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TEAM TRAINING IN SAFETY AND SECURITY VIA SIMULATION: A PRACTICAL DIMENSION OF MARITIME EDUCATION AND TRAINING

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Abstract

In the rather extended maritime domain, a term that should be the epicentre of any successful career-building path is tailor-made training via cutting-edge simulators. To cut a long story short, the breadth of operations on the various types of ships has expanded to such a large extent that extensive practical training drills are becoming a compelling need to contribute to competent seafarers. This type of training can guarantee the positive outcome in their decision-making process and help the seafarers often being under continuous pressure, to suitably respond to the various safety and security threats on-board a vessel. The several conventions and codes introduced by the International Maritime Organization (IMO) – including MARPOL (International Convention for the Prevention of Pollution from Ships), SOLAS (International Convention for the Safety of Life at Sea), but moreover ISPS Code (International Ship and Port Facility Security Code) and STCW (Standards of Training Certification and Watch-keeping) being probably the most well-known examples both within and outside the maritime community – posing and requesting significant performance demands on crews. Sophisticated simulation series that promote teamwork and cooperation are the tools urgently needed to maximize training efficacy.

Handling safety situations under stress (emergency response), crisis management and reactions towards a security incident are important aspects of Maritime Education and Training (MET). The authors' approach to address those aspects utilizes enhanced simulation based team training. They argue that an effective way to gain experience and achieve corresponding skills, are practice runs on specially designed simulators that realistically represent complex conditions on-board vessels, following the respective prompts though realistic scenarios. The concept of a safety & security training simulator is introduced; the research work related to the implementation of a learning objective oriented development of simulation training scenarios and the pedagogic value added by simulation to MET are also discussed. A very important recommendation is that maritime training needs should not be regarded simply as a means to achieve regulatory compliance. The value imparted by simulation as a pedagogic tool to the maritime teaching and learning process is tremendous; adopting the learning objective oriented development of simulation training scenarios in order to effectively address pre-identified learning outcomes is the right methodology to nurture competent seafarers.

Keywords: Maritime Education and Training (MET), Simulation Exercise, Maritime Safety and Security.

1 INTRODUCTION

Maritime Education and Training (MET) activities hold a pivotal role in the preparation of seafarers in order to safely and effectively respond during emergency situations. To name just a few of these activities, emergency response, crew resource and crisis management are crucial aspects of MET that can contribute in the quick discovery and very successful resolution of the numerous emergency situations that can be developed on-board the various types of vessels at sea, as well as ashore (for example during port operations). Several maritime conventions/regulations stipulate the training requirements for maritime personnel (with the importance and influence of MARPOL - International Convention for the Prevention of Pollution from Ships, STCW - Standards of Training Certification and Watch-keeping, SOLAS and the respective Codes (International Convention for the Safety of Life at Sea and ISPS - International Ship and Port Facility Security Code/ISM – International Safety Management Code), among others being well known within all members of the maritime community and many outsiders) [1]. In any case, adoption of an efficient training and development process is important for building a robust and proactive safety culture; this process may be over and above the existing regulatory requirements in its scope and ambition. Needless to mention, capacity building and

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strong motivation of the personnel supporting the creation and development of safety culture must be considered as an action of priority for a prosperous maritime industry. Training programmes should be designed and imparted to ensure operational safety onboard and sufficiently prepare personnel to adequately respond to emergency and hazardous occurrences. The 2010 Manila Amendments of the STCW are in force since 1 January 2012. These amendments prioritize emergency preparedness training for ship's officers and its crew. The training includes suitable emergency response as well as crises management onboard ships. Training for ship's personnel in skills, knowledge and appropriate procedures is now required in order to provide protection to the vessel and to ensure passenger and crew safety, particularly on-board passenger ships like ferries and cruise ships in case of an on-board emergency.

Maritime training is more than a means to achieve regulatory compliance; it can take the training programme over and above the requirements of minimum compliance. The authors of the current analysis demonstrate the value of maritime simulation in the maritime teaching and learning process and the benefits of adopting the learning objective oriented development of simulation training scenarios to effectively address pre-identified learning outcomes. This paper is an expanded version of Baldauf et al., 2015 [2] and presents enhanced results and the continuation of the research effort in the direction of maritime simulation and the pedagogic value it affords.

