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REDUCING OF MARITIME ACCIDENTS CAUSED BY HUMAN FACTORS USING SIMULATORS IN TRAINING PROCESS

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Abstract

Given the increasing prevalence of automated systems on board ships, it is important that the human element is considered throughout their design, implementation and operational use. Automation can be beneficial to operators of complex systems in terms of a reduction in workload or the release of resources to perform other onboard duties. However, it can also potentially be detrimental to system control through increasing the risk of inadvertent human error leading to accidents and incidents at sea.

A team of researchers from our University had participated at a study together with students, study which wants to release the dangerous situation on sea based on human factors. In this scope has been used a web base simulator, bridge and liquid cargo handling simulators, developing applications in navigation and ship handling area, with different grades of difficulty and risk. These applications brings the future deck officers in usually situations on board, forced to use the present navigation technology and study their options and reactions in these cases, focus on situations with risk of errors, human errors, appearance.

Keywords: Bridge technology, human factors, simulation, Bridge management.

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INTRODUCTION

Over the last 40 years or so, the shipping industry has focused on improving ship structure and the reliability of ship systems in order to reduce casualties and increase efficiency and productivity. We've seen improvements in hull design, stability systems, propulsion systems and navigational equipment. Today's ship systems are technologically advanced and highly reliable.

With all of these the maritime incidents rate is still high, we have not significantly reduced the risk of accidents. There is because ship structure and system reliability are a relatively small part of the safety equation. The maritime system is a people system, and human errors figure prominently in these situations. About 75-96% of marine accidents are caused, at least in part, by some form of human error. Studies have shown that human error contributes to:

- 89-96% of collisions
- 75% of fires and explosions
- 79% of towing vessel groundings
- 84-88% of tankers accidents
- 75% of allisions

Therefore, if we want to make greater strides toward reducing marine accidents, we must begin to focus on the types of human errors that cause these and their relationship with the new technology on board.

In recent years a problem in international maritime training became obvious: the lack of experiential learning of entry-level officers or "lost apprenticeship" (Chiotoroiu L., et all 2006). Like in many other technical work systems the work processes on board have been an object of extensive automation. Human beings on board modern ships are needed predominantly for planning, control and supervision. However, in critical and unusual situations they have to step in actively. Such situations require flexible problem solving, improvisation and intuition. Furthermore, decreasing number of (experienced) crewmembers on board and the pressure of fast promotion into responsible positions have increased the "experiential learning gap' of junior-officers. This problem is most obvious in tanker shipping, due to the demands on junior officers which are higher in this branch of our industry as compared for example with the field of container shipping.

HUMAN FACTORS

Most people would agree with the old adage "to err is human". Most too would agree that human beings are frequent violators of the "rules" whatever they might be. But violations are not all that bad, through constant pushing at accepted boundaries they got us out of the caves!

As it is inevitable that errors will be made, the focus of error management is placed on reducing the chance of these errors occurring and on minimizing the impact of any errors that do occur. In large scale disaster, the oft-cited cause of “human error” is usually taken to be synonymous with “operator error” but a measure of responsibility often lies with system designers.

To find a human error is necessary to identify active and latent failure in order to understand why mishaps occur and how it might be prevented from happening again in the future.

As described by Reason, active failures are the actions or inactions of operators that are believed to cause the accident (Wagenaar W.A. and Groeneweg J., 1987).

In contrast, latent failures are errors committed by individuals elsewhere in the supervisory chain of command that effect the tragic sequence of events characteristic of an accident.

The question for mishap investigators and analysts alike, is how to identify and mitigate these active and latent failures. One approach is the “Domino Theory”, which promoted the idea that like domino’s stacked in sequence, mishaps are the end result of a series of errors made throughout the chain of command.

Violations and errors

Assuming that the rules, meaning safe operating procedures, are well founded, any deviation will bring the violator into an area of increased risk and danger. The violation itself may not be damaging but the act of violating takes the violator into regions in which subsequent errors are much likely to have bad outcomes.

This relationship can be summarized quite simply by the equation:

Violations + errors = injury, death and damage

The resultant situation can sometimes be made much worse because persistent rule violators often assume, somewhat misguidedly, that nobody else will violate the rules, at least not at the same time! Violating safe working procedures is not just a question of recklessness or carelessness by those at the sharp end.

