Risk Management Training: The Development Of Simulator-Based Scenarios From The Analysis Of Recent Maritime Accidents

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ABSTRACT

This paper opens with a brief introduction to the development of crew resource and risk management training in the international shipping industry. A review of three case studies is used to highlight some of the current risk management issues raised by recent maritime casualties. The paper provides an overview of how these issues have led to research-led developments in simulator-based maritime risk management training and assessment. The first development has been the design of more effective training courses through a better understanding of the nature of the skill requirements. The current training is outlined and other areas of research, which are now being undertaken, are described. The paper concludes with a summary of further research and development needs.

1. The Development of Maritime CRM 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. The first simulators were introduced for radar training over thirty years ago. Training in the proper interpretation of radar information started as a result of a number of radar-assisted collisions in the 1950's, notably the collision between the passenger ship "Andrea Doria" and the "Stockholm". Those 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 in the 1970's 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. It was apparent from the casualty of the Very Large Crude Carrier (VLCC) "Metulla" in 1974, in which the vessel grounded in the Magellan Straits with two pilots and watch keepers present on the bridge, that bridge teams were not working effectively in supporting each other or the pilot. Simulator-based training courses were introduced primarily to train the skills of passage planning and the importance of the Master/Pilot relationship (Gyles and Salmon 1978). This training initiative developed into the Bridge Team Management (BTM) courses that are conducted today on many simulators world-wide and contain many of the elements to be found in Crew Resource Management (CRM) 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. (Helmreich and Merritt 1998). Bridge Resource Management (BRM) 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 use 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-ups 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 for the safety of passengers in emergency situations. The competence assessment criteria detailed within the Code are not based on specific overt behaviours, but rather on generalised statements of performance outputs, and as such are highly subjective and open to interpretation. Although these standards of competence indicate that IMO recognises 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 assessment, within an industry such as civil aviation.

In summary, resource management training to mitigate risk has become established in the curricula of many maritime training establishments. Courses take a variety of forms and cover both deck and engine room disciplines. The courses are often simulator-based, but not always, and their syllabuses reflect CRM training in other industries. As can be seen from the history of this development, most major training initiatives have resulted from the lessons learnt from a succession of casualties. The next section reviews three recent casualties and the resource, risk and crisis management issues they raise.

2. Case Studies in the Failure of Resource, Risk and Crisis Management.

A recent review of accident databases from the USA, UK, Canada and Australia confirms that human error continues to be the dominant factor in maritime accidents and reveals that in 70% of recorded incidents attributed to human error, failures in situation assessment and awareness predominate (ABS, 2004). The following three case studies illustrate how such factors contribute to accident causation.

2.1 Case Study 1: The Grounding of the "Royal Majesty".

2.1.1 The circumstances

In June 1995 the passenger vessel "Royal Majesty", with 1509 passengers aboard, went aground near Nantucket Island on a voyage from Bermuda to Boston. The vessel was fitted with an integrated bridge system including an autopilot which, when engaged, was capable of steering the vessel along a pre-programmed route using the vessel's GPS system as a primary source of positional information. In the case of insufficient satellite data, the GPS was designed to default to a Dead Reckoning (DR) mode. The autopilot, however, was not capable of recognising any change in GPS status and thus, with the GPS in DR mode, was only able to continue navigation without correction for wind or current.

The autopilot was set on departure from Bermuda, but after about an hour the GPS defaulted to DR mode (probably as a result of a loose connection on the receiver cable), and for the next 34 hours, the vessel was navigating on DR through the autopilot. At no time during this period was this situation detected by the bridge team, so that when the vessel eventually grounded, she was 17 miles off course.

The official National Transportation Safety Board report gave as the probable cause of the grounding:

> *"the watch officers' over reliance on the automated features of the integrated bridge system, Majesty Cruise Line's failure to ensure that its officers were adequately trained in the automated features of the integrated bridge system and in the implications of this automation for bridge resource management, the deficiencies in the design and implementation of the integrated bridge system and in the procedures for its operation, and the second officer's failure to take corrective action after several cues indicated the vessel was off course." (NTSB, 1997).*

2.1.2 The analysis

- This case illustrates the problems of over reliance on the available technology by the bridge team. All the officers have been lulled into a false sense of security by a modern system that appears to be protecting the vessel but is vulnerable. Their understanding of the system and its weaknesses is incomplete.