Quite often, a large number of seafarers significantly overestimate their competencies [3]. This finding of competency overestimation pointed to the inadequate assessment of the complex situation by the seafarers and an insufficient evaluation of the risks involved. Furthermore, a correlation was found between the experience of seafarers and their self-confidence. On the one hand, the seafarers with more than ten years of experience gave the most correct answers (54.6%); however, on the other, they significantly overestimated their competencies (91.2%). The study showed that the experience of shipboard emergencies increased the self-confidence of seafarers regarding their competencies by 20% and the gap between the subjective feeling/belief of competency and the objective competency of the seafarers increased with each subsequent emergency.

The authors of this paper argue that the gap between subjective competency and measurable objective competency can be effectively addressed by simulation training [4]. In the teaching and learning process, simulation provides the opportunity to revisit and rehearse complex training scenarios and reflect upon the training experience in the subsequent debriefing session following the simulation run. This paper expands upon and further reiterates the value of complex multi-dimensional team training in non-mandatory aspects of maritime safety and security training [2].

2 THE EVOLUTION OF THE STCW CONVENTION

The configuration of the Earth facilitates sea transport since three quarters of the planet's surface is covered by sea or lakes; with the exception of the North and South poles, the transport of passengers and goods by sea-going vessels is possible to and from any part of the world. This fact by itself constitutes a comparative advantage for sea transport against air or land transport. As a result, a vast number of ships transit each and every day, all year around, the various seas and oceans of our planet in order to deliver enormous quantities of goods - as well as a very large number of passengers- to their final destination. It is a rather self-explanatory fact that masters, officers and watch personnel on sea-going merchant ships play a crucial role in the normal operation of the shipping industry: only competent and well-trained seafarers can ensure safety of life at sea, deliver the level of required maritime security, perform all duties related to the conduct of the passage efficiently and finally maintain protection/preservation of the marine environment. The 1978 STCW Convention was the first to establish basic requirements on training, certification and watch-keeping for seafarers on an international level. Previously those standards were established by individual governments, usually without reference to practices in other countries; as a result, standards and procedures varied widely and the end result was often questionable.

The 1995 amendments, adopted by a Conference, represented a major revision of the Convention, in response to a recognized need to bring the Convention up to date and to respond to critics who pointed out the many vague phrases, such as "to the satisfaction of the Administration", which resulted in different interpretations being made. One of the major features of the revision was the division of the technical annex into regulations, divided into Chapters as before, and a new STCW Code, to which many technical regulations were transferred. Part A of the Code is mandatory while Part B is recommended. Dividing the regulations up in this way makes administration easier and it also makes the task of revising/updating them simpler: for procedural and legal reasons there is no need to call a full conference to make changes to Codes. Finally, in June 2010, another diplomatic conference in Manila adopted a set of far-reaching and comprehensive amendments to the 1978 International Convention on Training, Certification and Watch-keeping for Seafarers and its associated Code. The revised STCW Convention aims to provide the international standards necessary for training institutes and trainers to develop the much-needed skills and competencies for today's seafarer.

Very briefly, the STCW-78 Convention focused almost entirely on knowledge; the emphasis of STCW-95 shifted towards practical skills and competence underpinned by theoretical knowledge. The 2010 amendments continued to emphasize competence rather than statistics in the form of sea service or time-periods of training. In any case, it is important to emphasise that although there is a strong emphasis from International Maritime Organization (IMO) to integrate simulation in maritime training, the only mandatory simulator training under STCW has been that relating to the use of radar and ARPA. The 2010 amended STCW also makes use of simulators for training in Electronic Chart Display and Information Systems (ECDIS) a mandatory requirement during training. In these specific cases, simulators are the only accepted methods of demonstrating competence. In all other instances, approved simulator training and assessment is NOT mandatory, but just one of the methods accepted by the Convention for training and demonstrating competence. This category of optional simulator training and assessment covers navigation and ship handling, cargo handling, GMDSS communication, propulsion and auxiliary machinery.