Factors leading to deliberate non-compliance extend well beyond the psychology of the individual in direct contact with working hazards and include such organizational issues as:

— the nature of the workplace
— the quality of tools and equipment (IMO, 2000)
— whether or not supervisors or managers turn a “blind eye” in order to get the job done
— the quality of the rules, regulations and procedures
— organization’s overall safety culture, or indeed its absence.

Unsafe acts and preconditions

A brief description of the major components and causal categories follows beginning with the level "nearest" the accident – unsafe acts.

The unsafe acts committed by operators generally take on two forms, errors and violations. The unsafe acts operators commit can be classified among three basic errors types and two forms of violations.

The basic error forms are:

- Decision Errors – this is one of the more common error forms, represent the actions or in-actions of individuals whose heart is in the right place, but they either did not have the appropriate knowledge available or just simply chose poorly.
- Skill-based Errors – is best described as those basic operating skills that occur with little or so significant conscious thought, are particularly vulnerable to failures of attention and/or memory.
- Perceptual Errors – when your perception of the world is different then reality, errors can, and often do, occur, like visual illusions or spatial disorientation.

Violations in general are defined as the willful departure from authority and are two distinct types of violations, as:

- Routine/Infractions – tend to be routine/habitual by nature constituting a part of the individual's behavioural repertoire and can be further broken down in: routine violations, optimizing violations and situational violations.
- Exceptional – appear as isolated departures from authority, not necessarily indicative of an individual's typical behavior pattern, nor is it condoned by management.

Preconditions for unsafe acts are described by two major subdivisions: substandard conditions of operators and substandard practices of operators.

The substandard conditions of operators are categorized as:

- Adverse Mental States – those mental conditions that affect performance;
- Adverse Physiological States – those medical or physiological conditions that preclude safe operations;
- Physical/Mental Limitations – those instances when the task requirements exceed the capabilities of the individual at the controls.

The substandard practices of operators are categorized as:

- Crew Resource Mismanagement – often the substandard practices of the team will lead to the conditions and unsafe acts;
- Personal Readiness.

Till now we presented the errors as individual error. But, in most cases the work is done in a team organization that means many persons.

Team error is one form of human error. The difference is that team error considers how a group of people made human errors when they work in a team or a group. Then we can define team error as human error made in group processes. Reason categorized human errors into three types: mistakes, lapses and slips. Mistakes and lapses arise in the planning and thinking process, whereas action slips emerge primarily out of these execution processes. Mistakes and lapses are more likely to be associated with group processes. Slips are errors in the action process of a single individual and are likely to be divorced from the activities of the team as whole.

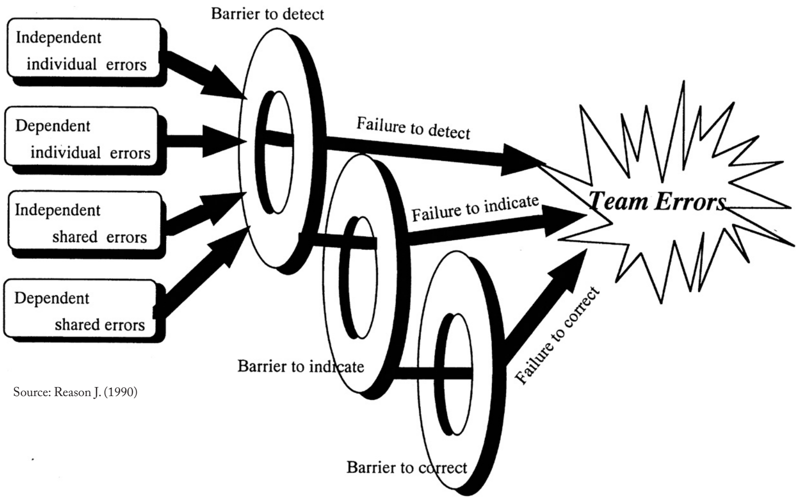

Figure 1. Team error process.

The error making process

Individual errors – are errors which are made by individuals. That is, an individual alone makes an error without the participation of any other team member. Individual errors may be further sub-divided into independent errors and dependent errors. Independent errors occur when all information available to the perpetrator is essentially correct. In dependent errors, however, some part of this information is inappropriate, absent or incorrect so that the person makes an error unsuitable for a certain situation.

Shared errors – are errors which are shared by some or all of the team members, regardless of whether or not they were in direct communication. Like individual errors, shared errors may also be sub-divided into two categories: independent and dependent.

