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Proposal of ECDIS simulation tests for dredging activity in seaports: A project management approach

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Abstract

The main purpose of dredging is to maintain the required depth of harbors and marine and inland waterways. Any investment work in port infrastructure should be planned in such a way as to minimize interference with the port operations and vessel traffic. The research aims to analyze work scenarios involving a proposed dredging fleet using a Navi-Trainer Professional 5000 navigational and maneuvering simulator connected to the Transas Navi-Sailor 4000 navigation information system. An analysis performed using these electronic chart display and information system (ECDIS) simulators allows the operational parameters of the dredging project to be determined. These parameters include driving time, time taken to fill a TSHD dredger to full capacity, scale of maneuverability of the dredger within the port area, and determination of the safe distance between dredging vessels and other ships. The proposed solution may be supplemented with additional computer-based programs, providing a valuable tool in the research and monitoring of planned and current dredging projects.

Introduction

Dredging is an activity connected with the exploitation of ports (Lewko, 2006) and the protection of coastal areas as well as construction, archaeology, and deep-sea mining. The main purpose of dredging is to maintain the required depth (Merkel & Holmgren, 2017) in harbors and marine and inland waterways. Such maintenance activities are carried out periodically to allow the efficient transportation of goods (Skiba, 2019; Karas, 2020). The practice of dredging is also applied with growing frequency during hydrotechnical construction projects and exploration and exploitation of the seabed.

When determining the appropriate choice of dredging method in a given region, there are a variety of conditions to be considered. The location and area of the dig, the required depth, the availability of equipment, the effectiveness of loosening, the characteristics of the soil, the method of storage, and the distance of transportation of the extracted material as well as the volume of vessel traffic are among the most important parameters that impact dredging operations. There are also many other aspects to consider in relation to the specific characteristics of the area to undergo dredging. Therefore, the appropriate choice of dredging technology must be analyzed in terms of a great many elements (Smolarek & Kaizer, 2015).

Dredging works constitute an obstacle to the smooth operation of shipping, therefore impacting the organization of a port's activity (Karas, 2020). Depending on the location of vessels in operation as well as their number, dredgers may negatively affect the transshipment efficiency of a port. This is caused by the necessity for extreme caution when avoiding or overtaking a dredging unit.

When carrying out investment projects close to port infrastructure, work should be planned to minimize any disruption to the operations of the terminal and vessel traffic. Delays to projects caused by disruptions caused by vessel traffic will greatly increase the costs of the investment.

Therefore, Autor proposed that port dredging activities supplemented with additional computer-based programs (Chen et al., 2021; Bashir, 2022;) provide a valuable tool in the research and monitoring of planned and current dredging projects. Further research to follow the present study may consist of using the developed simulation models for the needs of dredging companies and harbors, extending the proposed model with other elements, (e.g., related to the risk assessment and security of process organization), and using the model's results together with the computer application for further scientific research.

Scope and aims of the research

The research aims to analyze working scenarios of a fleet of dredging vessels using the Navi-Trainer 5000 navigational and maneuvering simulator connected to the Transas Navi-Sailor 4000 navigation electronic map system. The proposed simulation study allows for the estimation of additional operational parameters not included in the general methods used in the organization of dredging projects. Simulation tests enable the suitability of equipment proposed for use within a restricted area or an area characterized by high vessel traffic density to be verified, the approximation of the time required for a dredging vessel to complete its work, the time taken to sail to the slip and back, and the possibility and time taken to perform maneuvers, such as turning and allowing other vessels to pass clearly. Simulator analysis (Dae-Jae, 2007) also allows the duration of individual work phases to be determined to ensure that self-propelled dredgers reach their capacity during the final phase of each stage of the work, which gives maximum efficiency. The use of simulators in the organization of dredging projects is an innovative approach and one that requires a great deal of detailed data. Although simulation testing may be inconvenient, it is a necessity for many simulator models, which should closely represent the selected equipment in order to obtain reliable results.

Methods and results

The research was carried out by way of an operational simulation analysis (Tannuri & Martins, 2018) using a Transas Navi-Sailor 4000 navigational and maneuvering simulator. The operational simulation tests (Almaz & Altiok, 2012) aimed to provide answers to questions concerning the operation of trailing suction hopper dredgers (TSHD) within the approach fairway of the Port of Gdynia during normal shipping hours.