3 THE PEDAGOGIC TOOL OF SIMULATION

As already briefly discussed, the importance of marine simulators in MET is well recognised by the IMO and this advanced technology is incorporated in the international STCW convention and its subsequent amendments [5]. The IMO recognises the role simulator technology can play in maritime training and in raising safety standards and the incorporation in the STCW convention of simulator technology attests to this. STCW convention, part A specifically refers to the mandatory utilisation of Radar and ARPA simulators in navigation training. This paper however, refers to non-mandatory training in shipping and the benefits of advanced simulation technology are extended to shipboard safety operations by this approach, which are hitherto, largely unexplored [6].

Different transportation modes have utilised simulators for pedagogical instruction, such as aviation [7], rail transport [8], etc. A review of academic literature reveals that in shipping the focus is largely on pilot training and training of navigators (both in ship handling and operations). In other transportation modes as well, the focus is on training drivers for buses, trains and cars [9] [10]. The usefulness of innovative simulator technology is now beginning to be academically explored in training for maritime safety and security and this paper contributes to such studies [11] [12] [13].

Several benefits have been identified of simulation training; it has been found to be effective [14] [15]; it encourages positive transfer of learning from the simulated training scenario to the real life situation [16]; simulation training offers a risk free environment in which trainees can encounter potentially dangerous/hazardous/life threatening situations [17]; simulation training is found to be cost effective [18] and it improves decision making [19]. Absolute simulation fidelity is not required for skills to be transferrable [20] [21]. Collaborative exercises with multiplayer platform can be conducted with the help of advanced simulation technologies [22] [23]. Traditional training methods have been found to be wanting in situations that require fast response [24]. Therefore, simulation methods that are non-traditional need to be explored in maritime teaching and learning; this approach looks very appropriate when trying to deal with critical situations (crises), which demand fast decision making and response.

The potential for shipping accidents is identified through undertaking comprehensive risk assessments and it has previously been highlighted that in the century between the two accidents of Costa Concordia (2012) and Titanic (1912), we do not seem to have learned the lessons from these accidents that could serve to prevent such accidents in the future [25].

It is crucial to learn from accidents and responsible entities should constantly review training methods to improve the safety and security measures that have been put in place. A consistent high level of safety and security awareness can be created with the help of simulation training. This is helpful to guard against shipboard complacency and to motivate ships' crew.

4 INTEGRATED SIMULATION EXERCISES – REQUIRED ENHANCED SOFTWARE AND HARDWARE

The maritime industry extensively uses simulators for training in ship handling; these simulators provide real time training on well-equipped bridges that strongly resemble modern ships. A unique simulator has been developed for the purposes of training and research on non-mandatory, but crucial aspects of maritime safety and security. The combined Safety and Security Training simulator (hereafter SST) has been established in the maritime simulation laboratory of the Maritime Risk and System Safety (MaRiSa) research group at the World Maritime University (WMU) in Malmö (Sweden) [2]. Fig. 1 that follows describes in summary the simulator configuration.

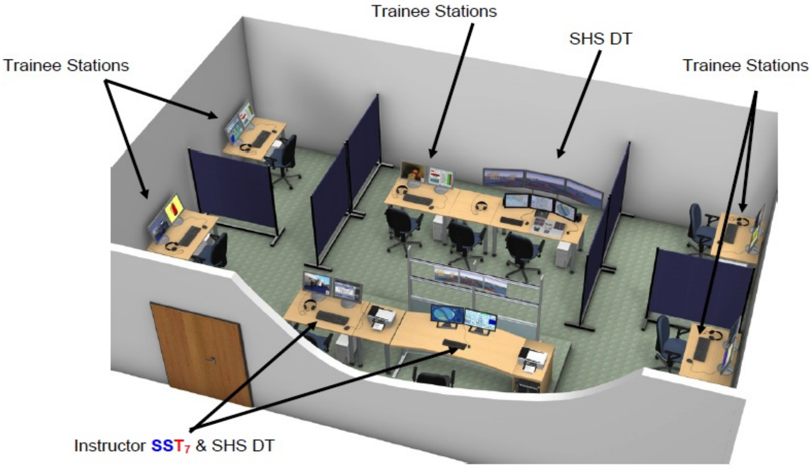

Figure 1: Configuration of the combined Ship-handling and Safety and Security Training Simulator

