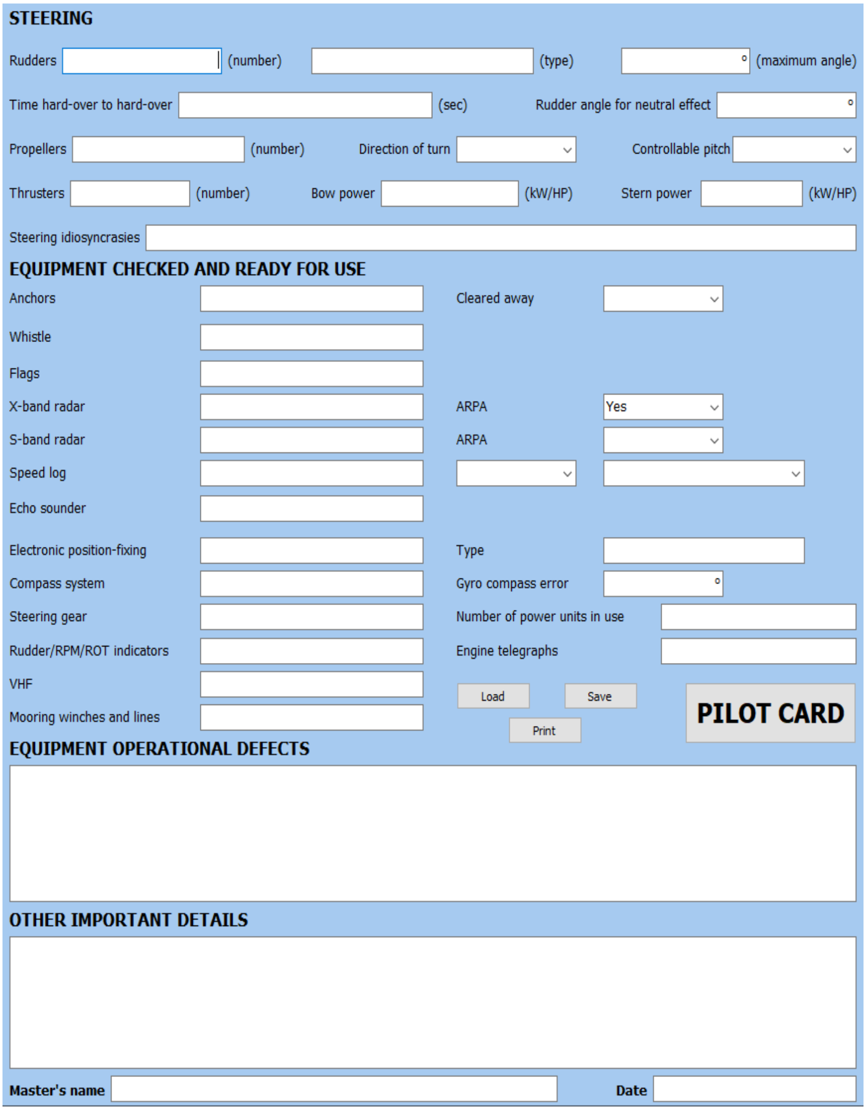
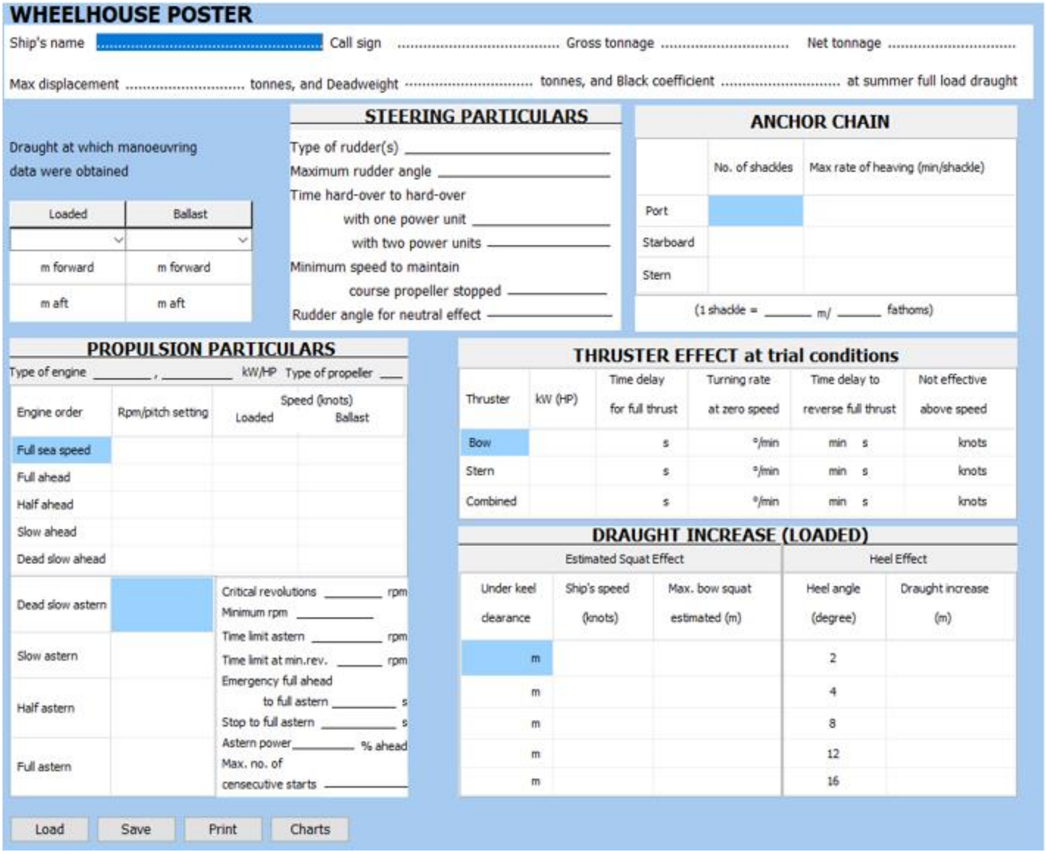