For the simulation of the dredging of the port approach fairway, the vessels with the most convenient parameters were chosen (Figure 1).

The purpose of the simulation test is to verify both the timing of each stage of the dredging work schedule and to determine the maneuverability and navigation capabilities within the waterway of concern. In this case, the waterway to be dredged is the approach fairway area between the bathymetric coordinate –17 m and vessel turning area 1 in the Port of Gdynia (Figure 2). The surface length of the

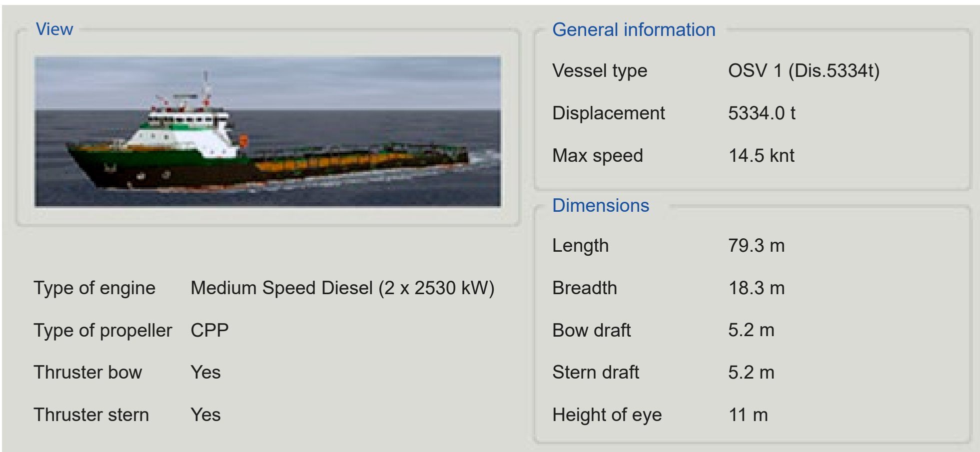

Figure 1. TSHD dredger simulation parameters shown by the Transas Navi-Trainer 5000 Simulator

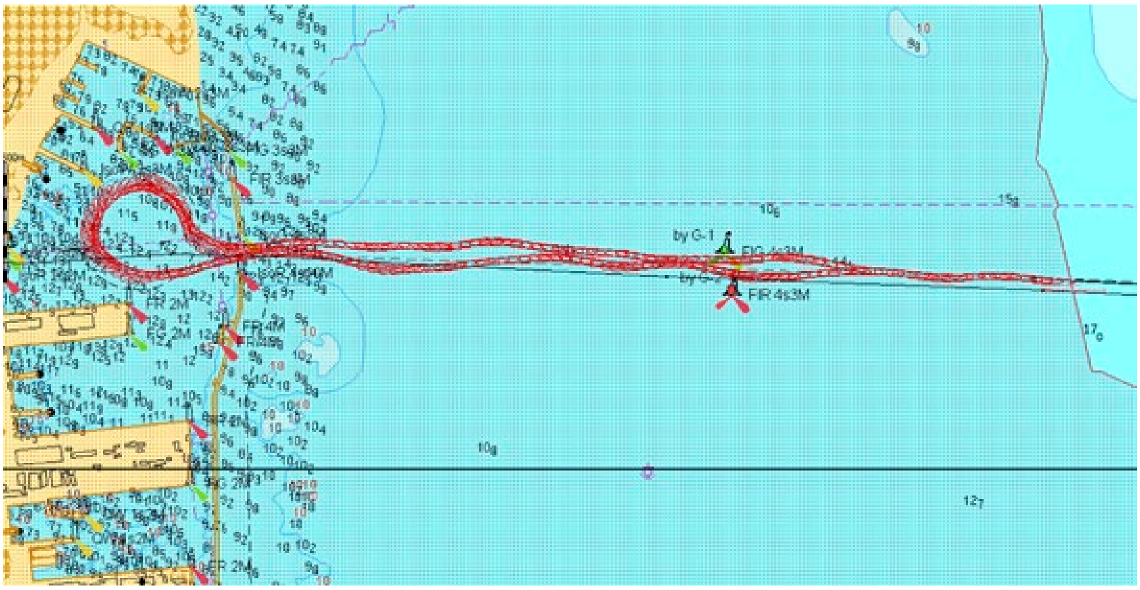

Figure 2. Map of the area to be dredged as part of the research project and the model trajectory of a THSD dredger shown by the Transas Navi-Trainer 5000 Simulator