The error recovery process

The error recovery process may fall into any one of three stages: detection, indication and correction.

1. Failure to detect – the first step in recovering errors is to detect their occurrence. If the remainders of the team do not notice errors, they will have no chance to correct them. Actions based on those errors will be executed.
2. Failure to indicate – once detected, the recovery of an error will depend upon whether team members bring it to the attention of the remainder. This is the second barrier to team error making. An error that is detected but not indicated will not necessarily be recovered and the actions based on those errors are likely to be executed.
3. Failure to correct – the last barrier is the actual correction of errors. Even if the remainder of the team notices and indicates the errors, the people who made the errors may not change their minds. If they do not correct the errors, the actions based on those errors will go unchecked.

ORGANISATIONAL FACTORS

The training of operators can only ever be part of the solution to reducing accidents. Organisational factors also play a significant part in accident causation.

The analysis of human factors in accident causation is still relatively immature in the maritime world (U.K. P & I Club, 1992). Although databases held by insurers and classification societies do include human error taxonomies, little analysis is undertaken to identify trends or patterns. Even less analysis has been attempted in assessing the significance or frequency of organisational factors such as the incidence of commercial pressure or the effects of organisational culture on accident causation.

The differences in organizational culture between shipping companies are a well known phenomenon, but there has been little work on understanding the effects of organizational culture on safe and efficient performance. In much the same way as we are striving to identify a set of behavioral markers to assess the competence of individuals, so there is a need to establish a set of organizational metrics to determine the competence of shipping companies to perform safely.

Not enough is known about the parameters governing functioning and performance of management systems. There is a little research evidence to indicate what makes a management system work or indeed what prevents it from working. Equally, not enough is known about the metrics that enable the status of a management system to be determined. Ideally, what is required is a set of "leading" indicators that will predict future performance so that interventions can be made before accidents occur.

The research conundrum is, first, to agree what constitutes organizational behaviour; second, in deciding which "behaviours" are leading indicators of profiency and third, in designing methods that can measure these indicators accurately.

HUMAN FACTORS ISSUES IN MARITIME INDUSTRY

What are some of the most important human factors challenges facing the maritime industry today? A study by U.S. Coast Guard found many areas where the industry can improve safety and performance through the application of human factors principles. The three largest problems were fatigue, inadequate communication and coordination on navigational bridge, and inadequate technical knowledge. Below are summaries of these and other human factors areas that need to be improved in order to prevent accidents (Huey, D. et all, 1993),.

Fatigue, has identified to be an important cross-modal issue, being just as pertinent and in need of improvement in the maritime industry as it is in the aviation, rail and automotive industries. Fatigue has been cited as the "number one" concern of mariners in different studies. It was also the most frequently mentioned problem in a recent Insurance and Classification Society survey. A new study has objectively substantiated these anecdotal fears: in a study of critical vessel casualties and personnel injuries, it was found that fatigue contributed to 16% of the vessel casualties and 33% of the injuries (IMO, 1999).

Inadequate Communications. Another area for improvement is communications between shipmates, between masters and pilots, ship-to-ship, and ship-to-VTS. Is stated that 70% of major marine collisions and allisions occurred while a pilot was directing one or both vessels. Better procedures and training can be designed to promote better communications and coordination on and between vessels. Bridge Resource Management is a first step towards improvement.

Inadequate General Technical Knowledge. This problem is responsible for 35% of accidents. The main contributor to this category is a lack of knowledge of the proper use of technology, such as radar and electronic charts. Mariners often do not understand how the automation works or under what set of operating conditions it was designed to work effectively. The unfortunate result is that mariners sometimes make errors in using the equipment or depend on a piece of equipment when they should be getting information from alternate sources.

Inadequate Knowledge of Own Ship System. A frequent contributing factor to marine casualties is inadequate knowledge of own ship operations and equipment. Several studies and accidents report have warned of the difficulties encountered by crews who are constantly working on ships of different sizes, with different equipment, and carrying different cargoes. The lack of ship-specific knowledge was cited as a problem by 78% of the mariners surveyed (McCallum M.C., et all, 1996). A combination of better training, standardized equipment design and an overhaul of the present method of assigning crew to ships can help solve this problem.

