TRANSNAV
http://www.transnav.eu
the International Journal
on Marine Navigation
and Safety of Sea Transportation
Volume 14
Number 3
September 2020
DOI: 10.12716/1001.14.03.07

Development of Evaluation Procedures for Watchkeeping Officers Using Bridge Simulator

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ABSTRACT: A comprehensive assessment of watchkeeping officers should be considered as a preventive measure in terms of safety of navigation. Watchkeeping officers are assigned after passing exams of state authorities and various evaluation procedures of companies. However, they are not subjected to comprehensive evaluations with practical implementations. Therefore, this study aims to develop effective use of simulators in terms of comprehensive evaluation of watchkeeping officers. In this study, simulation was designed with Goal-Directed Task Analysis (GDTA) technique to indicate important points on the situations watchkeeping officers face in navigation. 3 parameters were determined for difficulty adjustment; visibility, traffic density, geography. At the last phase of this study, performance evaluation method was prepared for performance evaluation of watchkeeping officer and scenario was evaluated for comprehensiveness by oceangoing masters. Hereby, the developed performance evaluation method for navigation can be used to generate more reliable method to evaluate the officers' competence of technical skills.

1 INTRODUCTION

Watchkeeping officers are evaluated according to exams by state authorities and company evaluation procedures during recruitment, promotion and being certificated. However, these theoretical exams and procedures don't cover evaluation in terms of practical application. The evaluation bases such as reactions to compelling navigation circumstances of watchkeeping, the way they show their navigation skills and experiences at bridge could just be seen with the simulation which is real-like and has different difficulty levels. In this regard, to perform evaluation phase more efficiently, it has been surmised that using bridge simulator would be an effective method.

By compiling comprehensively from international conventions, guidebooks and company ISMs (International Safety Management), requirements for officers and procedures during navigation in different circumstances should be well considered. At this point, competences that STCW (Standards of Training and Certification of Watchkeepers) asks to officers and which competences could be evaluated with education based on simulator are stated in this study. In addition, watchkeeping principles, how to maintain a proper look-out, the principles of performing navigation watch are stated. Moreover, information about rules that are obligatory to obey by COLREG (Convention on the International Regulations for Preventing the Collisions at Sea) and two important subjects in BPG (Bridge Procedure Guide), situational awareness and risk of collision, are detailed.

In the light of this information, the study aims to create a bridge simulator application that could be

used for evaluating the watchkeeping officers effectively and comprehensively. It was planned that writing a scenario consists of four steps and difficulty levels increase at each step, then these scenarios were rendered as playable in simulator.

In the study, firstly the following questions were answered:

- What are the requirements that are asked to watchkeeping officers by international conventions, guidebooks and companies for safe navigation?
- What should be considered to write a scenario that could supply best efficiency?
- What are the required parameters for evaluating watchkeeping officers most effectively in simulator?

1 GENERAL REQUIREMENTS AND RECENT STUDIES

1.1 *General requirements for watchkeeping officers*

With STCW convention many rules came into force about standards of competence. These competences can be demonstrated with four different methods and one of these methods is simulator training. Also this convention provided watchkeeping principles in general as well as explanation of watchkeeping under different conditions and in different areas. How to maintain a look-out and how to perform the navigational watch are also its significant topics about watchkeeping issue. All these topics under STCW serve to improvement of watchkeeping skills and are guide for watchkeeping officers.

For safety of navigation all vessels must comply with rules of COLREG. Especially on high traffic density areas COLREG plays an important role in collision avoidance. A safe watchkeeping depends on following the rules of COLREG. Therefore watchkeeping officers must know, understand and apply the rules.

Apart from STCW and COLREG, other significant informations are gathered from Bridge Procedures Guide and ISM system. Situational awareness and risk of collision are stated in this study according to BPG. On the other hand the requirements for watchkeeping under restricted visibility and during coastal navigation as well as CPA (Closest Point of Approach) /TCPA (Time to Closest Point of Approach) limits are investigated.

