

# Nautical Access Study Based On Real Time Bird's Eye View Simulations

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**ABSTRACT:** Real time ship manoeuvring simulations are a valuable source of information in the detailed design phase of nautical studies. The feedback of pilots, which is not available for fast time simulations that are carried out by a computerized autopilot, is an important asset in the evaluation of the feasibility of ship manoeuvres. However, real time simulations are significantly more expensive in that realistic 3D visuals are needed so that the pilot can immerse himself in a sailing environment. Modelling and generating such 3D views is time consuming and requires expensive hardware and special skills. Real time simulations that offer only a 2D bird's eye view for the execution of manoeuvres by pilots, can sometimes be used as a cheaper and faster alternative. This paper presents a case study that evaluates the nautical access to two harbours and discusses some of the advantages and disadvantages of a real time bird's eye view setup

## 1 INTRODUCTION

Different stages should be considered in the design of harbours involving diverse tools. As described in the methodology to design a navigation channel provided by PIANC [4], a concept design is initially selected based on guidelines. This first design can then be used as a basis to develop a more detailed design which consist of refining the initial one using more accurate input data. At this stage, a real time simulator is a useful tool to reproduce the behaviour of the vessels in specific hydro-meteorological conditions and to assess the operational limitations of the selected design based on nautical expertise as well as feedback from pilots.

Real time simulations are also used extensively to evaluate the accessibility of larger ships using existing access channels, as for example is the case for ships calling the port of Antwerp [2]. Specific critical locations can be examined and the results of the

simulations can be used to propose solutions to tackle those bottlenecks by for example proposing additional AtoN (Aids to Navigation). Full mission bridge simulators can also be used for the improvement of vessel traffic services and personnel training to improve safety of navigation as presented by Senčiča et al. [7].

The level of realism of simulations relies mainly on the accuracy of the mathematical manoeuvring model and of the hydro-meteorological model which are used to reproduce the behaviour of a specific ship in specific environmental conditions. The degree of realisms can differ significantly. For example, the bottom of a waterway could be represented as a flat hard surface, but could also be represented as an irregular surface composed of mud with varying density properties (e.g. [8]). Although it is common practice to use state of the art mathematical models and complex post-processing techniques to implement accurate hydro-meteorological data as described by

Donatini et al. [1], it is difficult for a pilot or a client to perceive this level of complexity. Indeed, the core of the simulator is hidden behind its walls and the fidelity of the visual setup can sometimes have a more significant influence on the user immersion [5].

An important advantage of full mission bridge simulators is the integration of the human factor but this involves challenges to guarantee a good immersion of the user. Therefore, it is important to reproduce the ship bridge as completely as possible with all the monitors and controls that could be found in real-life [3]. The pilot can then interact with this interface and displace the ship in an environment with the same level of easiness/difficulty as in reality. The visualization of the environment above the waterline is the main aid for the pilot to position the ship. Most simulators reproduce the environment in 3D and display it in front or around the pilot. However, depending on the level of details and the size of the environment, the development of this three-dimensional environment can have a significant impact on the cost and preparation time of a project.

This paper describes the use of real time simulations that are carried out to assess the operational limits of two ports within a limited time frame. In order to reduce time and cost, the study was carried out using a specific two-dimensional bird's eye view setup to represent the outside view on the harbour as an alternative to a 3D view which can be found on most common full mission bridge simulators.

Section 2 explains how these real time simulations were set up. Section 3 presents the criteria which were used to evaluate the safety of entrance and exit manoeuvres and discusses the results. The advantages and disadvantages of the 2D view in comparison to a 3D view are discussed in section 4. In Section 5, finally, the conclusions are given.

## 2 2D BIRD'S EYE VIEW SIMULATOR

### 2.1 Objectives of the study

In order to assess the accessibility levels of new designs for the ports of Ténès and Annaba in Algeria, a simulation study was commissioned by Laboratoire d'Études Maritimes (LEM) and executed by ISL Ingénierie together with the Maritime Technology Division at Ghent University (UGent) and Flanders Hydraulics Research (FHR). Different manoeuvres of entry and exit of the ports (total number of 50) were simulated with bulk carriers, container ships and general cargo ships of different sizes in the most critical hydro-meteorological conditions (two for each port) in order to determine the maximum allowable size of the vessels calling to both ports and the operational limits.

### 2.2 Manoeuvring simulator

The simulations were carried out on one of the full mission manoeuvring simulators at Flanders Hydraulics Research dedicated for maritime studies and training. This maritime simulator is composed of

a ship bridge with a 225° aerial view projected on screens as shown on Figure 1. The 3D view displayed outside the windows of this ship bridge requires some 3D designing work and large graphics resources which would have been too time consuming and would have significantly increased the cost of the total study presented in this paper. In order to save some time and to restrict the overall cost of the project, it was proposed to the client to carry out the simulations using a two-dimensional bird's eye view. Hence, no 3D visuals needed to be prepared and the screens displaying the outside view on the ship bridge were turned off. Instead, the environment was displayed on a monitor located in front of the pilot, as shown in Figure 2.