Poor Design of Automation. One challenge is to improve the design of shipboard automation. Poor design pervades almost all shipboard automation, leading to collision from misinterpretation of radar display, oil spills from poorly designed overfill devices, and allisions due to poor design of bow thrusters. Poor equipment design is cited as a causal factor in one-third of major marine accidents (Perrow C., 1984). The solution is relative simple: equipment designers need to consider how a given piece of equipment will support the mariner's task and how that piece of equipment will fit into the entire equipment "suite" used by the mariner. Human factors engineering methods and principles are in routine use in other industries to ensure human-centered equipment design and evaluation.

Decisions Based on Inadequate Information. Mariners are charged with making navigation decisions based on all available information. Too often, we have a tendency to rely on either a favored piece of equipment or our memory. Many accidents result from the failure to consult available information, such as than from a radar or an echo-sounder. In other cases, critical information may be lacking or incorrect, leading to navigation errors, for example, bridge supports often are not marked or buoys may be off-station.

Faulty Standards, Policies or Practices. This is an oft-cited category and covers a variety of problems. Included in this category is the lack of available, precise, written and comprehensible operational procedures aboard ship, for example, if something goes wrong, and if a well-written manual is not immediately available, a correct and timely response is much less likely. Other problems in this category include management policies which encourage risk-taking, like pressure to meet schedules at all costs and the lack of consistent traffic rules from port to port.

Poor Maintenance. Poor maintenance can result in a dangerous work environment, lack of working backup systems and crew fatigue from the need to make emergency repairs. Poor maintenance is also a leading cause of fires and explosions.

Hazardous Natural Environment. The marine environment is not a forgiving one. Currents, winds and fog make for treacherous working conditions. When we fail to incorporate these factors into the design of our ships and equipment and when we fail to adjust our operations based on hazardous environment conditions, we are at greater risk for accidents.

SIMULATORS AND THE PROCESS OF TRAINING

The use of simulation in providing solutions to the problems of risk and crisis management and the optimal use of crew resources has a long established pedigree in maritime training (Barnett, M.L. et all 2002).

The early simulators consisted of real radars, located in a set of cubicles, and fed with simulated signals. Individuals or teams could learn the skills of radar plotting under the guidance of an instructor working at a separate master console. Other navigational aids in the simulator were fairly basic and certainly did not include a visual scene.

Bridge simulators with a nocturnal visual scene made their appearance later and allowed teams to conduct simulated passages in a realistic environment but with only a few lights available to indicate other vessels and shore lights.

Simulator-based training courses were introduced primarily to train the skills of passage planning and the importance of the Master/Pilot relationship (Hensen H., 1999). This training initiative developed into the Bridge Team Management courses that are conducted today on many simulators world-wide and contain many of the elements to be found in Crew Resource Management courses developed in other industries, such as aviation. These courses were developed to focus on the non-technical skills of flight operations and include group dynamics, leadership, interpersonal communications and decision making.

Bridge Resource Management courses are a more recent initiative, adapted directly from the aviation model for training the non-technical skills of resource management, and are not always based on the use of simulators.

The 1980s saw the introduction of Engine Room simulators and towards the end of that decade, cargo operations simulators also became available. These types of simulator have primarily been used to train officers in the handling of operations, including fault finding and problem diagnosis, and increasingly to train teams in the skills of systems, resource and risk management.

Many types of simulator: bridge, engine and cargo control room, have tended to emphasise a physically realistic environment in which these exercises occur, although the of PC-based simulators for training some tasks is increasingly widespread.

In some parts of the world, simulators have been developed which have very high levels of physical fidelity, for example, multi-storey engine room mock-up and bridge simulators including features such as 360 degrees day/night views, pitch and roll, and full vibration and noise effects.

The only mandatory requirements in the maritime domain for the development of the non-technical skills of crisis management are those of the International Maritime Organization's (IMO) Seafarer's Training, Certification and Watchkeeping Code (International Maritime Organization, 1995). Table A-V/2 of this code specifies the minimum standard of competence in crisis management and human behaviour skills for those senior officers who have responsibility in emergency situations.

The competence assessment criteria detailed within the Code are not based on specific overt behaviours, but rather on generalized statements of performance outputs, and as such are highly subjective and open to interpretation.

Although these standards of competence indicate that IMO recognizes the need for non-technical management skills, both the standards and their assessment criteria are immature in comparison with the understanding of non-technical skills, and their assessments, within an industry such as civil aviation.