1.1.1 *STCW*

An officer in charge shall be required to plan and conduct a passage and determine position as a competence. Officer must have the ability to determine the ship's position by use of landmarks, aids to navigation including lighthouses, beacons and buoys, dead reckoning, taking into account winds, tides, currents and estimated speed. He/she must also have the ability to perform those by use of electronic aids. STCW also requires competence for manoeuvre. Depending on this competence officers must have the knowledge of the effects of deadweight, draught, trim, speed and under-keel clearance on turning circles and stopping distances and the effects of wind and current on ship handling. For any man over board situation all officers shall know the manoeuvres and procedures for the rescue of person overboard. Also squat, shallow-water and similar effects must be known as well as proper procedures for anchoring and mooring (STCW, 2011). All abilities mentioned above, can be demonstrated in bridge simulator.

1.1.2 *COLREG*

The following rules of COLREG can be evaluated in simulator. Rule 5 (Look-out) which is laid emphasis on STCW and BPG, Rule 6 (Safe speed), Rule 7 (Risk of collision). A watchkeeping officer should be aware of the collision risk according to the related conditions under the Rule 7 (Deseck, 1983). Rule 8 (Action to avoid collision), Rule 9 (Narrow channels), Rule 10 (Traffic separation schemes), Rule 13 (Overtaking), Rule 14 (Head-on situation), Rule 15 (Crossing situation), Rule 16 (Action by give-way vessel), Rule 18 (Responsibilities between vessels), Rule 19 (Conduct of vessel in restricted visibility) and light, shape and sound signals can be also evaluated in bridge simulator.

1.1.3 *Bridge Procedure Guide*

Bridge Procedures Guide of International Chamber of Shipping is a well-known guide book for safe bridge procedures. It is generally used by Masters, watchkeeping officers, companies and training institutions. BPG emphasises the importance of situational awareness of watchkeeping officers for safe conduct of vessels. BPG also gives suggestions about risk of collision. These suggestions must be taken into account to avoid any risk of collision situation.

According to BPG, a qualified watchkeeping officers should develop and maintain situational awareness of the area around the ship, the ship's activities and the possible impact of external influences on the safety of the ship. And this awareness must include following issues (ICS, 1998).

- A clear understanding of the passage plan;
- An effectively managed Bridge Team;
- A proper and continuous look-out by all available means;
- Familiarity with and understanding of bridge equipment and the information available from radar, AIS, ARPA and ECDIS;
- Using look-outs, ECDIS, radar and visual monitoring techniques to confirm the navigation safety of the ship;
- Using look-outs, radar and ARPA to monitor traffic; and
- Cross-checking information from different sources.

1.1.4 *Company ISM*

ISM systems of shipping companies have directives on different navigation conditions like restricted visibility, coastal navigation for watchkeeping officers. These include efficient radar

practices, position fix methods, monitoring of traffic etc. Some company ISM can also define the minimum CPA and TCPA; "*if the circumstances permit, the CPA should be at least 1.0 nm and the TCPA should be at least 15.0 minutes, if not; the turning circles of the vessel should be taken into account to define the minimum CPA/TCPA. Minimum CPA should not be set at radars less than the diameter of the ship specific turning circle from 0° to 180º and minimum TCPA should not be set less than the time which vessel completes its turn to a contrary heading with maximum rudder angle. If the vessel navigating at Pilotage waters, canals or straits CPA and TCPA values should be set as safe as possible*."

1.2 *Recent studies*

In earlier studies, Cook et al. (1981) performed a simulator study to assess cognitive performances of marine officers. They used the criteria which are mean track, cross track variability (XTE), mean speed and rpm, mean frequency of engine, rudder and course orders, mean CPA to each vessel and lowest CPA to each vessel for performance measurement.