During the simulations, the pilot can visualize the contour of the ship moving in the 2D representation of the port, the coastline and the boundaries of the approach channel (when available). Other information such as wind direction and speed, ship's speed and under keel clearance are displayed as well.



Figure 1. Manoeuvring simulator for maritime studies (Flanders Hydraulics Research, Belgium).

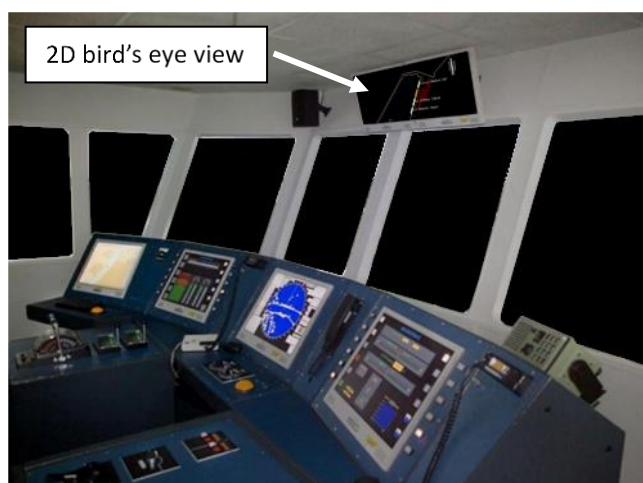


Figure 2. 2D bird's eye view of the Port of Ténès as seen by the pilot on the simulator.

### 2.3 Port environment

The part of the port above the water level is represented by a simplified 2D aerial view on the

simulator bridge, as shown in Figure 2. The environment that is shown includes the layout of the port, the coastline and the specific mooring areas for different types of vessels. The approach channel was also displayed for the port of Annaba. No approach channel was designed for the port of Ténès. The part under water is modelled in 3D based on a bathymetric model implemented in the simulator for each port, as shown in Figure 3 for the port of Ténès. This part under the waterline is not shown to the pilot during the real time operations, but is used for the post-simulation analysis.

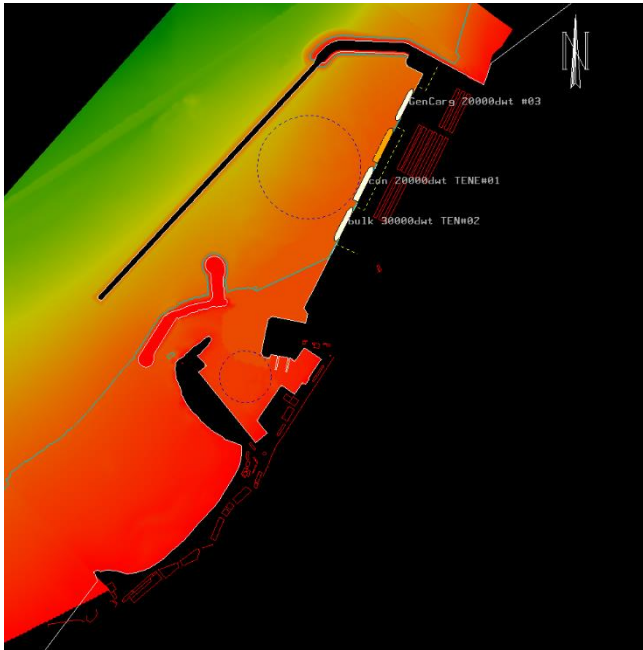


Figure 3. Bathymetry of the port of Ténès. From deep (green) to shallow zones (red).

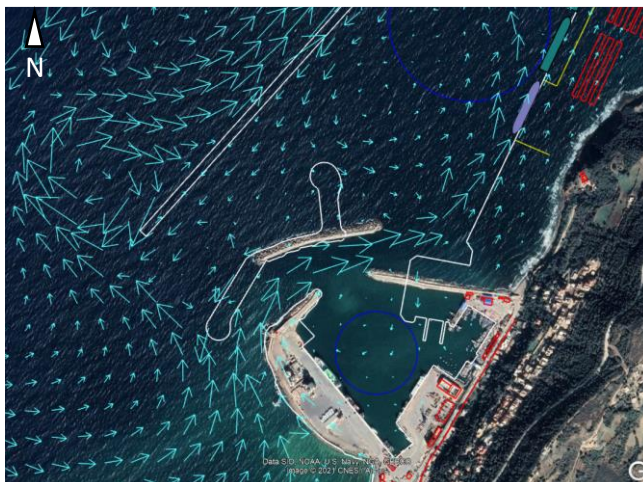


Figure 4. Current field in the extreme hydro-meteorological condition at the entrance of the harbour of Ténès (harbour new design in white).

Wave induced vertical motions were not simulated as they were considered to have a limited impact on the manoeuvres, especially in comparison to the impact of the wave induced currents on the horizontal motions. A second reason is the fact that only a top view is used so vertical motions would not enhance the level of fidelity of the simulations as would be the case in a traditional 3D visual environment.