work area is approximately 3800 m, and the planned width of the fairway is 280 m. The initial estimate of the weight of the dredged material by the investor is 3.3 million m^3. The excavated material will be discharged at the Gdynia Port dumpsite, which is located 4.4 nautical miles northeast of the port's main entrance (central coordinates of the dumpsite: 54°33.3' N; 18°42.5' E). The hydrometeorological conditions assumed in the simulation are 'very good' with wind force of up to 5 knots and a wave height of approximately 0.4 m (Figure 3).

The dredger has a total length of 79.3 m, a width of 18.3 m, and can dredge to a maximum depth of 5.2 m. It has its own hold, with an estimated filling time when dredging to a depth of –20 m in well-worked areas of approximately 2 hours. The maximum speed of the dredger during sailing to the slip is 14.5 knots, and the speed during dredging is between 2 and 3 knots. During loading of the material through the bottom traps, the dredger reduces its speed to 3 knots.

As a result of the load capacity and the high dredging efficiency of the proposed dredger, the deepening of the approach fairway of the port of Gdynia may be completed in a single stage. In such a scenario, the dredger begins dredging at 17 m depth and continues in the direction of the harbor where it completes its work at the breakwater heads in order to turn around at vessel turning area 1 (avanport) and return to the approach fairway (Figure 4). After leaving the port, the dredger returns to the work area and continues dredging. The simulation time for a single working passage through the work area is

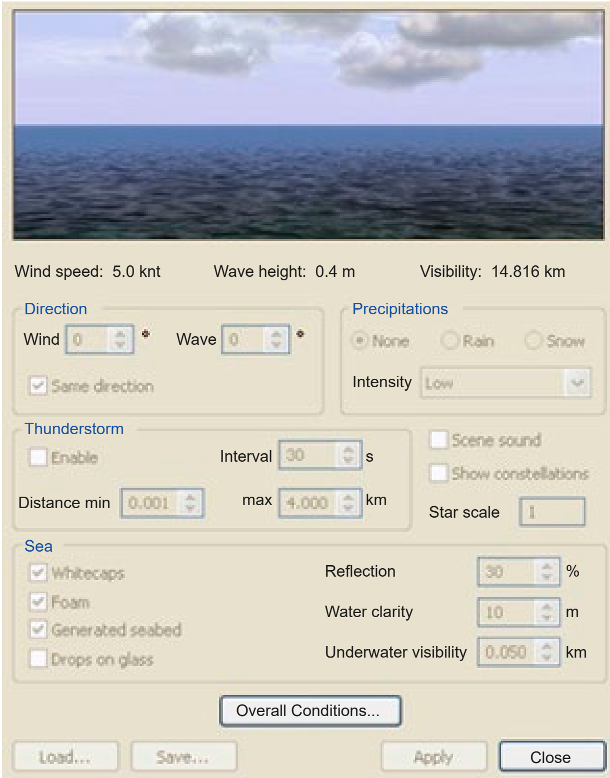

Figure 3. Assumed hydrometeorological conditions shown by the Transas Navi-Trainer 5000 Simulator

approximately 50 minutes, and turning the dredger within the vessel turning area at a speed of 2–3 knots takes approximately 20 minutes.