WMU simulator system outline has a unique feature which is that the SST is combined with a Ship-Handling Simulator (SHS). This joint configuration of the two simulators permits the application for a wide range of scenarios for simulation training which includes complex team training in safety related as well as security rated scenarios. The combined simulator is used for research in addition to teaching and learning purposes. A novel potential research use of the simulator is to study on-board safety and security plans and procedures and their overall effectiveness. Scientific evaluation of the efficiency of shipboard procedures can be facilitated by the simulator. Different conditions can be tested and the course of events can be varied in the different runs of the simulation exercises.

The MaRiSa research group at WMU focuses on the development, implementation and integration of simulation-based modules into training units and post graduate degree courses. The in-house simulation laboratory provides enhanced test facilities due to the combined Ship Handling and Safety and Security Simulator. The simulator is a procedure trainer that allows 3D visualization of spaces on-board a ship [26] and enables its personnel to move inside the virtual spaces using safety equipment and utilize the emergency systems available on-board. These interactive systems can be activated via interactive consoles on the bridge and/or the engine control room [27] [11]. A wide range of maritime safety and security related research can be conducted in this enhanced laboratory. The effects and impacts of onboard safety and security plans and procedures can be tested in a virtual simulated environment. MaRiSa cooperates with the Maritime Simulation Centre at Wismar University, Rostock and develops and tests training concepts and scenarios for basic, advanced and management level training. Functional tests of the developed system have been concluded successfully and first practice courses have been carried out. Studies on user acceptance have yielded good results and have been discussed in Baldauf et al., 2015 [2], while the current analysis discusses enhanced results from other simulation exercises carried out in continuation of this research effort.

The availability of highly sophisticated simulators with advanced functionality requires that academicians thoroughly consider the processes of knowledge acquisition and transfer in order to ensure effective learning [28] [29]. This can be achieved via the learning objective oriented development of training scenarios. The cognitive aspects of the underlying training methodology of a learning objective oriented approach to training with pre-identified training outcomes are discussed in the following section.

The integral capabilities of the combined safety and security simulator trainer allow training to benefit personnel, both aboard and ashore. The simulator training benefits have been extended ashore to port security personnel in the European Union funded, “Leonardo da Vinci” lifelong learning programme – METPROM. Both WMU and Hochschule Wismar integrated simulation training scenarios for the training of port security personnel required by the ISPS code [30] and EC regulation [31] and directive [32] [33]. The combined simulator is utilised to teach and train post graduate students regarding Bridge Resource Management (BRM) and Crew Resource Management (CRM).

5 LEARNING OBJECTIVES AND DEVELOPMENT OF TRAINING SCENARIOS

Anecdotal evidence and spotlight reviews suggest that the most common method for the development of scenarios for simulation exercises is primarily retrospective and driven by past/experienced events. Usually, scenarios of real accidents or near-misses (usually experienced by the instructor(s)) are implemented in a simulation setting to discuss the errors committed and to identify the training needs so that in the future, trainees could avoid making the same errors in subsequently reconstructed scenarios.

A similar retrospective approach is utilised in the engineering discipline which is driven by the identification of a particular lack or failure which leads to the development of a technical solution, device or sophisticated system. The retrospective/backward looking focus of engineering assumes and presupposes that it has identified and fixed the fault once the solution is developed. However, this backward looking outlook is not applicable to MET as training essentially needs to be proactive and forward looking. A backward looking event driven approach in MET seems to assume that training in a particular accident scenario will stop similar accidents from occurring in the future. However, it has been seen that despite introducing new sophisticated technical systems, rules, regulations, accidents recur [2]. On the basis of this, the authors argue that the retrospective event-driven approach of designing simulation training scenarios is not effective, particularly in MET.