The currents modelled in the two ports are mainly generated by the annual swell. Two current conditions, referred as moderate and extreme in the next sections, were implemented in the simulator for each of the two ports. These data were provided in the form of current velocity vector fields, as shown in Figure 4 and Figure 5. Wind conditions of force 6 to 9 Beaufort were included as well.

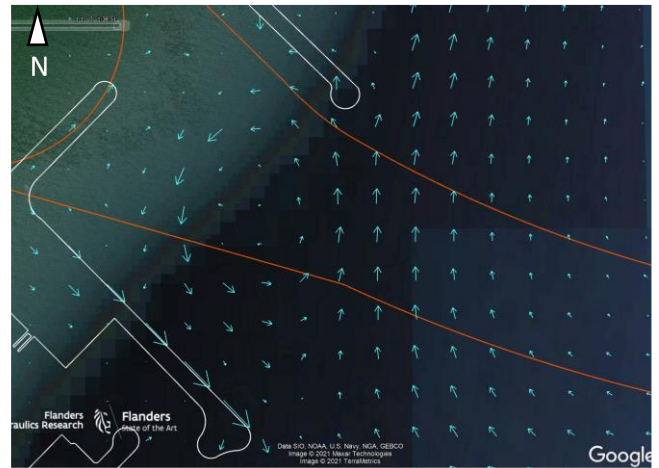


Figure 5. Current field in the extreme hydro-meteorological condition at the entrance of the harbour of Annaba (harbour new design in white, access channel in red).

#### 2.4 Ship models

For this study, four standard manoeuvring models from the FHR database were selected and scaled to represent the 6 design vessels as described in Table 1. ASD tug boats were modelled based on the communicated towing capacities of the ports (see Table 2).

Table 1. Design vessels characteristics implemented in the simulator.

| Characteristics                      | Container ship | Bulk carrier | Cargo vessel |
|--------------------------------------|----------------|--------------|--------------|
| DWT (ton)                            | 20000/30000    | 30000/60000  | 20000/30000  |
| LOA (m)                              | 184/218        | 181/235      | 170/193      |
| LPP (m)                              | 177.1/209.8    | 173.1/224.8  | 162.3/184.3  |
| B (m)                                | 28.7/30.2      | 27/34        | 24.9/27.8    |
| T (m)                                | 10/11.1        | 10.6/13.5    | 10.4/11.9    |
| Bow thrusters (kW)                   | 800            | -            | -            |
| Frontal wind areas (m <sup>2</sup> ) | 924/1079       | 431/691      | 415/531      |
| Lateral wind areas (m <sup>2</sup> ) | 3098/4074      | 1411/2334    | 1228/1595    |

Table 2. ASD tug characteristics implemented in the simulator.

| Port   | Tug  | Bollard pull | Engine power | Mode         |
|--------|------|--------------|--------------|--------------|
| Ténès  | fore | 20 ton       | 1100 kW      | Push or pull |
|        | aft  | 40 ton       | 2x1400 kW    | Push or pull |
| Annaba | fore | 40 ton       | 2x1400 kW    | Push or pull |
|        | aft  | 40 ton       | 2x1400 kW    | Push or pull |

For each simulation, 2 tugs (one attached to the fore part of the ship and one attached to the stern most of the time) were provided and controlled by the

operator, as shown in Figure 6, under the orders of the experienced pilot.

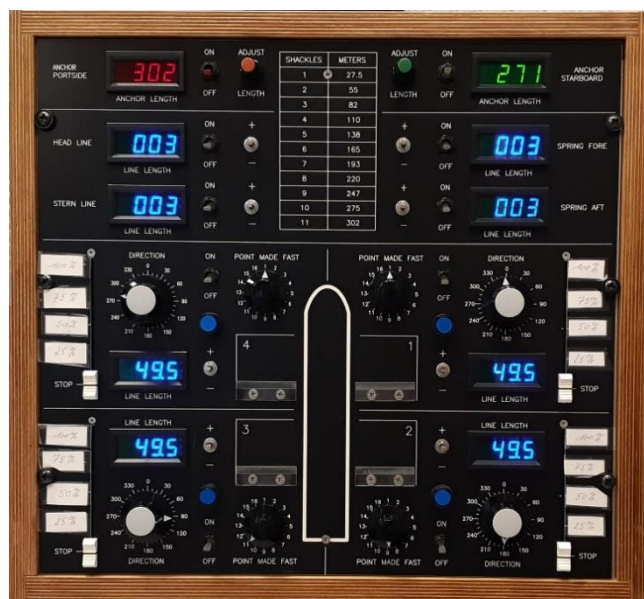


Figure 6. Console dedicated to control 4 tug boats from the instructor room.

Moored vessels models have also been added to the 2D bird's eye view in order to add more realism to the actual situation and available space, especially during a mooring manoeuvre in the port basins.

### 2.5 Pilots

The real time simulations were carried out by 4 different Flemish pilots (Flemish pilotage DABL) during 4 days (one different pilot each day) to check the accessibility level of the critical configurations which were defined while setting up the protocol for the simulations. The pilots are familiar with the simulators at FHR and in particular with port to river entry/exit manoeuvres with vessels of the same size as the design vessels.