Fig. 4. Steering (source: own study)

Another element of the program is the tab supporting the creation of another document, ie "Wheelhouse Poster" (fig. 5) containing several tables with additional maneuver information.
The program's Charts function includes a link to an interface for creating turning circle charts and stopping charts. After processing the data, the program presents the recorded information from maneuvering tests in the form of graphs (Fig. 9).
The last document in the application presents a comparative analysis of the results obtained from maneuvering tests with the IMO requirements in terms of maximum values of the turning circle diameter or vessel stopping characteristics. All of it, designated

as IMO Criteria, is reflected in Annex 6 (Fig. 6). Part of the information is obtained from the previously completed maneuver documentation. Selecting the ship type through the Type load function automatically loads the relevant criteria, and the data from the maneuvering elements (turning circle, stopping characteristics) are downloaded by selecting the Load information button.

The key used in the document allows you to verify the relevant result data. Red highlighting of the text suggests to the user that the requirements set by IMO have not been met during the maneuvers, while the green color is an indicator of data correctness and a suggestion that a given unit meets the safety requirements. All documents can be printed and used on the ship.



WHEELHOUSE POSTER

Ship's name .... Call sign .... Gross tonnage .... Net tonnage ....

Max displacement .... tonnes, and Deadweight .... tonnes, and Black coefficient .... at summer full load draught

Draught at which manoeuvring data were obtained

Loaded	Ballast
m forward	m forward
m aft	m aft

STEERING PARTICULARS

Type of rudder(s) ____
Maximum rudder angle ____
Time hard-over to hard-over
with one power unit ____
with two power units ____
Minimum speed to maintain
course propeller stopped ____
Rudder angle for neutral effect ____

ANCHOR CHAIN

	No. of shackles	Max rate of heaving (min/shackle)
Port		
Starboard		
Stern		

(1 shackle = ____ m/ ____ fathoms)

PROPULSION PARTICULARS

Type of engine ____ , ____ kW/HP Type of propeller ____

Engine order	Rpm/pitch setting	Speed (knots) Loaded	Speed (knots) Ballast
Full sea speed			
Full ahead			
Half ahead			
Slow ahead			
Dead slow ahead			
Dead slow astern			
Slow astern			
Half astern			
Full astern			

Critical revolutions ____ rpm
Minimum rpm ____
Time limit astern ____ rpm
Time limit at min.rev. ____ rpm
Emergency full ahead
to full astern ____ s
Stop to full astern ____ s
Astern power ____ % ahead
Max. no. of
censecutive starts ____