In other studies, the complicated scenarios those difficulty levels vary from easy to difficult, were used for performance measurement. Robert et al. (2003) constituted 6 scenarios including routine or emergency collision threat, alterable or fixed target behaviour and traffic density. They took the variabilities of collision risk, deviation from track, course changes, rule following, target acquisition, test manoeuvre, bearings taken for ship control measures. Grabowski and Sanborn (2003) determined better performance parameters of operators as smaller XTE, fewer manoeuvring order command, fewer communication and sufficient CPA in three levels of navigation scenario. While lower level of scenario contains clear visibility and low traffic, medium level has high traffic and equipment failure and high level of scenario contains tidal currents, speed restrictions, restricted waterway, traffic congestion, bad weather and heavy traffic. Similarly, Gould et al. (2009) developed the difficulty levels of the scenarios for performance evaluation using geography, visibility and traffic density variables.

Kim et al. (2010) constituted the scoring index including collision avoidance ability, decision making time and degree of deviation based on only COLREG rules. Maurier et al. (2011) in the same way as in previous studies, have performed performance measurement in routine and unplanned events by making the traffic multilevel. Kircher and Lutzhoft (2011) used criteria such as position taking, rule following (COLREG), and detection range of targets, keeping a safe CPA, communication and attention variabilities for performance evaluation with the similarity of previous studies.

2 METHOD

2.1 *Goal-Directed Task Analysis (GDTA) for scenario design*

In the performance evaluation, the GDTA method which is based on the Situation Awareness (SA) model of Endsley (1993) (Figure 1) was used for the outputs requested from the operators. According to model, situation awareness is the *perception* of the elements in the environment within a volume of time and space, the *comprehension* of their meaning, and the *projection* of their status in the near future (Endsley, 1993).

Figure 1. Goal-Directed Task Analysis model (Endsley,1993).

The outputs requested from the operators has integrated to GDTA in maritime domain as in Figure 2. These are collected and harmonized from previous studies.

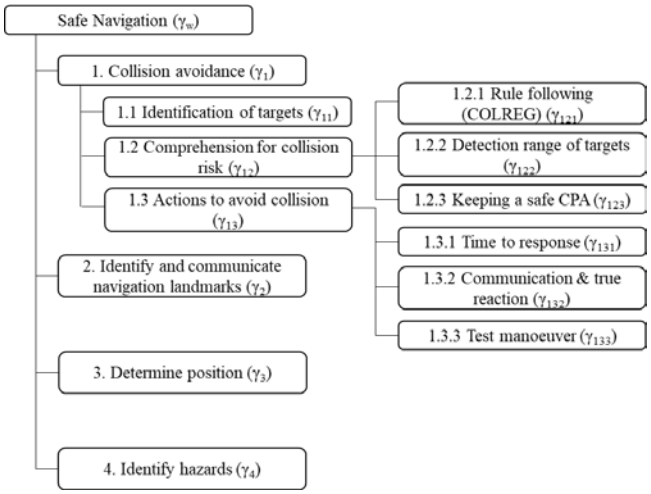

Figure 2. Integration of GDTA to safe navigation parameters.

While 'Safe Navigation' is main goal of the task, 'Collision avoidance', 'Identify and communicate navigation landmarks', 'Determine position' and 'Identify hazards' are sub-goals of the task. The items 1.1, 1.2 and 1.3 are respectively perception, comprehension and projection process items of SA model. Scoring index of performance will include the items such as 1.2.1, 1.2.2 etc.

Figure 3 presents the integration of GDTA to better performance parameters in similar with the integration of GDTA to safe navigation parameters.