The last three days were organized in the presence of the client LEM, ISL and Direction des Travaux Publics (DTP). The last day, two Algerian pilots also performed a number of simulations and shared their local experience and navigational habits with the Flemish pilots.

## 3 MANOEUVRING ASSESSMENT

### 3.1 Methodology

After each simulation, the pilot is invited to the control room to discuss the scenario being tested and sometimes there is an exchange of opinions. The track of the ship is shown to the pilot on the operator screen together with the bathymetry, wind vectors and current vectors, as shown in Figures 3 to 5. The pilot then assigns two marks out of 6 points to the manoeuvre according to an evaluation grid as shown in Table 3. It should be noted that the reserve reflects the safety margin available as estimated by the pilot, while the degree of difficulty reflects the level of

stress and concentration of the pilot. When a run is not acceptable, measures are discussed with the pilots. The nautical expert takes into account the pilot feedback and gives a conclusion on the accessibility level (acceptable or not acceptable) after a more detailed analysis of all the post-processed trajectories and time series of the control parameters (ship's velocity, rudder angles, use of tugs power, current velocities etc...). This analysis is discussed internally and reported to the client with conclusions.. The pilots were instructed to use the tugs only when necessary. The use of the tugs was not imposed, but they were made available for each simulation. The assistance of the tugs was discussed during the analysis of the simulations and specified in the protocol.

Table 3. Protocol and results of the simulated entrance (In) and exit (Out) manoeuvres in moderate (Mod.) and extreme (Extr.) hydro/meteo conditions presented in section 3.2 with BC = Bulk Carrier, CN = Container Ship.

| Simulation protocol |        |      |       | Results  |            |          |
|---------------------|--------|------|-------|----------|------------|----------|
|                     |        |      |       | Pilots   |            | Nautical |
|                     |        |      |       | feedback |            | expert   |
| Port                | Vessel | Dir. | Cond. | Reserve  | Difficulty | Access.  |
|                     |        |      |       | /6       | /6         | level    |
| Ténès               | CN     | In   | Mod.  | 2        | 2          | Acc.     |
| Ténès               | BC     | In   | Mod.  | 1        | 1          | Acc.     |
| Ténès               | BC     | In   | Extr. | 2        | 2          | Acc.     |
| Ténès               | BC     | Out  | Extr. | 2        | 2          | Acc.     |
| Annaba              | BC     | In   | Ext.  | 3        | 3          | Not acc. |
| Annaba              | CN     | In   | Extr. | 1        | 2          | Acc.     |
| Annaba              | BC     | Out  | Extr. | 1        | 1          | Acc.     |

### 3.2 Analysis of entrance and exit manoeuvres

The main results and observations of the simulations are presented in this section through examples of simulated entrance and exit manoeuvres in both ports highlighting the use of the 2D bird's eye view.

Some general observations can first be made. Depending on the vessel type and dimensions, different levels of accessibility were obtained. The container ship is equipped with a bow thruster which allows for more manoeuvres without requiring the assistance of tugs, whereas the bulk carrier and general cargo vessels require the use of tugs most of the time. Bulk carriers and general cargo are also less manoeuvrable. The container ships, on the other hand, can be more challenging to control in strong wind conditions due to the larger windage areas.

An approach in longitudinal current is easier than an approach in cross current. As the current at the port entrance is directed from southeast (cf. Figure 4), the pilots tried to approach the port from the northwestern side, almost perpendicular to the jetty as shown in Figure 7, in order to sail in the opposite direction of the current flow. However, during the manoeuvre it can be noticed that the ship encounters some difficulties while turning to enter the harbour because the current on the stern counteracts with the turning moment of the ship. Powerful tugs are therefore required to assist the ship in its turning manoeuvre, thus allowing to pass safely the harbour entrance. This manoeuvre was not possible in extreme conditions with a bulk carrier.



Figure 7. Entrance of the port of Ténès of a bulk carrier with tug assistance in moderate conditions (vessel in purple, fore tug in orange and aft tug in white).

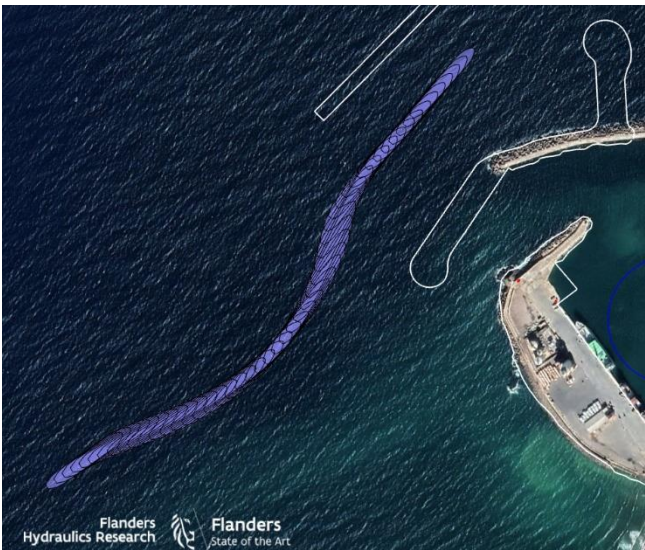


Figure 8. Entrance to the port of Ténès of a bulk carrier with a large drift angle due to current in extreme hydro-meteorological conditions.