THRUSTER EFFECT at trial conditions

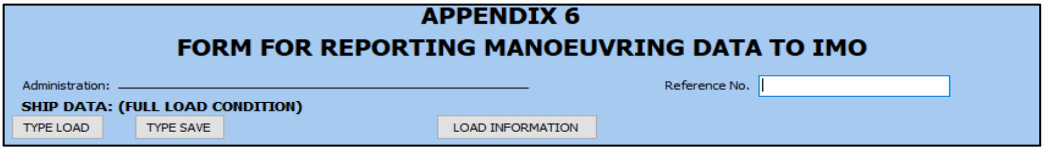
Thruster	kW (HP)	Time delay for full thrust	Turning rate at zero speed	Time delay to reverse full thrust	Not effective above speed
Bow		s	°/min	min s	knots
Stern		s	°/min	min s	knots
Combined		s	°/min	min s	knots

DRAUGHT INCREASE (LOADED)

Estimated Squat Effect			Heel Effect	
Under keel clearance	Ship's speed (knots)	Max. bow squat estimated (m)	Heel angle (degree)	Draught increase (m)
m			2	
m			4	
m			8	
m			12	
m			16	

Load Save Print Charts

Fig. 5. Wheelhouse Poster (source: own study)



APPENDIX 6
FORM FOR REPORTING MANOEUVRING DATA TO IMO

Administration: ____ Reference No.

SHIP DATA: (FULL LOAD CONDITION)

TYPE LOAD TYPE SAVE LOAD INFORMATION

Fig. 6. Location of the data loading buttons (source: own study)

4. Tests verifying the correct operation of the application

In order to verify the correct operation of the application, simulation tests were carried out. These tests were performed on the basis of the Wartsila navigation and maneuvering simulator. The simulation tests consisted in connecting the measurement platform to the ECDIS (Navi Sailor 4100) system (Fig. 7.).

The ECDIS system enabled data transmission in the form of NMEA messages in the same format as on the real vessel. In the presented test, maneuver documentation of the EMMA MAERSK container ship was prepared (Fig. 8).

After the scenario was prepared and launched in the simulator environment, the maneuvering data recording process began. These data were saved in a text file that was imported into an application that enables the generation of maneuver documentation. After the user completed all the additional data about the vessel, the application generated the maneuver documentation, which is shown in figures 9 and 10.

The first document generated is Wheelhouse Poster. It was automatically completed based on the actual data recorded during the tests and elements imported from the application database. It contains both textual data describing the ship's circulation and attempts to stop, as well as their graphical presentation.

The turning circle-stopping diagram is displayed on a separate interface (Fig. 9).

The second document is the pilot card, which was generated on the basis of information contained in the Wheelhouse Poster. This information on shipbuilding, equipment and settings of the engine telegraph is required for the pilot.

Fig.7. Simulation tests

AIS DATA		MASTER DATA	
AIS Type	Cargo ship (HAZ-A)	IMO number	9321483
Flag	Denmark	Vessel Name	EMMA MAERSK
Destination	FRLEH > MAPTM	Ship type	Container Ship
ETA	Jan 8, 16:00	Flag	Denmark
IMO / MMSI	9321483 / 220417000	Homeport	
Callsign	OYGR2	Gross Tonnage	171542
Length / Beam	399 / 56 m	Summer Deadweight (t)	156257
Current draught	15.8 m	Length Overall (m)	398
Course / Speed	20.5° / 0.0 kn	Beam (m)	56
Coordinates	49.4595 N/0.1505 E	Draught (m)	
Last report	Jan 5, 2020 20:05 UTC	Year of Built	2006

Fig. 8. Real equivalent of the test unit, (source: https://www.vesselfinder.com)