Based on the above verification, it can be determined that the filling of the hold that allows the vessel to set sail for the discharge location takes place after two working passes through the working area. The estimated time of travel for a round-trip to the

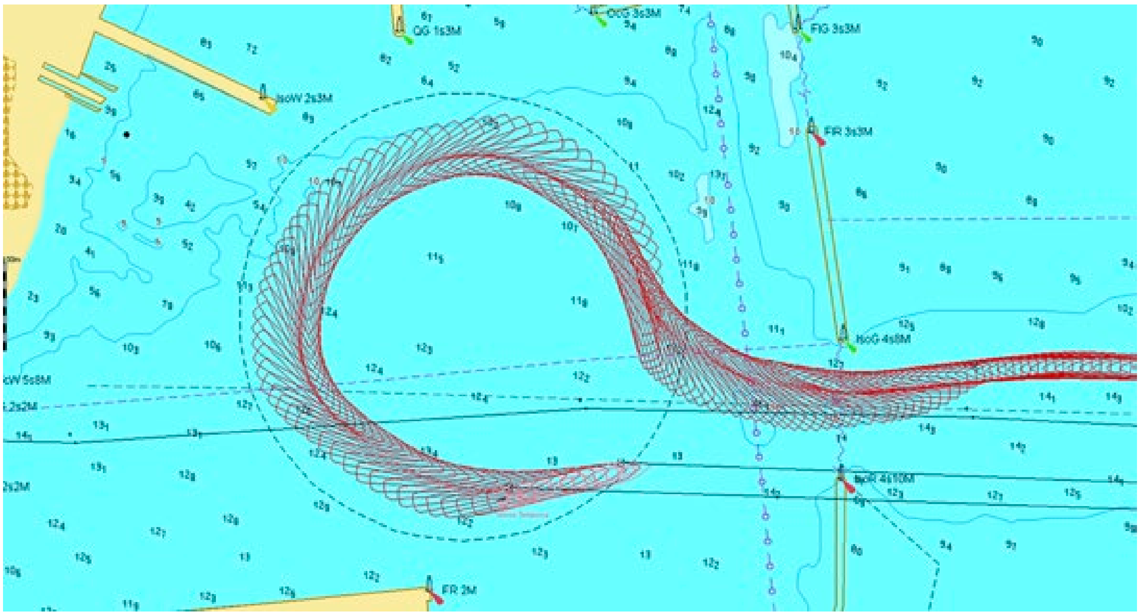

Figure 4. Simulation of a turn-around of a TSHD dredger at vessel turning area 1 in the Port of Gdynia shown by the Transas Navi-Trainer 5000 Simulator

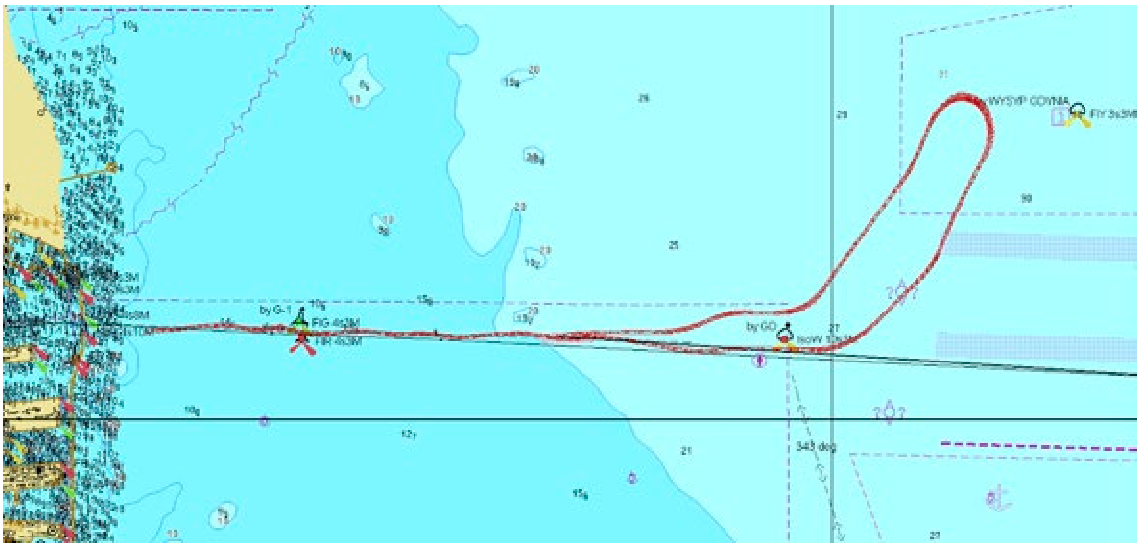

Figure 5. Map of the proposed dredging area and the location of the dumpsite shown by the Transas Navi-Trainer 5000 Simulator