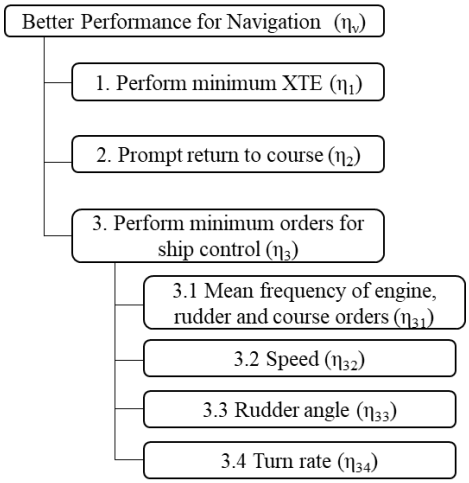

Figure 3. Integration of GDTA to better performance parameters.

2.2 *Ship, geographical area and voyage particulars for created scenario*

A LNG vessel was chosen for scenario (Figure 4). She has 297,5 m length overall and 10,8 m maximum draft. Dover Strait was chosen to ensure having realistic conditions of strait passage in terms of traffic density (Figure 5).

Figure 4. The LNG vessel used in scenario

Figure 5. Dover Strait

More than 400 commercial vessels use the Dover Strait every single day. Geographically, Dover Strait has strong tides, sandbanks, shoals. Weather condition can change rapidly. Also restricted visibility is possible and this situation makes navigation difficult. Cross channel traffic density is high because of ferries. (UK., 2018)

The scenario was divided to 4 steps those have different difficulty levels. 3 parameters were determined for difficulty adjustment:

- Visibility
- Traffic density
- Geography

The outputs requested from operators vary with regard to the difficulty level of step.

2.2.1 *Step 1*

As difficulty levels of first step, operator perform the scenario in high visibility, low traffic density and easy geography. The operator is requested to alter course to starboard to avoid collision and overtake another vessel as seen in Figure 6.

Operator should consider the related COLREG rules about collision avoidance and overtaking situations in this step. Moreover he/she is evaluated according to the better performance parameters for navigation (Figure 3).

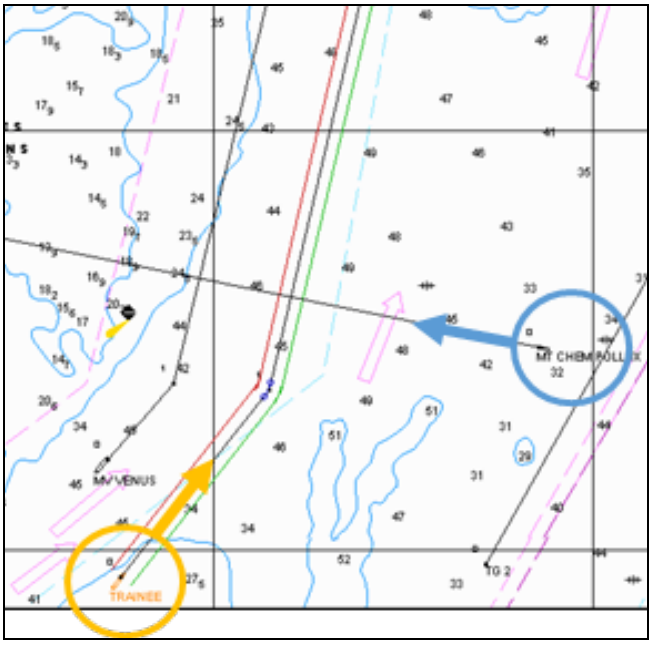

Figure 6. The interactions of Step 1.

2.2.2 *Step 2*

In this step of the scenario, visibility is high, traffic density is moderate and geography is easy. Operator is requested to perform the necessities of vessel being overtaken and do necessary actions for two risks of collision as seen in Figure 7.