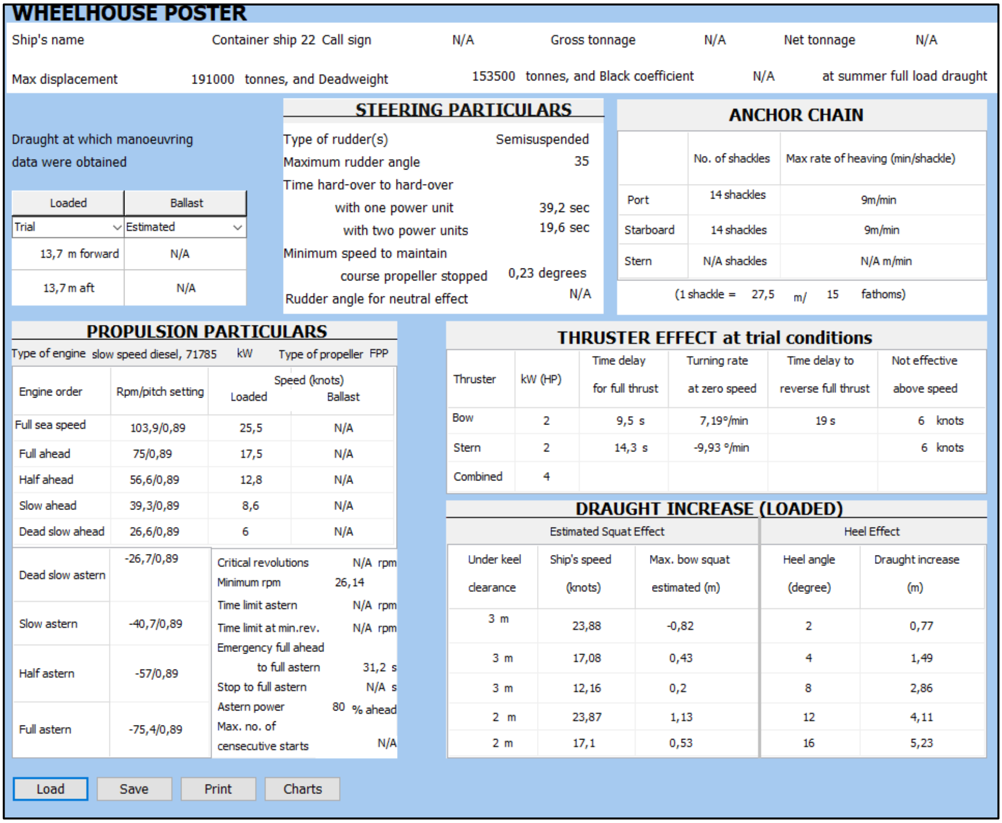


Fig. 9. Wheelhouse Poster document supplemented with data from the tested unit (source: own study)

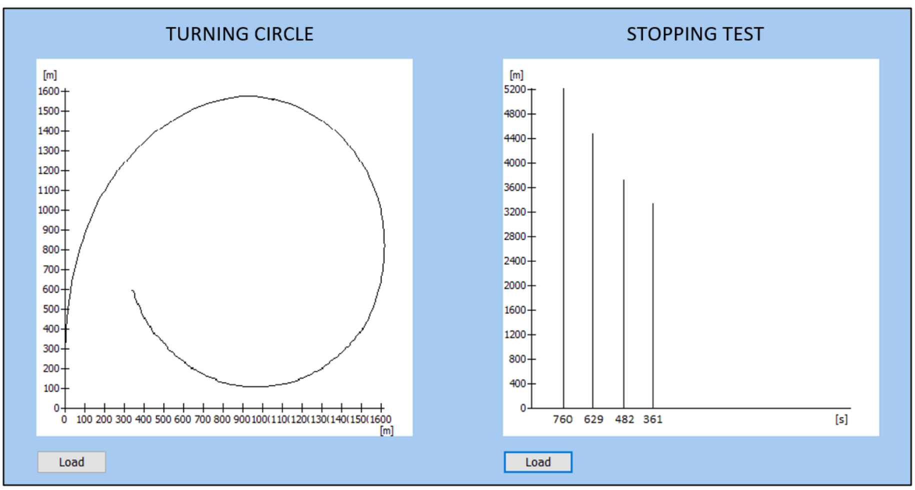


Fig. 10. "Wheelhouse Poster" Charts tab for the simulation model (source: own study)