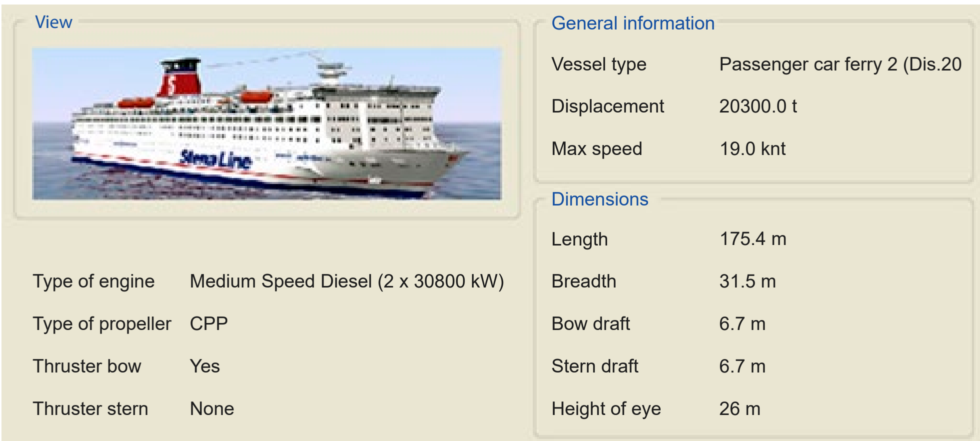

Figure 6. Technical specifications of the Stena Line passenger ferry simulator model shown by the Transas Navi-Trainer 5000 Simulator

Port Gdynia dumpsite in accordance with Figure 5 is 1 hour.

The estimated time for the completion of the verified project based on the proposed dredging work scenario is 495 working hours (approx. 21 days), assuming the uninterrupted operation of the dredger 24 hours per day and 7 days per week. Such a work scenario does not consider technological breaks, public holidays, bunkering, restocking, crew changeovers, and other impediments to the organization of the dredging process.

The simulation of the passing of a typical Stena Line Passanger ferry, a ferry operator that regularly calls at the port in Gdynia (Figure 6), with the dredger was also performed. According to the results of the simulation, the passing of the ferry and the dredger at the current width of the approach fairway (150 m on the seabed) is possible with a distance of approximately 60 m between the vessels (Figure 7).

Discussion and summary

The execution of dredging projects constitutes an impediment to the uninterrupted movement of ships, thereby affecting the organization of port operations (Kaizer, 2020; Kaizer & Neumann, 2021). Depending on the area of operation of dredging vessels and the size of the dredging fleet, such an impediment may negatively impact the transshipment efficiency of port terminals. This results from the necessity