Simulation and modeling

Sea trials are a poor method of investigating human performance issues. Firstly, crisis situations cannot be replicated safely in live systems. Secondly, only a limited number of people can participate in a sea trial making the observed results difficult to extrapolate to entire marine community. Thirdly, it is difficult to control for variables in sea trials making it very difficult for investigators to identify cause-and-effect relationship. As a result of these three shortcomings, new technology and processes are often introduced with little knowledge of its impact on human performance.

The work being done to improve simulation technology has resulted in the growth of open systems that are modular and recyclable. The efforts to define High Level Architecture and the development of readily available Run Time Infrastructure are examples of development in simulation technology. We believes that such developments will ultimately reduce the costs associated with simulation projects in the maritime sector making simulation and modeling more accessible for commercial applications.

The lesson to be learned from the other sectors, like aviation and military, is that simulation has a much wider application than training in the reduction of human error. Simulation is aggressively being pursued as a tool to address latent human factors issues that are present in the general failure types. The maritime community has not picked up on simulation to the same extent as the other sectors.

Although simulation is now a mandatory component in mariner training , the use of simulation to address the human factors in maritime operations is sporadic and haphazard. As far as human performance is concerned, the maritime industry continues to rely upon “trial-and-error” when implementing new technology or work processes.

The following examples illustrate the potential benefits of insertion simulation and modeling into the maritime innovation cycle.

An example of how simulation and modeling could reduce the latent error in maritime systems would be mission rehearsal. The mission rehearsal process could be used to evaluate the impact of new technology or doctrine on human performance, and result in improved design; effective operational and contingency plans; efficient publicly funded infrastructure; and, improved regulatory controls. To use mission rehearsal, the operating conditions would need to be modeled, and then professionals would participate in a series of simulations.

Simulation and modeling, in this sense, represents a tool to generate “artificial experience” that would significantly improve professional judgment in the consultation process, especially with respect to human performance.

Mitigating the impact of psychological precursor to human error involves using modeling and simulation to observe and quantify human performance of mariners, particularly their cognitive performance in operational context.

It would be important, for example, to conduct baseline studies to determine the stress absorbing capacity of mariners under a variety of operational conditions. The baseline studies would serve to highlight operations and situations where over-simulation is likely to occur.

Another important area of research would to be look at the fatigue induced by highly integrated displays. Most automated display systems have the potential to be integrated with other displays. The question becomes one of the degree to which these displays should be integrated in order to maintain optimal human performance.

Error detection and correction, as well as crisis management, are the last defences in the human error chain. At the present time, maritime simulators are used to train mariners how to detect and correct errors, and to a limited extent on how to manage a crisis.

The scope and amount of simulator based training in crisis management needs to increase. Areas such as initial actions to an spill oil and a distress incident need to be incorporated into simulation training programs. Simulation based training in the corporate emergency procedures also needs to be conducted to ensure that mariners are not reaching for the emergency manuals to find out what to do once an incident happens.

An improved understanding of how crisis management is conducted in the maritime environment is also required to the development of effective decision support systems.

Simulation and modeling capabilities needed for innovation

The use of simulation and modeling in the innovation cycle demand a higher degree of flexibility in simulation technology than required for the training function. Simulators need to be able to accept input from a variety of model data, and need to be able to interact with other simulators in unusual and unique situations.

Open systems with modular and recyclable components are required in order to mobilize the boarder academic, scientific, engineering and corporate communities to integrate simulation and modeling into the innovation process.

A recent requirement to introduce simulation into an offshore oil and gas emergency command and control training exercise illustrates the benefits of modular simulation. For the purpose of this exercise, an input from the process control system is required for the participants. The Faculty of Navigation and Maritime Transport at our parent university, Constanta Maritime University, use a process control simulator for research and training purposes. Through an internet connection, we propose to utilize the simulator to present a process control display to the participants of the training exercise (Barsan E., 2006).

The above example illustrates another important concept. Simulation and modeling components need not be concentrated within a single organizational unit to be successful. Open systems that permit various facilities to collaborate on a project specific basis can be equally, if not more, effective.

With the example of the process control simulator, as the Faculty of Navigation and Maritime Transport adds capabilities to their simulator through research activities, the emergency command and control exercises utilizing the simulator benefits as well.

Such an organizational concept is not without problems, and requires careful planning and management to be successful.

Our University is in the process of defining its system architecture requirements to permit a broad scope of collaborations amongst its simulation and modeling units.