To enter the port of Ténès with a bulk carrier in extreme conditions, one of the pilots requested to try an approach with a cross current to evaluate the drift generated by the current flow. Figure 8 shows that the pilot anticipates first the effect of the south east current by sailing to the north east direction and then let the ship drifting for about 100 m. The pilot corrects his heading just before the entrance of the port, which is then protected from cross current. During this manoeuvre it is important to feel the effect of current accurately. During the simulation, the pilot requested to optimize the view on the 2D screen to have a more detailed view on the ship relative to the northern jetty and he had to use the radar and draw lines to visualize the drift motion of the ship which was difficult to estimate on the 2D bird's eye view. In reality or in a 3D environment the pilot would have more reference points to feel the ship drifting.

In moderate hydro-meteorological conditions, an entrance manoeuvre under cross current is also acceptable when a container ship is approaching parallel to the jetty and counteracting the drift due to current and wind with sufficient safety margins when passing the harbour entrance (100 m from the southern jetty), as shown in Figure 9. Tugs were used to assist the ship in the manoeuvre to turn to the mooring area. A collision can be noticed during the

mooring manoeuvre, but the pilot claimed that in reality visual reference points would have helped to position the ship more accurately and would have allowed to prevent the collision. This part of the trajectory could not be exploited since the level of realism of this manoeuvre was not sufficient according to the skipper. Note that this example is only used to illustrate a limitation of the simulation setup and has no consequences on the accessibility assessment which focuses on the approach manoeuvres.



Figure 9. Entrance to the port of Ténès of a container ship with a large drift angle due to current and wind in moderate conditions (vessel in purple, fore tug in orange, aft tug in white).

The entrance of the port of Annaba follows an access channel. In extreme hydro-meteorological conditions, the pilot is using the current effect, shown in Figure 10, and sails very close to the boundaries of the channel (i.e. 6 m was measured from the vessel to the channel boundary), as shown in Figure 10. However, the distance from the ship to the jetty (about 45 m) is accurately controlled since the pilot has a clear view on the channel boundaries on the 2D bird's eye view. In reality, the pilot would see this only on an electronic chart or on the radar. This example shows that the current field and the bathymetry need to be well known by the pilot in those hydro-meteorological conditions.

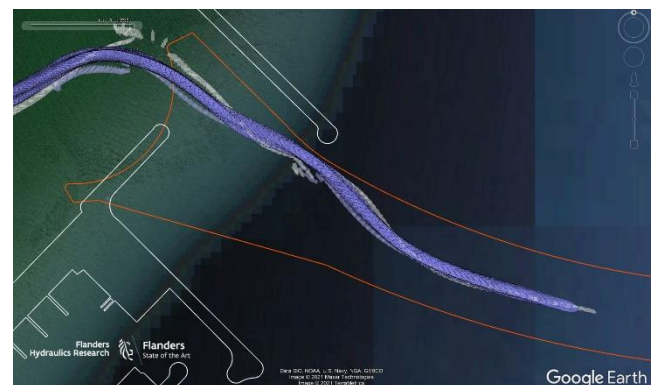


Figure 10. Entrance of the port of Annaba of a bulk carrier in extreme hydro-meteorological conditions (vessel in purple, aft tug in white, access channel dredged to -17 m in red).

After a couple of runs with a container ship in extreme conditions, the pilots recommended to approach the harbour entrance from the south and let the ship drift in the current field toward the north by setting a NNW heading to pass the second jetty and

then turn toward the harbour, shown in Figure 11. Those observations can be used to provide recommendations for the training of pilots.

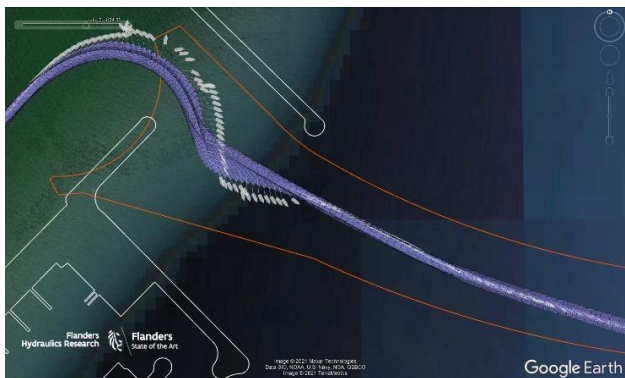


Figure 11. Entrance of the port of Annaba of a container ship in extreme hydro-meteorological conditions (vessel in purple, aft tug in white, access channel dredged to -17 m in red).

To exit the port of Ténès, since bulk carriers and cargo vessels are not equipped with bow thrusters, tugs are used to help the pilot in order to move away from the quay against current and wind, as shown in Figure 12. This manoeuvre was successfully performed on the simulator and the fidelity of the 2D bird's eye view in combination with the tug console was sufficient. It may be noted that the exit manoeuvre is not as difficult as the entrance manoeuvre since the ship can accelerate and reach enough speed and space to manoeuvre.