- The reliance on technology has led the team to use only a limited number of sources of information to determine the vessel's position. Other sources are ignored and not used for cross-checking. This deviance from normal watch keeping practice has gradually become the accepted norm by all members of the team.

- There were several opportunities when both the chief officer and the second officer on their respective watches could have avoided the grounding through the observation of buoys visually and by use of the radar. However, because of their over confidence in the GPS, the team is in a "mind set" where conflicting evidence is not analysed critically and assumptions are not questioned. The result is that the individuals remain confirmed in their bias towards the information from one source and remain in blissful ignorance of the real situation.

2.2 Case Study 2: The Grounding of the "Green Lily".

2.2.1 The circumstances

On 18th November 1997, the 3,624 grt Bahamian registered vessel "Green Lily" sailed from Lerwick in the Shetland Islands with a cargo of frozen fish for the Ivory Coast. The weather on departure was bad with wind speeds increasing to severe gale force 9. The following morning, while hove to about 15 miles south-east of the island of Bressay in the Shetland Isles in storm force 10 winds, a sea water supply line fractured in the engine room. The engineers controlled the flooding and pumping out had begun when the main engine stopped. Unsuccessful attempts were made to restart the engine while the vessel drifted northwards towards Bressay. Shetland Coastguard was advised and three tugs, the Lerwick RNLI lifeboat and a coastguard helicopter prepared to proceed to the casualty.

Attempts were made by two of the tugs to secure a line and tow the "Green Lily" away from land but although initially successful, each line parted. The starboard anchor was released and the third tug attempted to snag the cable and pull her head to wind, but the cable parted. At this time, the lifeboat rescued five crewmen, including two injured, from the ship's deck. The ten remaining crewmembers were rescued by the Coastguard helicopter, but the winchman, who had remained on the deck of the ship, was swept into the sea and lost. The "Green Lily" went aground and started to break up. The investigation by the Marine Accident Investigation Branch (MAIB), published in June 1999, advised the cause of the grounding was:

> *"the lack of propulsion and failure to restart the main engine to arrest the drift of the vessel towards the shore in the prevailing environmental conditions. Contributory causes included flooding of the engine room, failure to reset the mechanical over-speed trip, inadequate knowledge of the cooling water system, failure of the towage attempts and inadequate teamwork"* (MAIB, 1999; pp. 9)

2.2.2 The Analysis

- An initial technical failure precipitated events and was compounded by a hostile environment and further technical problems and failures. The situation was escalating in severity. An emergency was becoming a crisis, but the actors in this tragedy did not have the benefit of hindsight to read the 'script'.
- The available emergency plans, which tended to be procedures based on single failures, were not applicable. The individuals involved were forced to fall back on their experience to cope with an increasingly complex and unpredictable set of circumstances.
- Initial diagnosis of the technical failure was incorrect and led to a faulty but persistent mental model of the situation. In this case, the chief and second engineers, together with the electrical engineer, failed to understand why the main engine stopped and were consequently unable to restart it. They believed that the main engine failure was due to the effect of the flooding, previously caused by the fracture of the sea suction pipe. The probable reason for the main engine stoppage was actually due to the mechanical over-speed trip either not being reset or reset incorrectly.
- Awareness of the overall situation by individuals was based on incomplete or inaccurate information. In this case, both the Master, based on his calculation of drift, and the engineers, were over optimistic in their belief that a tow would be available before the ship ran aground. Meanwhile, the skippers of the rescue craft had unexpressed reservations about various aspects of the operation including the appropriateness of some of the towing gear, the weather conditions and sea room, and the ability of the ship's crew to handle the towlines.
- Individuals and units were separated physically and several agencies were interacting through various forms of communication. In these circumstances, it was very difficult for the key players to communicate meaningfully and maintain a shared and agreed awareness of the rapidly changing situation.