The Virtual Center of Marine Simulation is in the process of defining the organizational structure required to mobilize the University simulation and modeling community to deal with maritime issues.

VIRTUAL SIMULATOR TRAINING PROCESS

Inside the project develop by our university about web based simulation training; four tankers related IMO Model Courses was implemented with the new instructional design strategy (Familiarization, Oil tanker, Chemical Tanker, Gas Tanker). All courses have combined three different but interdependent content levels:

Theory Modules (with online-assessment)
Simulator Exercises (with online assessment)
Practical Training Tasks (planned in form of a tanker qualification record book)

The instructional design considered the general aim of the courses. In the Familiarization course the simulation-modules and/or practical tasks were implemented into the theory. Since in many cases the course was made prior to sailing on a tanker, a lot of tasks could be fulfilled either by simulation or on-board practice (Brown A., 2000).

It should be clear that all courses covered more than the requirements of the IMO-model courses. Every course starts with a “pre-test” to ensure that all participants are starting with at least a comparable level of knowledge. The main menu will follow the IMO-model course

The structure of the theory modules themselves is different. A linear structure of explanations seems to be appropriate for those modules describing physical phenomena such as pump- characteristics. A non-linear structure is able to cover wider fields of knowledge such as cargo-hazards. “Story telling” with imbedded explanations and simulation modules represents another useful ways for competence based modules such as "cargo operations". The complete solution will be offered on the worldwide market with a learning management system running on a server in Norway. In this way, the solution is available not only to the above mentioned partners but to all maritime training institutes worldwide.

1. *Theory module* (in .pdf or Macromedia format). The theory is presented in a comprehensive way and can be found and access on the LMS. Moreover, an exercise and evaluation form are shown from the beginning to the trainees:

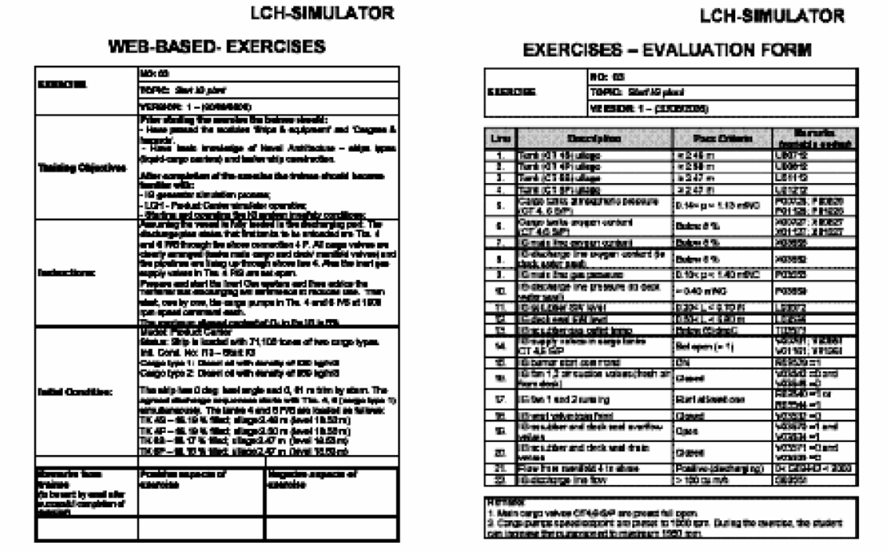

Figure 2 Standard exercise and evaluation form

2. *Step by step demonstrator* (simulator interactive demonstration, ViewletBuilder format). This represent all the steps (with pop-up messages) the students or the trainee need to follow when a specific process is running on the simulator.
3. *Simulator exercises* (with e-Coach and evaluation editors): When creating simulators exercises, a certain procedure shall be followed. It has many steps, starting with the need analysis for the exercise to be carried out and finishing with implementing in the LMS after successful testing and improvement the package. Each exercise has an evaluation form consisting of various evaluation criteria. All these evaluation figures became evaluation actions inside the simulator. After the student/ trainee runs a specific e-learning package and therefore a simulator exercise, the LMS monitors and track all his exercise and finally, by accessing a .txt file, the instructor have the students exercise results.