Figure 12. Exit of the port of Ténès of a bulk carrier in moderate hydro-meteorological conditions (vessel in purple, fore tug in orange, aft tug in white).

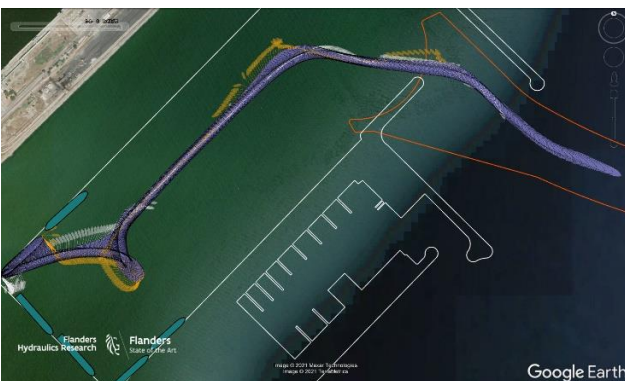


Figure 13. Exit of the port of Annaba of a bulk carrier in extreme hydro-meteorological conditions (vessel in purple, fore tug in orange, aft tug in white, access channel dredged to -17 m in red).

To exit the port of Annaba, the pilot needs to find the best time to initiate the turn toward the exit, as indicated in Figure 13. During the simulations, the pilot managed to find the best spot by calculating his turning rate and estimate the trajectory from the top view. However, in reality this is trickier without electronic equipment. Leading lights were recommended by the pilots to position the ship from the exit extremities of the harbour.

### 3.3 Recommendations for accessibility improvement

Based on the analysis of the ship trajectories and pilots' feedback, different recommendations have been suggested and the main output consists of a proposal for optimal approach trajectories and AtoN. It is worth noting that the simulations were carried out by several pilots, not all of whom were familiar with the site conditions. This enabled several opinions to be obtained on the complexity and the measures to be adopted. The opinions of the different pilots turned out to be quite similar which, thus giving credibility to the assessments provided.

To enter the port of Ténès, two approach paths can be considered according to the pilots' feedback. An approach trajectory from the north, facing the current, requires a 90° turn. It is then necessary to rapidly reduce the vessel's rate of turn once aligned with the jetty to avoid contact with the breakwater or jetty. In extreme hydro-meteorological conditions, this trajectory was validated only for container ships and for general cargo vessels. For bulk carriers, it was advised to approach the port parallel to the jetty, which is less subject to drift due to the wind. Container ships can approach the port aligned with the jetty or from the north. It should be noted that approaching from the north requires a good knowledge of the current and adequate training. An approach parallel to the coastline allows the vessel to sail with a large drift angle for a considerable distance, especially in strong winds.

To exit the port of Ténès, the drift due to wind seems important and the current inside the harbour requires the use of at least one tug. It is advisable to align with the jetty as soon as possible.

The AtoN recommended for the port of Ténès are shown on Figure 14. Vessels must navigate at least 150 m from the northern tip of the jetty in extreme conditions to avoid being in a field of currents reaching high velocities. It is recommended to place two buoys in a 90° line with the jetty and at a distance of 100 m from the extremity. The depth line at -12 m should also be marked with buoys. This identifies the direction of the current along the coastline and aligns with the harbour entrance. This allows vessels to safely approach as close as possible to the coastline to anticipate drift due to the current in extreme conditions when approaching parallel to the jetty.

At the entrance of the port, two 40-ton tugs are needed to assist bulk and cargo vessels to enter the port in extreme conditions. For ships wishing to approach from the north by making a 90° turn, three tugs are required to stop the ship's turn once it has entered and align it with the jetty. Inside the port, two 40-ton tugs are needed to assist bulk carriers and

general cargo ships in their docking manoeuvre. The exit can be carried out with only one tug hooked up to the rear, even in extreme conditions.



Figure 14. AtoN proposed for the port of Ténès (green and red buoys).

To enter the port of Annaba, no specific approach path was suggested since the width of the access channel is wide enough for safe navigation and the orientation of the existing approach path seems natural to pilots. It does not seem to be a priority to add buoys to the access channel, in addition to the buoys required from a regulatory point of view.

The AtoN recommended for the port of Annaba are shown on Figure 15. The green buoy is located in the extension of the northern jetty and delimits the starboard side of the access channel. The red buoy is perpendicular to the southern jetty and delimits the port side of the access channel.

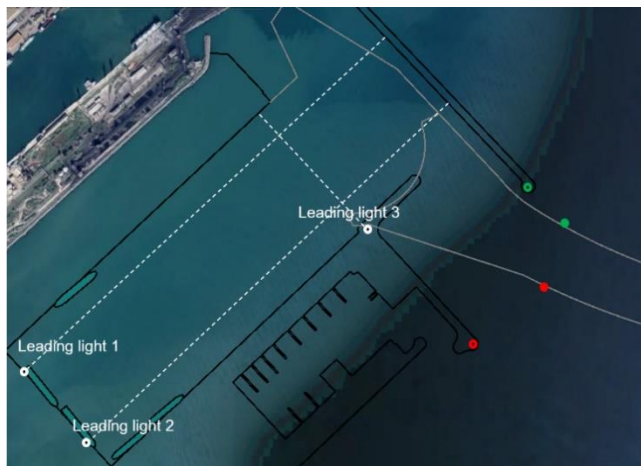


Figure 15. AtoN proposed for the port of Annaba (leading lights, green and red buoys).