Based on an in-depth review of learning theories [34] [35], it is appropriate to focus on the proactive forward looking learning objective-oriented development of simulation training scenarios and accompanying scale as an MET tool. State of the art modern simulators with enhanced functionalities provide an extremely wide range of possibilities and options for increased training effectiveness. However, one needs to take into account, the process of knowledge acquisition by the trainee during the implementation of training scenarios. Accordingly, the educational potential of the simulation platform design and its control functionalities have to be identified. This can be effectively realized when the retrospective event-driven scenario design approach is at least accompanied by or even substituted by the learning-objective oriented development and design of training scenarios.

5.1 Development of training scenarios in accordance with learning objectives

This section describes a systematic approach towards the development of simulation scenarios. Such an approach is grounded in academic literature [36] [37] [38] [39] [40] and draws upon the explorations of simulator training scenario development and its principles [41]. The core elements of this approach are visualized in fig. 2 and were developed in the EU-funded MASSTER project [37].

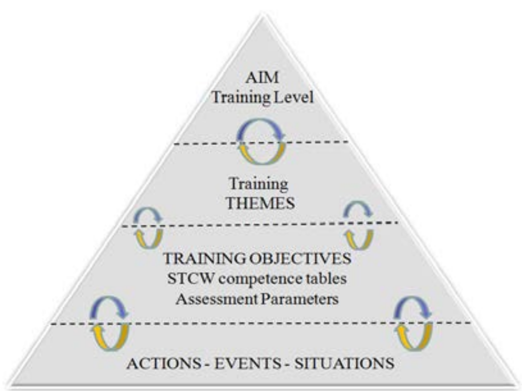

Figure 2: Principle layers and elements of the scenario development process (according to [37])

The key phases of the scenario development process are represented by the four principle layers. Feedback arrows are depicted between the layers and link training objectives to the general training aim, and the events sequence to training objectives. The development of well-designed training scenarios requires feedback between the different layers of the scenario development process. The first feedback loop covers the AIM and THEMES and takes place between the simulator operator and the client. The loops are extremely important and are required to be carried out by training establishments. These loops are envisioned for the consideration of the suitability of the events sequence in relation to training objectives within a given area. It is depicted that training objective(s) should define the sequence and the course of events of the simulation scenario in that order of development.

Simulation exercises are intended to fulfil well-defined goals. The general training objectives need to be well defined. The learning objectives also depend upon the on the qualifications, skills and experience of the trainees as well as the required competencies to be achieved.

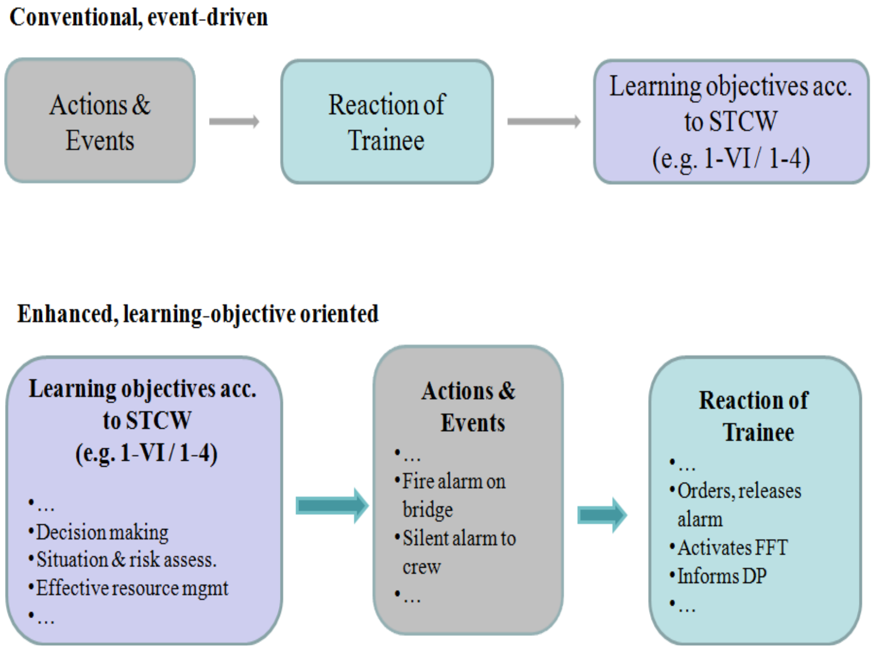

Figure 3: Basic steps for conventional and enhanced learning objective-oriented approach to scenario design

Detailed objectives are derived from general objectives. After the conduct of the simulation exercise, trainees' performance is evaluated, assessment and compared against the corresponding training requirements.