The encouraging results obtained in final tests by our students give us the right to consider that the use of multimedia tools, computer program and web enable simulation modules must be constantly improved and extended. Also, the interactive methods prove to be efficient and have to be developed widely in the future. Distant learning combined with simulators will make a new and flexible training approach possible. Therefore, we can finally consider that e- Learning has a great and positive impact on the maritime education field and moreover learning combined with training will be by far the most effective way to increase skills and competence

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EVALUATION REPORT - Mon Apr 23 20:06:10 2007

SCENARIO    : Start IG
REPORT MODE: manually print
SIM. TIME   : 00:03:30

 ID : Description          (trigger:    ID) LOW-LIM    HIGH-LIM WEIGHT     SUM
-------------------------------------------------------------------------------
+E01: IG discharge line o (trigger: +X01) 0.00      5.00     2.00       0.00
+E02: IG main line oxy co (trigger: +X01) 0.00      8.00     2.00       0.00
+E03: Atm. pressure CT4S  (trigger: +X01) 0.14      1.13     1.00       0.17
+E04: Atm. pressure CT4P  (trigger: +X01) 0.14      1.13     1.00       0.17
+E05: Atm. pressure CT6S  (trigger: +X01) 0.14      1.13     1.00       0.17
+E06: Atm. pressure CT6P  (trigger: +X01) 0.14      1.13     1.00       0.18
+E07: IG main line gas pr (trigger: +X01) 0.10      1.40     1.00       0.00
+E08: IG discharge line p (trigger: +X01) 0.40      1.00     1.00       0.36
+E09: IG scrubber SW leve (trigger: +X01) 0.20      0.70     1.00       0.19
+E10: IG deck seal SW lev (trigger: +X01) 0.50      0.80     1.00       0.00
+E11: IG scrubber gas out (trigger: +X01) 20.00     65.00    1.00       0.00
+E12: IG fan1 air suction (trigger: +X01) 0.00      0.00     2.00       0.00
+E13: IG fan2 air suction (trigger: +X01) 0.00      0.00     2.00       0.00
+E14: IG vent valve       (trigger: +X01) 0.00      0.00     2.00       0.00
+E15: IG supply valve CT4 (trigger: +X01) 1.00      1.00     2.00       0.00
+E16: IG supply valve CT4 (trigger: +X01) 1.00      1.00     2.00       0.00
+E17: IG supply valve CT6 (trigger: +X01) 1.00      1.00     2.00       0.00
+E18: IG supply valve CT6 (trigger: +X01) 1.00      1.00     2.00       2.00
+E19: Tank ullage CT4S    (trigger: +X01) 2.48      25.00    1.00       0.04
+E20: Tank ullage CT4P    (trigger: +X01) 2.50      25.00    1.00       0.04
+E21: Tank ullage CT6S    (trigger: +X01) 2.47      25.00    1.00       0.03
+E22: Tank ullage CT6P    (trigger: +X01) 2.47      25.00    1.00       0.03
+E23: Flow from manifold  (trigger: +X01) -1000.00 2000.00   1.00       0.00
+E24: IG scrubber SW drai (trigger: +X01) 0.00      0.00     1.00       0.00
+E25: IG deck seal SW dra (trigger: +X01) 0.00      0.00     1.00       0.00
+E26: IG discharge line f (trigger: +X01) 0.00      8000.00  2.00       0.00
+E27: IG discharge line o (trigger: +X00) 0.00      5.00     2.00       2.67
+E28: IG main line oxy co (trigger: +X00) 0.00      8.00     2.00       0.00
+E29: Atm. pressure CT4S  (trigger: +X00) 0.14      1.13     1.00       0.09
+E30: Atm. pressure CT4P  (trigger: +X00) 0.14      1.13     1.00       0.09
+E31: Atm. pressure CT6S  (trigger: +X00) 0.14      1.13     1.00       0.09
+E32: Atm. pressure CT6P  (trigger: +X00) 0.14      1.13     1.00       0.09
+E33: IG main line gas pr (trigger: +X00) 0.10      1.40     1.00       0.00
+E34: IG discharge line p (trigger: +X00) 0.40      1.00     1.00       0.50
+E35: IG scrubber SW leve (trigger: +X00) 0.20      0.70     1.00       0.12
+E36: IG deck seal SW lev (trigger: +X00) 0.50      0.80     1.00       0.00
+E37: IG scrubber gas out (trigger: +X00) 20.00     65.00    1.00       0.00
+E38: IG fan1 air suction (trigger: +X00) 0.00      0.00     2.00       0.73
+E39: IG fan2 air suction (trigger: +X00) 0.00      0.00     2.00       0.17
+E40: IG vent valve       (trigger: +X00) 0.00      0.00     2.00       0.23
+E41: IG supply valve CT4 (trigger: +X00) 1.00      1.00     2.00       0.00