At the entrance of the port of Annaba, general cargo vessels require the presence of a tug attached to the stern of the ship with a power of at least 40 ton. Bulk carriers require the assistance of at least two 40-ton tugs for safe entry and exit. Finally, container ships require only one tug to assist them in their entry manoeuvre in average conditions and exit manoeuvre in any conditions, two tugs are required in extreme conditions. Inside the harbour, two 40-ton tugs are needed to push the bulk carriers and cargo ships away from the quay and to make a turning manoeuvre. In addition, in extreme conditions, the tugs must assist these ships in crossing the entrance channel to counter the drift caused by the current. In the event of a NW 7

Beaufort wind, both tugs must assist all types of ships to the quay.

#### 4 EVALUATION OF THE SIMULATION SETUP

The analysis presented in Section 3 shows that it was possible to investigate the level of accessibility of the ports of Ténès and Annaba and its operational limitations using just a 2D bird's eye view simulator. Although the view is simplified, after several runs, a learning curve could be observed and the manoeuvres to be carried out were better anticipated, thus leading to improved manoeuvring conditions. This is in line with reality, where manoeuvres are entrusted to pilots who know the site conditions well. Overall, the study showed that it is possible to give recommendations for harbour improvement and formulate approach/exit guidelines using a 2D bird's eye view simulator.

However, feedback from the pilots indicated that there are several disadvantages related to the use of a 2D bird's eye view simulator. First of all, the execution of the manoeuvres was considered more difficult on the simulator compared to reality because the 2D view does not allow the pilot to have good visual reference points. This was especially true when the pilot needed to pinpoint his position in the harbour and when he needed to feel the drift due to the current at the same time. Some runs with unexpected collisions and missed approaches were in the end omitted because the pilot's feeling about the realism of the manoeuvre was not satisfactory. This led to a repetition of runs. .

A second disadvantage is due to a mismatch between the setup using a 2D bird's eye view simulator and the setup found on a full mission bridge simulator and onboard. Several pilots remarked that they require a good overall view of the ship bridge, rather than having to tweak a button as is the case using a 2D bird's eye view simulator (e.g. to zoom in and zoom out, move, rotate, measure...), because by the time they do, the ship has already moved a couple of meters. With the 2D bird's eye view proposed in this study, this was only possible if a second person would take care of the controls while the first pilot would analyse the 2D screen into greater detail. In reality, a helmsman is also taking care of the controls while the pilot is giving orders. In reality, other crew members would also support the pilot. On the simulator, this means that more persons would need to take part to the study thus leading to an extra cost and a situation that is more challenging in terms of planning and management. An alternative would be that the operator would control the rudder and the propeller, in addition to controlling the tugs, but this can sometimes lead to human erroneous action due to excessive cognitive load. As a consequence, simulations may have to be terminated prematurely, which in turn leads to repeat simulations.

In this study, two pilots could work together at the end of the simulation campaign and the exercise was noticeably easier when one pilot was giving orders to the other one and the first one could focus on the 2D bird's eye view and the use of extra tools, such as the

radar. By drawing target lines, the pilot could estimate the drift due to current. The operator could also assist the pilot by adjusting the position and the size of the 2D bird's eye view for him.

The limitations of the simulation setup are brought up by the pilots during the debriefing moment after each simulation. When the limitations are clearly identified at this instance, some repeat simulations are necessary using some extra information (such as bathymetry and current field) on display. It is therefore preferable to foresee extra time while planning simulations using such a 2D bird's eye view setup so that repeat simulations can be carried out when necessary.

Most of those limitations can be tackled when pilots are already familiar with simulators or the site conditions. However, if a pilot has no experience whatsoever on a simulator and has never experienced the real situation, it is difficult to make a distinction between what should be ascribed to a lack of fidelity or to the pilot's lack of experience. On the other hand, if a pilot is too familiar with the simulator but has no experience with the on-site conditions, his feedback on the safety of the manoeuvre might be biased as the level of stress during the simulation is less important than in real life, especially if the level of immersion is low. Therefore, it is important that the pilot feels comfortable with the tool while simultaneously experiencing a sufficient level of immersion. During the study, both type of pilots (i.e. a pilot who had not worked with a ship manoeuvring simulator before on the one hand and a pilot who performs simulations very regularly but who was not familiar with the site conditions on the other hand) were present and it could be noticed that both pilots were complementary.