It shall be highlighted that the same methodology can be applied for the development of simulation scenarios for research purposes as well. Research aims and objectives as well as related research questions can be used to derive and carefully define a certain sequences of events in order to measure and record parameters that are needed to research effects and impact, for e.g. a newly developed decision support system or the application of theoretical models to practical cases. Results gained from simulation trials usually provide the first if not the ultimate answer to a research question and proves the hypothesis.

5.2 Brief Case Study

For the purpose of training in maritime operational risk management, a simulation exercise was developed for the specific case of collision avoidance. The trainees should solve the task with the equipment provided by the Desktop Ship-Handling Simulator.

For this purpose, a simulation exercise according to the STCW requirements for collisions avoidance skills and ARPA use was designed and implemented with the following parameters shown in Table 1 and a snapshot of the area and the traffic situation is depicted in Fig. 4, left.

The task given to the Captain and his team was to plan and perform a section of a voyage in a safe and most time efficient manner. The simulation exercises were performed in teams with a mixture of mariners (experienced navigators) and students that had no experience on-board of a ship. The experienced navigators were assigned to be responsible for the safe passage and assigned to take the lead for bridge operation and organize, supervise and coordinate actions. As criteria for assessment, passing distances and travel times have been used.

Table 1. Scenario design for collision avoidance exercise

Area of competency	Use of all available means for assessment of risk of collision and decision making (if necessary perform collision avoidance manoeuvre according to COLREGs [45])
Objectives	• Determination of CPA / TCPA; • Use of ARPA/AIS, ECDIS within COLREGs • Use of equipment to keep a defined safe passing distance • Use of radar in case a substantial alteration of course is needed to avoid collision
Configuration	Own ship - LNG-tanker vessel (LOA115m, BOA 19m), open sea area, daylight, no current, winds, sea state 0 and no precipitation; good visibility
Traffic situation	Medium to dense (1–3 targets per minute) in coastal sea area with offshore wind mill installations and north - and southbound traffic separation scheme (TSS) Øresund (The Sound), Easterly part, South of the bridge)
Duration	medium (30 – 45 min)
Event description	For the own ship's collision risk (vessel passing along the wind mill park, encounter situations on crossing courses and overtaking has been programmed for minute 25 with coaster and later with a Cruise ship (approaching from South)

Prior to the exercise, the navigators were asked via a questionnaire to provide the minimum distances that they would accept to be safe according to the International Regulations for Preventing Collisions at Sea (COLREGs). All participating teams undertook thorough voyage planning, including the decision on a safe and short route through the area and organized a sufficient regime for observation of the area around the ship and navigating to the point of destination for their watch on the bridge. However, one interesting aspect besides the organization and leadership of the captains was the assessment of risk of collision by the navigators compared to values given by them before the exercise run (see Fig. 4 right).