2.3 Case Study 3: The "Diamant" and "Northern Merchant" Collision.

2.3.1 The circumstances

On the morning of 6th January 2002, two ferries were crossing the Dover Strait in reduced visibility of less than 200 metres. The "Diamant" had sailed from Oostende and was heading for Dover. The "Northern Merchant" was heading to Dunkerque from Dover. Both vessels were travelling at close to normal cruising speed: "Diamant" a high-speed craft was travelling at 29 knots, and the "Northern Merchant", a Ro-Ro ferry, was travelling at 21 knots. If both vessels had continued their course and speed, their paths would have taken them to within half a mile of one another. However, at just over a mile apart, the bridge teams started to question the assumptions they had made about each other's probable course of action and started to implement course changes, but not speed changes, that would, they believed, put a greater distance between themselves. At 0952 they collided.

The MAIB report lists 18 possible causes and contributing factors in this accident, including the unsafe speed of both vessels, bridge team failures in risk assessment, violation of collision regulations and adherence to an "unwritten rule" that high speed craft will keep clear of all other craft. (MAIB, 2003; pp. 43-44)

2.3.2 The Analysis

- This case is similar to previous incidents in reduced visibility in which the participants have violated regulations and operational practices. Both teams are making assumptions about the intentions and actions of others and, at the speeds involved, have little time to rectify the developing crisis situation when they realise what is actually happening.
- However, this case also raises questions about the ability of training to provide solutions to this type of problem. The actors in this case were all experienced and professional officers who know the rules perfectly well but, for one reason or another, violate them, probably as a matter of routine. The root causes of these violations may not be resolved simply by sending "offenders" on remedial training in the interpretation of radar interpretation or the collision regulations.
- Organisational culture plays an important part in reinforcing the appropriate behaviours required. If an organisation's shore-based management team pays "lip service" to its own operating policies and procedures by failing to implement them on the vessels and, at the same time, tacitly accepts or rewards deviant behaviour, then the individual officers on board will adopt a similar cultural attitude.

3. Advances in Research for Maritime Training and Assessment.

In the year 2000, the Maritime Coastguard Agency (MCA), following a recommendation of the Marine Accident Investigation Branch (MAIB) in response to the loss of the "Green Lily", awarded a project to a research team at Warsash Maritime Centre. The remit of the project was to investigate the potential use of simulators for training in the handling of escalating emergencies. This project enabled the researchers to review current concepts and models in the field of crisis management across a range of safety critical industries and to conduct a survey of expert opinion on the optimal training and assessment regimes for handling escalating emergencies (Barnett et al 2002). One of the findings of this study was the recognition of the essential differences between emergency and crisis situations and the need for different training syllabuses to address them.

An emergency can be defined as a situation outside normal operating parameters where corrective decisions and actions are based on documented procedures. In the maritime context, examples might be "Man overboard", steering gear failure or a report of a fire in a cabin. Emergency procedures can be trained effectively both on board and at onshore training establishments.

A crisis differs from an emergency in that successful decisions and actions may not necessarily be based on documented procedures. Appropriate pre-defined responses may not exist, and even if they do, in practice they may have conflicting requirements. Those responsible for handling crises will have to think through the situation, and respond in creative and flexible ways.

This distinction between emergencies and crises has a significant impact on the training requirements for their management. Training in handling emergencies may simply be training in following pre-prescribed procedures and drills. Training in crisis management is likely to require a much more demanding approach to practise the situational awareness and decision making skills required in these situations.

So what skills *are* required to handle crises? There is now considerable evidence from both military and civilian sources that the main requirements are for the high-level cognitive skills of problem solving and decision making. Crichton and Flin (2002) suggest that, at its most simplified, there are two fundamental and inter-related skill requirements:

- Situation assessment – "what's the problem"
- Decision making – "what shall I do".

The following sections describe three research-led initiatives in the field of maritime CRM, risk and crisis management currently being undertaken at Warsash:

1. To develop more effective CRM training courses through a better theoretical understanding of the nature of shared situational awareness and mental models in "real world" maritime operations.
2. To identify a set of behavioural markers for assessing the non-technical skills of crisis management.
3. To explore the role of organisational factors in safe operation, in recognition of the limitations of operator training to prevent the reoccurrence of accidents.