A 2D bird's eye view can therefore be sufficient for studies where the pilot knows the site conditions well, but it is recommended to carry out the simulations with more than one pilot present. In this way, they can share opinions and help each other to manipulate the tools. An advantage of having two pilots involved in a study, is having two different opinions on the manoeuvres that have been carried out. A disadvantage of having two pilots involved is the extra budget that needs to be taken into account. However, this extra budget in general is relatively small in comparison to the budget that is required to generate complete 3D visuals of the environment in which the simulations are carried out.

Another advantage of using simulations with a 2D bird's eye view is that adaptations can be applied easily and quickly. Moreover, these simulations can be run on any computer without requiring a lot of computing power and without requiring a series of display screens. For instance, small training computers were suggested to the pilots of the port of Lomé after a design study conducted at Flanders Hydraulics Research, as shown in Figure 16 [9].



Figure 16. Example of a simple setup with a 2D bird's eye view.

3D visuals have become the standard on ship manoeuvring simulators worldwide and they do appear necessary in confined environment or in scenarios where visibility is an important factor for the safety of the manoeuvre (e.g. an inland navigation vessel sailing under a bridge). The use of 3D views could also be relevant when waves and vertical motions are implemented in the mathematical model [6].

Moreover, not all ports are equipped with electronic AtoN (e.g. Portable Pilot Unit) and it is possible that those devices do not function properly. Therefore, visual AtoN, such as lights and buoys, are necessary. Recommendations from simulations with a 2D bird's eye view will only be able to provide an approximate location for these visual aids. These positions would need to be implemented in a 3D environment to make sure that the visual aids are clearly visible from the ship bridge.

One alternative to a 2D bird's eye view would be to provide a very simplified representation of specific reference points in a 3D environment. However, the poor level of details seen on the screens could give a wrong impression about the quality of the study. Some pilots will, for instance, feel better immersed and will focus more easily on a realistic simulator and some clients will also be more convinced by the quality of the study by what he sees rather than what is hidden in the core of the simulator.

No matter what level of detail is selected, there is always a difference from the view in reality and it is important that the level of fidelity, i.e. the limitations of the realism of the simulation tool, is well known during the analysis of the data and well reported to the user and the client.

Nowadays technology allows to develop detailed 3D visuals relatively quickly and easily by virtue of powerful computers, graphical cards and software development. New technologies are now going towards Augmented Virtual Reality and solutions for which the outside view of the simulator would for instance follow the eyes of the pilot. Similar to the level of accuracy of a mathematical model (3 degrees of freedom (DOF), 6 DOF, 6 DOF including bank effects, 6 DOF including waves...), the cost and time of the development of the visuals need to be balanced with the required level of realism for the purpose of a study and the public. As shown in the overview in Figure 17, simulations using a 2D bird's



eye view only could nevertheless have their place for certain studies where the execution time and the overall cost of the project are restricted.

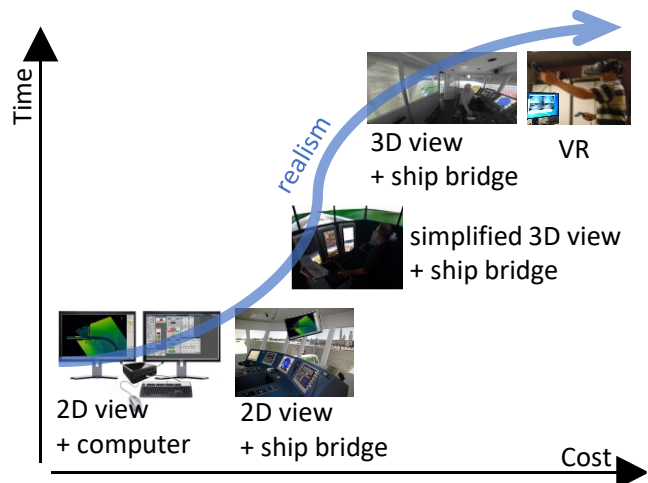


Figure 17. Comparison of cost, time and realism of different solutions for the visual representation of ship manoeuvring simulations.

## 5 CONCLUSIONS

A study was carried out to evaluate the operational limits of a concept design proposed for two harbours. Real time simulations were carried out with experienced pilots on a dedicated full mission bridge maritime simulator at Flanders Hydraulics Research using a 2D bird's eye view setup as an alternative to the common 3D views to optimize the timing and budget of the study.

The use of a 2D view was sufficient to identify bottlenecks and suggest solutions to improve the port operations and except from the pilots experiencing difficulty to be fully immersed in the environment, the harbour design could be validated for the current operational limits. As a consequence, recommendations on required AtoN and training of pilots were provided to the client who commissioned this study.

The difficulties related to the lack of realism of the simulations were fully identified and taken into account in the analysis. The study shows that the combination of experienced pilots and the use of 2D bird's eye view simulator can be used able to test a design and to help to understand bottlenecks during a study or a training.

The level of details and type of visuals (2D or 3D) used to represent the outside view of the simulator needs to be specified in the simulation report and the level of realism of the simulator should be taken into account and discussed in the analysis.

This study has shown that in spite of all these developments, real time simulations using a 2D bird's eye view could be a valid option if budget and execution time are a limiting factor. Nevertheless, it is

recommended to carry out these simulations with at least two pilots with complementary experience (port and simulation based).

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