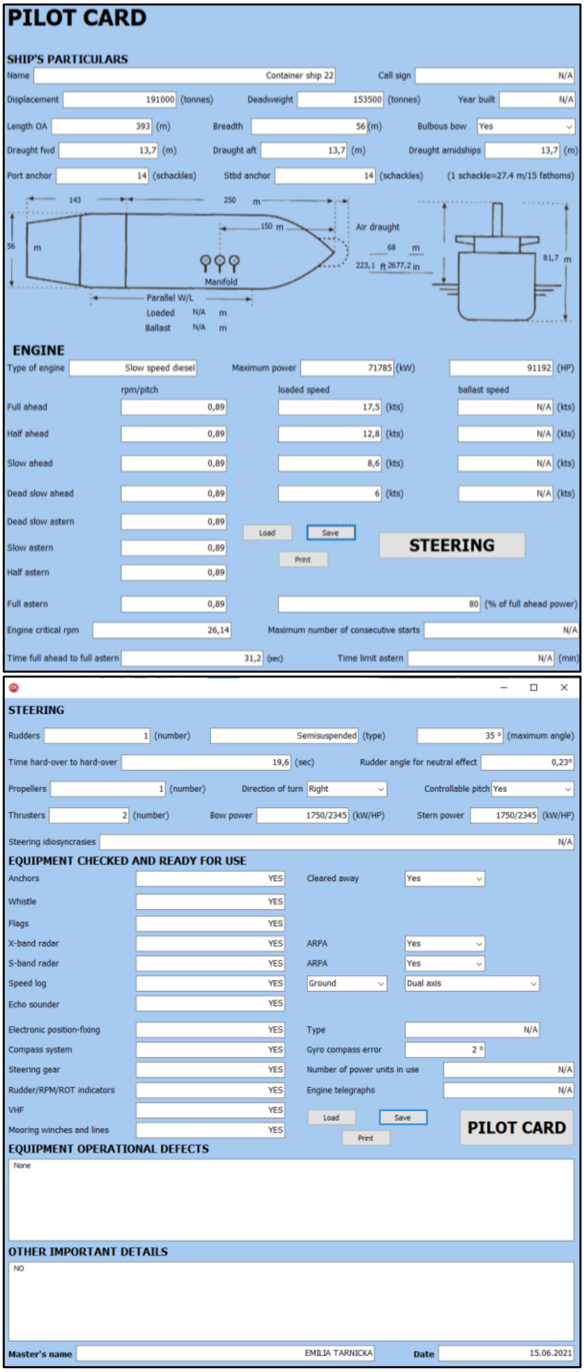
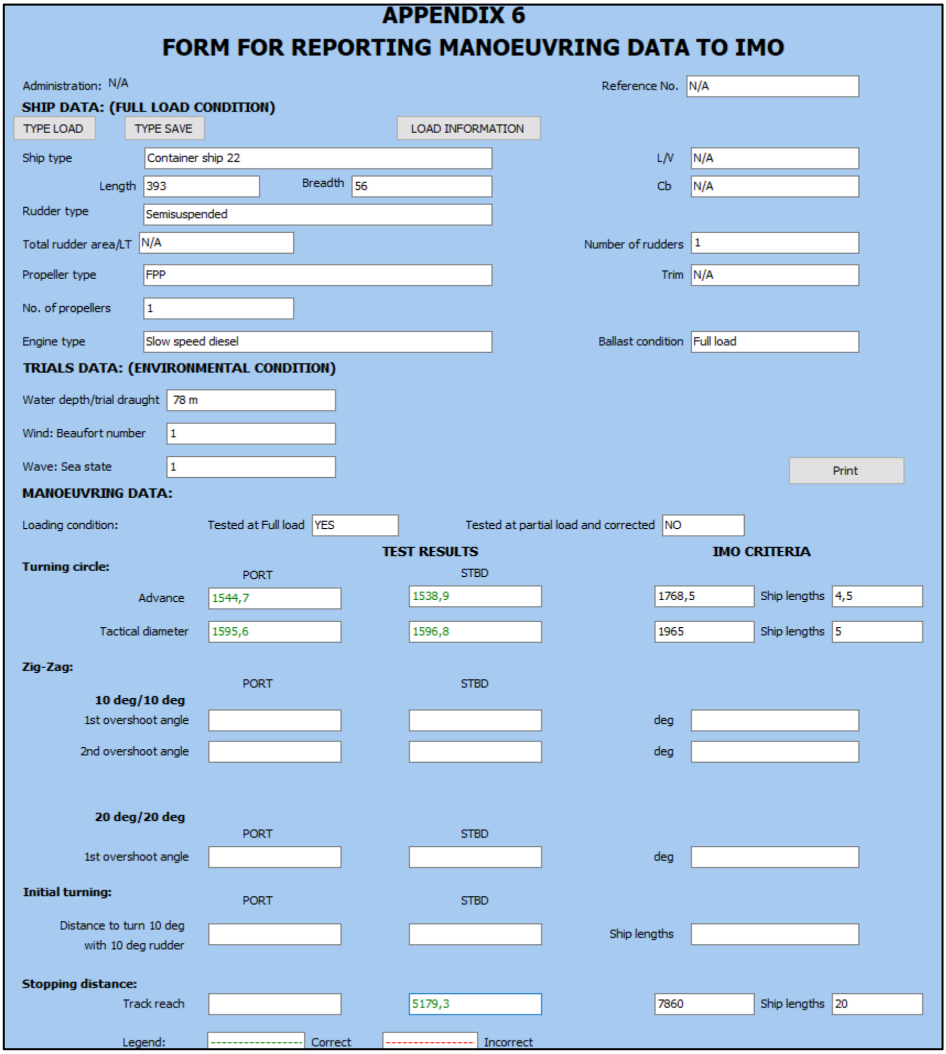