3.1 Situational Awareness, Mental Models and the Paradox of RPD

Modern concepts for understanding decision-making have progressed from classic rational choice models to ones that try to reflect the way decisions are actually made in the real world. The most influential of these models is the naturalistic decision-making (NDM) model and has been defined as follows:

> *"The study of NDM asks how experienced people, working as individuals or groups in dynamic, uncertain, and often fast-paced environments, identify and assess their situation, make decisions and take actions whose consequences are meaningful to them and the larger organization in which they operate."* (Pruitt et al, 1997)

This definition reveals a number of characteristics of the situations in which NDM takes place:

- The situations in which decisions are made are uncertain, unpredictable and dangerous.
- Knowledge of the situation is incomplete, and constantly changing.
- The consequences of decisions and actions based on poor situational awareness are potentially catastrophic.
- Experienced people, not novices, generally conduct decision making in such situations.

Another important feature of NDM is that, unlike classical models of decision making, where the objective is to provide optimal decisions, the objective for real world decision makers is to arrive at actions based on decisions that will satisfy the immediate concerns of the situation, without those decisions necessarily having to be the best ones. There are a number of different models within an NDM approach to describe the process by which decisions are made. The dominant model is the Recognition-Primed Decision (RPD) model. Orasanu (1997) provides a comprehensive description of the process:

> *"Its basic principle is that experts use their knowledge to recognise a problem situation as an instance of a type, and then retrieve from their store of patterns in memory an appropriate response associated with that particular problem type. The response is evaluated for adequacy in the present context, and if it passes, it is adopted. If it is found wanting, either another interpretation of the situation is sought or a second level response is retrieved and evaluated."*

The RPD model works well to describe decision-making situations in the maritime context. But the model does have serious implications for the training of "real world" decision-making skills.

In crisis situations, just when the expert needs to draw on a reliable repertoire, the situation is unpredictable and atypical, so no repertoire can be called upon. The crisis handler has to revert to a creative response i.e. they have to think their way through the novel situation. The primary justification for the direct training for crisis management is based in the belief that by exposing individuals or teams to a variety of potential crisis scenarios, their 'patterns' or mental models of situations will be enriched, thus enhancing their situational awareness techniques and their repertoires of decision making. The key to this approach is in the 'richness' of the mental models developed by the individual or team, but paradoxically, the problem is that if the training scenarios are too prescriptive, then the learned repertoires may be inappropriate to the real emergency encountered.

This repertoire driven process can lead to dangerous consequences when facing an unpredictable situation. On the one hand, the decision-maker may derive increasingly bizarre hypotheses to explain the available information cues – the "kaleidoscopic" effect; or the decision-maker may become fixated on one pattern, refusing to change repertoires in the face of obviously conflicting information – the "mind-set" problem as exhibited by the "Green Lily" engineers and the watch keepers on the "Royal Majesty".

Decision-making is a skill. Like all skills, it may be honed through practice. By reducing cognitive load through practice, experts will be less stressed than novices in threatening situations. In addition to specific contextual skills, there is a set of more general cognitive skills involved in situational awareness and decision making. The direct development of such generalised critical thinking skills, which encourage team members to question their assumptions about their assessment of situations, might counteract the RPD paradox and the consequences of stress.

In summary, the nature of crisis situations suggest that there are at least two specific training requirements for the development of situational awareness and decision making skills:

1. To provide exercise scenarios in which the individual's mental models of systems, situations and the cues by which they recognise them, may be enriched;
2. To develop a general critical thinking skill which resolves conflicting information and tests the assumptions on which decisions are based.

Based on the principles described above, an innovative CRM training course is currently being developed at Warsash. The course uses a number of forms of simulation, including role playing exercises and full mission simulator exercises, which combine both bridge and engine room teams. In addition to the specific development of critical thinking skills and the enhancement of situational awareness, the objectives of the course also include the development of the other non-technical skills of CRM, for example, communication, team co-ordination and leadership development.
The course builds the learning experience from classroom lectures on theoretical aspects, followed by brief exercises to practice specific techniques, culminating in simulator-based scenarios in which the various elements can be brought together. The final exercises bring both bridge and engine room teams together, through linked simulators, where complex evolving situations have to be managed by both teams.