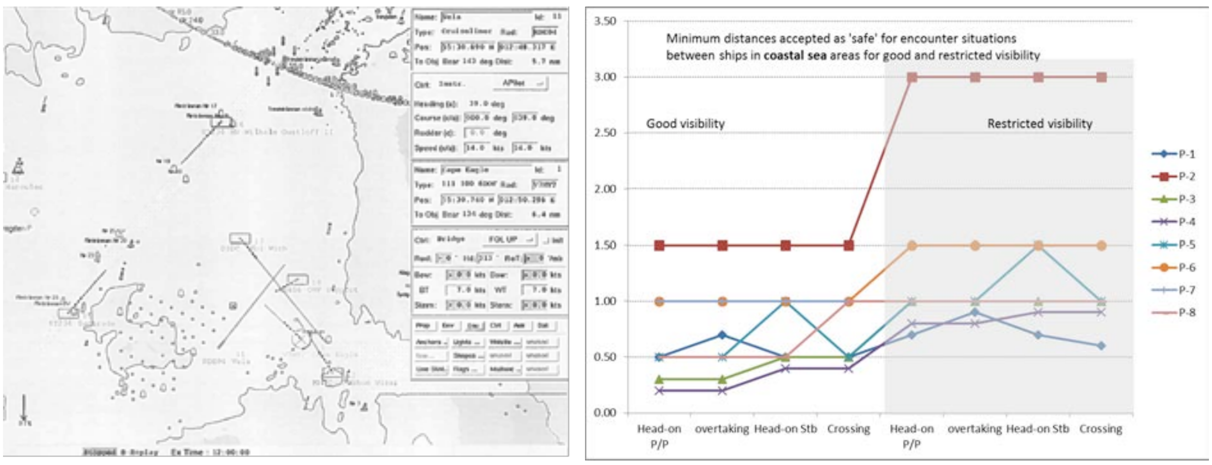

Figure 4: Exercise area and snapshot of the traffic situation (right) and spectrum of accepted safe passing distances given by participants before the exercise run (left)

The passing distances accepted as to be ‘safe’ in relation to COLREGs varied widely even in the individual types of situations (head-on, meeting or crossing) with same conditions, as e.g., the minimum distance accepted as to be safe according to COLREGs for an encounter situation on opposite or almost opposite courses with passing port-side-to-port-side varies from 0,3 up to 1,5 nm. However, the analysis of the tracks sailed during the individual exercises with respect to action taken to avoid a risk of collision showed, that the navigators substantially deviated from the safe passing distances they had indicated before the exercise. In practice, navigators passed at a lesser distance indicating their risk taking behaviour, which could, in part be due to their navigation experience and comfort level. Further research is required to explore insights into the deviances in navigation behaviour reported and observed in practice. Simulation allows for detailed and situation-specific discussion of such aspects and can contribute also to the harmonized application of risk assessment criteria.

6 SUMMARY AND CONCLUSIONS

Today, sea-going vessels are the most important means of transport; associated statistics indicate that about 90% of the total volume of global trade is borne (exclusively – or, at least partially) by sea [42]. Safe (and secure) shipping is a prerequisite for the normal conduct of world-wide trade, therefore the “backbone” of globalization [43]; many other of the activities that are related to maritime transport (such as ship-building and repairs, logistics support and bunkering, legal services, insurance etc.) are also very important contributors to the cumulative output of the global economy. It is crucial to emphasize the fact that maritime transport is a very demanding endeavour; the level of safety at sea clearly depends heavily upon the professionalism and competence levels of seafarers. It is no coincidence that the (former) International Maritime Organization’s Secretary-General Koji Sekimizu himself has emphasised numerous times the fact that the shipping industry depends on competent, well-trained seafarers to ensure safety of life at sea, maritime security, efficiency of navigation and protection and preservation of the marine environment [44].

The role of the human element in the delivery of safe and efficient ship operations has long been recognized by the IMO. In order to operate the sophisticated modern ships in an optimized manner and above all safely, the competence of seafarers is one of the most critical factors. The key to maintaining a safe shipping industry and preserving the marine environment lies in all seafarers across the world possessing high standards of competence and therefore fulfilling effectively their duties on-board. The purpose of the Standards of Training, Certification and Watch-keeping (STCW) Convention, 1978, as amended, is to ensure that all seafarers on sea-going vessels are properly qualified to perform their respective duties. The STCW Convention of 1978, as amended in 1995 and again in 2010, sets those standards, governs the award of certificates and controls watch-keeping arrangements. Last but not least, its provisions do not only apply to seafarers, but also to ship-owners, training establishments and national maritime administrations.

The simulation exercise under discussion was developed according to the STCW requirements for collisions avoidance skills and ARPA use; its purpose was to conduct (and evaluate) training in maritime operational risk management. The rather simple task given was to plan and execute a very short voyage in a safe and most time efficient manner. The most interesting finding was the assessment of risk of collision by the navigators involved when compared to the values provided by them before the respective exercise execution; navigators passed at very short distances indicating a risk taking behaviour, which could, in part be due to their navigation experience and comfort level. However, with such a small sample of data a safe conclusion cannot be drawn; further similar exercises are required to explore insights into the deviances in navigation behaviour.

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