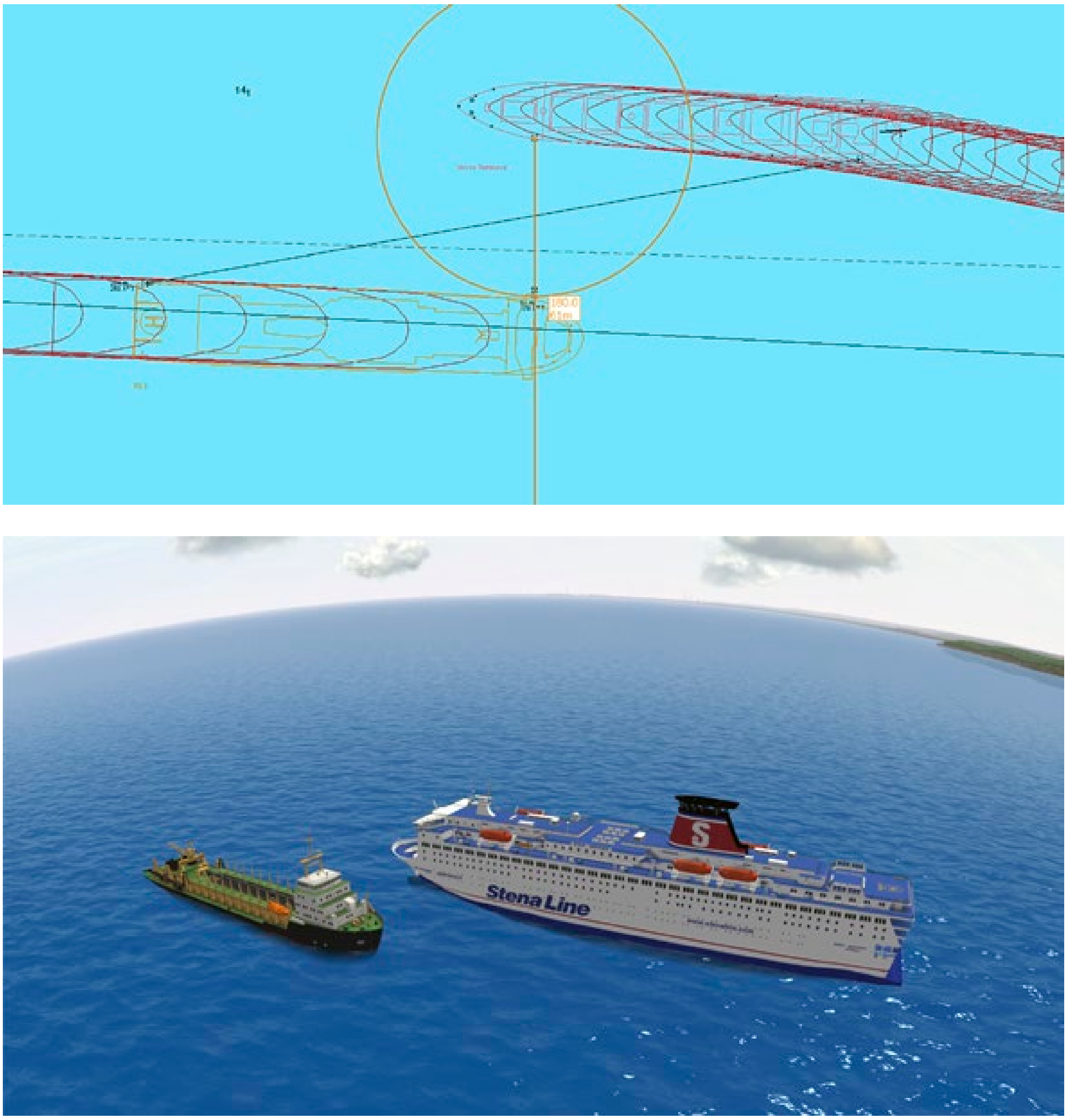

Figure 7. Simulation of the passing of the dredger and a Stena Vision ferry on the approach fairway of the Port of Gdynia with both vessels in motion (Transas Navi-Trainer 5000 Simulator)

for extreme caution when passing or overtaking an operational dredging unit. The scope of navigation safety regulations, both for dredgers and any other vessels located in the area of dredging works, is regulated by the COLREG regulation and local regulations supervised by harbor masters' offices.

Simulations based on actual data and carried out according to the author's solutions allow the most convenient working technologies to be used in conjunction with the proposed schedule, thus keeping costs and work time to a minimum (De Padova et al., 2020).

Unfortunately, however, it should be emphasized that the proposed solutions are not without limitations because they require the use of many simulator models, which closely represent the selected equipment in order to obtain reliable results. There are, therefore, high costs associated with the purchase of specific simulators.

It is the opinion of the author that an analysis of the conditions in which dredging work is to take place provides results that are instrumental in determining the most appropriate equipment and convenient work schedule to be proposed. These simulator results can be used for cost reduction and efficiency improvement of both dredging and port terminal operations as well as the operation of vessels in waterways currently undergoing dredging works (Soliwoda, Kaizer & Neumann, 2021). The proposed solution may be extended using additional computer applications and, therefore, constitutes a valuable tool in the research and monitoring of planned and ongoing dredging projects (Jung et al., 2007; Kouřil & Liarokapis, 2018; Myszka & Kaizer, 2020).

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