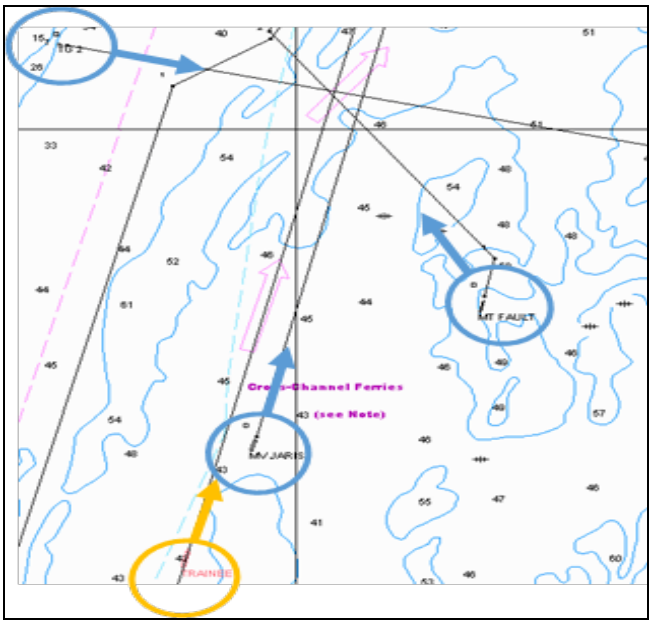

Figure 7. The interactions of Step 2.

Operator should consider the related COLREG rules as previous step and try to perform scenario in area where the traffic density is higher than first step.

2.2.3 *Step 3*

Visibility is moderate, traffic density is high and geography is moderate in third step of the scenario.

At the beginning of the step, the vessel which is at the other side of the separation, is altering her course and making a short cut. This causes collision risk for operator later. Besides, operator is requested to handle two more collision situations during the step (Figure 8).

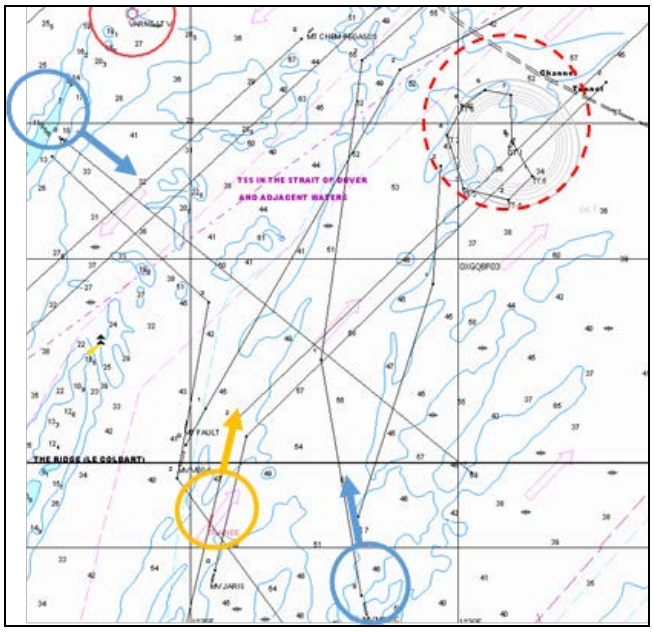

Figure 8. The interactions of Step 3.

After waypoint, operator is faced with damaged tanker and leakage. Operator should proceed safely at that area. With the decreasing of visibility to 4 miles, operator should reduce the speed and make the proper arrangements on radar to use it effectively. Acceptable CPA limits, identification of buoys, rule following for separation are other parameters which operator should consider in addition to parameters of previous steps.

2.2.4 *Step 4*

In the last step of the scenario, visibility is low, traffic density is high and geography is hard. At the beginning of the step, the operator is requested to make a sharp turn to proceed opposite side of the separation. There are 3 risk of collision situations in 15 minutes and operator is overtaken by another vessel (Figure 9). At 20th minute of the step there is strong current causes the vessel drift to a wreck. Moreover, there are nets of fishing vessels at the port side of the course.

Operator should reduce the speed due to decrease of visibility to 1.5 mile, high traffic and short distance to pilot station. Current affects operator in terms of manoeuvre of ship as well as the visibility in this step. Safe manoeuvre of ship becomes crucial due to fact that there is wreck, fishing nets and current. Hence, operator is evaluated according to especially ship control measures.