Fig. 11. Pilot Card supplemented with container ship data (source: own study)



APPENDIX 6
FORM FOR REPORTING MANOEUVRING DATA TO IMO

Administration: N/A
Reference No. N/A

SHIP DATA: (FULL LOAD CONDITION)

TYPE LOAD | TYPE SAVE | LOAD INFORMATION

Ship type	Container ship 22	L/V	N/A
Length	393	Breadth	56
Cb	N/A		
Rudder type	Semisuspended		
Total rudder area/LT	N/A	Number of rudders	1
Propeller type	FPP	Trim	N/A
No. of propellers	1		
Engine type	Slow speed diesel	Ballast condition	Full load

TRIALS DATA: (ENVIRONMENTAL CONDITION)

Water depth/trial draught	78 m
Wind: Beaufort number	1
Wave: Sea state	1

Print

MANOEUVRING DATA:

Loading condition: Tested at Full load YES Tested at partial load and corrected NO

	TEST RESULTS PORT	TEST RESULTS STBD	IMO CRITERIA		
Turning circle:					
Advance	1544,7	1538,9	1768,5	Ship lengths	4,5
Tactical diameter	1595,6	1596,8	1965	Ship lengths	5
Zig-Zag:					
10 deg/10 deg					
1st overshoot angle				deg	
2nd overshoot angle				deg	
20 deg/20 deg					
1st overshoot angle				deg	
Initial turning:					
Distance to turn 10 deg with 10 deg rudder				Ship lengths	
Stopping distance:					
Track reach		5179,3	7860	Ship lengths	20

Legend: ---------------- Correct ---------------- Incorrect

Fig.12. Appendix 6 for Container ship 22 (source*:* own study)

The next element was the IMO CRITERIA tab (Annex 6). It confirms the compliance of our unit's maneuvering data obtained during sea trials with the requirements set by one IMO.
The analysis of the maneuvering parameters data is presented in Figure 11. Only the elements for which the maneuvers were performed were filled in.
The authors started further work on the use of the created measurement platform in real conditions. These tests will be carried out on selected ships of the Polish Navy. This will enable the preparation of standardized maneuver documentation for all ships which, according to the regulations, are not convention vessels. Until now, the authors have carried out research on one type of ship. Fig. 13 shows the measurement stand, which was used, inter alia, to develop the maneuvering documentation of the ship.

Fig. 13. Mobile measurement platform with external navigation devices providing the necessary measurement data (source: own study)

5. Conclusions

1. Measurement platform invented by the authors could be a comprehensive module for obtaining data indispensable for the preparation of maneuver documentation of any watercraft. It can be used by shipyards performing maneuvering tests as well as ship classification organizations, research units or shipowners.
2. The presented test results based on the ship simulation model are one of the checking elements of the developed measurement set. The verification is also carried out in reference to the actual registrations on the ships of the Navy of the Republic of Poland. However, due to the confidentiality clause, they will not be published in the form of scientific articles. Further research by the authors will be carried out on civilian vessels and then the research results will be presented in subsequent publications presenting the modernization of the platform described in this article.
3. Work is currently underway on the miniaturization of the measurement set which will enable it to increase its mobility. The operational capabilities of the presented measurement platform (software + external sensors) will be to be used not only to generate maneuver documentation, but also in many other research areas in the field of automating the collection of data from a specific ship as well as conducting analyses in the area of increasing ship safety at sea.

Acknowledgment

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