+E42: IG supply valve CT4 (trigger: +X00) 1.00      1.00     2.00       0.00
+E43: IG supply valve CT6 (trigger: +X00) 1.00      1.00     2.00       0.00
```

Figure 3. Exercise results.

CONCLUSIONS

Without addressing the chronic issue of human error, the maritime transportation system all over the world, already feeling the effects of spiraling costs associated with accidents, will have difficulty in absorbing the sweeping changes currently underway. Without mitigating the impact of human error, innovation in the maritime sector may introduce more cost than benefit and not be sustainable in the long run.

In order to reduce the number of accidents caused by human error, effort will have to focus on reducing latent error, mitigating the impact of psychological precursors, and improving the crisis management capability within the maritime community. Such an effort will not only reduce the accident rate, but will help to stimulate the innovation process by making new initiatives more likely to succeed.

Simulation, modeling and web base simulation training represents an important capability to ensure that innovation delivers on its promise of improved activity. To achieve this goal a concentrated effort is required to incorporate maritime simulation, modeling and web base training process into the innovation cycle.

REFERENCES

Anthony Peterson M.M. (2002), Simulation and Modelling in Innovation, Proceedings of The 29th Annual General Meeting of the International Marine Simulator Forum, Keelung, Taiwan.

Barnett, M.L., Gatfield, D., Habberley, J (2002), Shipboard crisis management: A Case Study, *Procceding International Conference Human Factors in Ship design and Operation*, Royal Institution of Naval Architects. pp 131-145.

Barnett M.L. (2004), The development of simulator-based scenarios from the analysis of recent maritime accidents, Proceedings of the Advances in International Maritime Research Conference, Tasmania, Australia.

Barsan E. (2006), Bridge and engine room teams cooperation, in loss of remote control scenarios, International Navigation Simulator Lecturers Conference, ISBN 8-8901-2481-X, Pub.Algraphy S.N.C., Genova, Italy.

Brown A., (2000), Optimum Risk Tanker (ORT) - A Systematic Approach to a TAPS Tanker Design, *Ship Structure Committee (SSC) Symposium*, Arlington, VA, US.

Chiotoroiu L., Dinu D., Hanzu-Pazara R., Pana I. (2006), Simulation Models in Maritime Distant Learning: Tankers Topping-Off, *Conference "TECHNONAV '2006"*, Constanta, Romania.

Hensen H. (1999), *Ship Bridge Simulators: A Project Handbook*, Nautical Institute, ISBN 1870077504, London, UK.

Huey, Beverly Messick and Christopher D. Wickens (1993), *Workload transition – Implications for Individual and Team Performance*. Washington D.C: National Academy Press.

International Maritime Organization (1999), MSC/Circ.565 *Fatigue as a contributory factor in Marine Accidents*, International Maritime Organization., London, UK.

International Maritime Organization (2000), MSC/Circ.982 *Guidelines on Ergonomic Criteria for Bridge Equipment and Layout*, International Maritime Organization, London, UK.

McCallum M.C., Raby M., and Rothblum A.M. (1996), *Procedures for Investigating and Reporting Human Factors and Fatigue Contributions to Marine Casualties*. Washington, D.C.: U.S. Dept. of Transportation, U.S. Coast Guard Report No. CG-D-09-97. AD-A323392.

Perrow C. (1984), *Normal Accidents: Living with High-Risk Technologies*. Basic Books, pp. 215-218..

Reason J. et al (1991), *Errors in a team context,* Mohawe Belgirate Worksho.

Rothblum, A.M., *Human error and marine safety*, Volume 4 in U.S. Coast Guard Risk-Based Decision-Making Guidelines, U.S. Coast Guard Research and Development Center, 2006.

The International Maritime Human Element Bulletin: www.he-alert.org

U.K. P&I Club, (1992), The United Kingdom Mutual Steam Ship Assurance Association (Bermuda) Limited. Analysis of Major Claims. www.ukpandi.com

Wagenaar W.A. and Groeneweg J. (1987), *Accidents at sea: Multiple causes and impossible consequences*. Int. J. Man-Machine Studies, 27, 587-598.