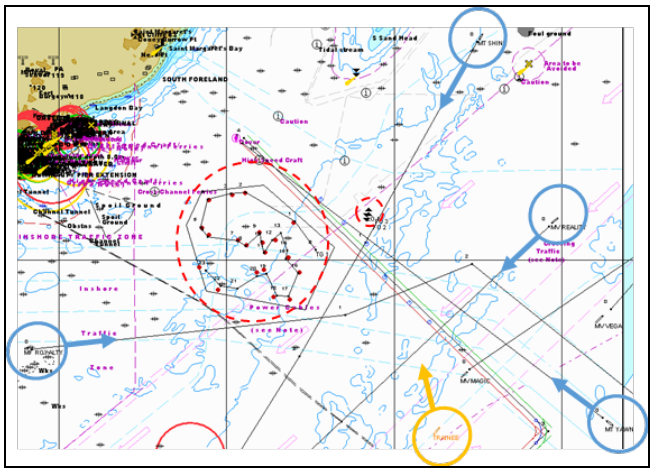

Figure 9. The interactions of Step 4.

3 RESULTS

3.1 *Expert comments*

The questions were asked to ocean-going masters to evaluate the whole scenario in terms of consistency of scenario to be used for evaluation of watchkeeping officers. The questions and related answers are stated below;

- How much the interactions, which are specified in steps, reflect the truth?
  1st reviewer:
  "The extreme occurrences in your scenario could not happen simultaneously. However the possibility of happening simultaneously should taking into consideration too. Also watchkeeping officers should always be well prepared against this kind of situations because the regions as Dover Strait have high traffic density. So in my opinion it is close to real-like."
  2nd reviewer:
  "Scenario generally summarize complications at strait area. However beside our own decisions, communicating with VTS and port authority and listening directions are very important. If this point would improve, scenario could be more affective for evaluation."
  3rd reviewer:
  "This complications and even more complicated situations and events are possible to happen in the regions have high traffic density and separation areas. Especially in the Singapore Strait and region of continent the traffic density is even higher."
- Are performance measures proper and adequate for evaluation of watchkeeping officers? Do you think is there any criterion to add or take out?
  1st reviewer:
  "In my opinion situational awareness is most important evaluation criterion. If watchkeeping officer is calm and confident, situational awareness will expand correspondingly. And this helps to

notice of parameters in sight and by electronic equipments. Most significant thing is usage of these information during watchkeeping. As is seen this study emphasised on these."
2nd reviewer:
"Accordance with passage plan and knowledge of watchkeeping officers about each COLREG rule are the two criterion which can be add to performance measures."
3rd reviewer:
"Most of collisions arise from reason that intention of ship could not be figured out before. Evaluation in the simulator also should involve the criterion: the start time of avoiding manoeuvre from collision. It is really important to communicate by VHF directly, verbally and actively with the faced ship. Under the favour of asking "what is your intention please" question in the right time and receiving the answer, the officer could manoeuvre in the right time and right direction. The officer should manoeuvre properly in advance by avoiding from the risk of collision or should not be late for VHF communication. In this context performance measures are enough and I advise to add the starting time of avoiding manoeuvre from collision and time of communicating with other ships as criteria."

– Are the steps in a linear form?
1st reviewer:
"Steps are linear and becoming difficult in proper proportion. Parameters are changing properly. The only deficiency that I noticed is bad weather conditions are important too apart from restricted visibility. And if it is possible weather conditions should be added to further studies."
2nd reviewer:
"Distribution of parameters to steps are excellent and proportional."
3rd reviewer:
"Yes, difficulties are rising at each step and it is in correct form."

3.2 *Performance evaluation*

Performance evaluation was generated based on Goal-Directed Task Analysis (GDTA) structure by ocean-going masters. Table 1 presents the sample coefficients of the necessary evaluation parameters for each step of the scenario.

Table 1. The coefficients (α) of each criteria for each step.

			Step 1	Step 2	Step 3	Step 4
Safe Navigation	γ_1^*	γ_{11}	0.1	0.15	0.1	0.1
	γ_{12}	γ_{121}	0.1	0.1	0.1	0.05
		γ_{122}	0.1	0.15	0.1	0.05
		γ_{123}	0.2	0.15	0.1	0.05
	γ_{13}	γ_{131}	0.15	0.15	0.15	0.15
		γ_{132}	0.15	0.2	0.1	0.1
		γ_{133}	0.05	0.05	0.05	0.05
	γ_2		0.05	0	0.05	0.05
	γ_3		0.1	0.05	0.1	0.15
	γ_4		0	0	0.15	0.25
	Total		1	1	1	1
Better Performance for Navigation	η_1^*		0.2	0.2	0.2	0.2
	η_2		0.2	0.2	0.2	0.2
	η_3	η_{31}	0.2	0.2	0.2	0.2
		η_{32}	0.1	0.1	0.1	0.1
		η_{33}	0.1	0.1	0.1	0.1
		η_{34}	0.2	0.2	0.2	0.2
	Total		1	1	1	1

* γ_w represents the symbol of score for 'safe navigation' parameters, η_v represents the symbol of score for 'better performance parameters for navigation (See Figure 2-3 for other symbols).

The operator's performance is equal to the weighted sum of the scores evaluated for the relevant parameters. Following equation presents the performance score for 'safe navigation':

$$\text{Psafe} = \sum_{w=1}^{p} \alpha w \,.\, \gamma w \tag{1}$$

where α_w = coefficient of criteria; γ_w = performance score on related parameter of 'safe navigation'.

Similarly, following equation presents the performance score for 'better performance for navigation':

$$\text{Pbetter perf.} = \sum_{v=1}^{q} \alpha v \,.\, \eta v \tag{2}$$

where α_v = coefficient of criteria; η_v = performance score on related parameter of 'better performance for navigation'.

4 CONCLUSION

State authorities and shipping companies evaluate watchkeeping officers according to written theoretical exams during the process of recruitment and promotion. However, as the theoretical exams and similar procedures do not evaluate watchkeeping officers in terms of practical implementation, evaluation of navigation performance on bridge during navigation cannot be done properly. This makes difficult the decision-making process on selection of watchkeeping officers. Therefore, the simulator-based assessment is thought to improve the quality of the watchkeeping officer selection.

In this study, it was tried to be evaluated the applications in ISM documents of companies and

requirements of BPG and STCW. It was seen that some items such as celestial navigation, pollution prevention, passage planning cannot be evaluated in simulator environment. However, most of technical skills of navigation can be evaluated and simulated in the scenario.

Experts mainly argued the scenario that is mostly real-like, performance measures of that is sufficient to evaluate the officers and the steps are progressively designed, the difficulty levels are distributed properly. One of the experts stated that the detection time and range of targets is important issue to avoid any collision. The novel performance evaluation method involves this parameter. Another one suggested that VHF communications should be in steps to carry out the ship-to-ship and ship-to-shore interactions. It is important to reflect the truth for navigation scenario.

Goal-Directed Task Analysis (GDTA) method is seen to be used for a performance evaluation method in navigational watch. The coefficients, stated in Table 1, can be re-evaluated for different steps of different scenarios. In this study, for example, the coefficient of criteria 'Identify hazards (γ_4)' is 0 for step 1, 0.25 for step 4. The coefficient may be increased for another step where hazards are more common. Therefore, this performance evaluation method can be upgraded for other simulator scenario designs.

As a result, the developed performance evaluation method for navigation can be used to generate more reliable method to evaluate the officers' competence of technical skills.

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