The development of the course is leading to further research. A major issue is to what extent will the CRM skills, learned in a simulated environment, *transfer* to the real world? It is hoped to use questionnaires to follow up course participants to assess what has been retained from their training after a defined period.

Two other research issues are of particular interest in the maritime context. The first is related to the sharing of situational awareness between members in a team and also between distributed teams. Both the "Diamant" and the "Green Lily" cases demonstrate difficulties in communicating mental models between teams on the same vessel and/or between separate agencies involved in a crisis situation. Video observations from our own simulator exercises suggest that team leaders can find it difficult to articulate their understanding of the situation to other team members. This difficulty is not limited to intra-team communication, but as the "Green Lily" case shows, can work at an inter-team level too. In addition, it is apparent that one team can easily become oblivious to the information needs of a separate team when under stress, for example, bridge and engine room teams habitually fail to update each other as a training scenario unfolds. Measuring the effectiveness of synchronous training and the characterisation of behavioural markers for distributed teams represent interesting challenges to the maritime training community.

The international shipping industry shares with the offshore industry a similar working environment in that multi-national, multi-cultural crews work and socialise together in an isolated environment for months on end. Cultural and linguistic effects on team working is a particularly challenging area of research. Our experience from simulator training suggests that different national cultures do work together in noticeably different ways, for example, a UK/US team does display a more individualistic way of sharing situational awareness than those from a more "collective" culture (Hofstede, 1991). Questions that have yet to be addressed include:
What effects are produced by cultural factors and how may they be characterised? What is the impact on the overall safety performance of a team, especially in stressful situations, by placing individuals from one culture into a different culturally based team?

3.2 Towards the Development of a Maritime Assessment Framework

A PhD research programme is also currently being undertaken at Warsash that is intended to provide an understanding of how a behavioural marker system could be used to assess the competence in crisis management of merchant marine engineering officers.

Behavioural markers that could be used to assess competence in crisis management within the context of a simulated merchant vessel's engine room control room are being determined. Experiments are being undertaken to investigate the efficacy of these behavioural markers to assess competence in crisis management, and it is intended that this research will then go on to show if these behavioural markers can be used as the basis for an objective competence assessment framework.

The aims of this research programme are:

1. To understand how behavioural markers can be used to objectively assess competence in crisis management of merchant marine engineering officers.
2. To develop and validate an assessment framework that utilises specific overt behavioural markers to facilitate the objective assessment of competence in crisis management of merchant marine engineering officers.

3.3 Organisational Factors

The argument has been made earlier in this paper that the training and assessment of operators can only ever be part of the solution to reducing accidents. Organisational factors also play a significant part in accident causation. So what are the research issues in maritime operations, at an organisational level, which need addressing?

The analysis of human factors in accident causation is still relatively immature in the maritime world. Although databases held by the MAIB and other parties interested in the causal factors of accidents – e.g. 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 organisational culture between shipping companies is a well known phenomenon, but there has been little work on understanding the effects of organisational culture on safe and efficient performance. In much the same way as we are striving to identify a set of behavioural markers to assess the competence of individuals, so there is a need to establish a set of organisational 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 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 organisational behaviour; second, in deciding which "behaviours" are leading indicators of proficiency; and third, in designing methods that can measure these indicators accurately.

4. Summary and Conclusions

As in similar safety-critical industries, the analysis of maritime accidents over the years has revealed shortcomings in the ability of operators to manage both resources and crises. CRM training has been seen increasingly as a fundamental part of the human error management philosophy. The International Maritime Organization recognises the need for non-technical or resource management skills, but both the standards of competence and their assessment criteria are immature in comparison with civil aviation.

Studies of recent casualties involving human failures in resource, risk and crisis management confirms that lack of situational awareness is the predominant factor in operator error. Analysis of recent casualties also suggest that CRM training alone, although important, may not be a panacea for operator error and that organisational factors must also be taken into account.

A theoretical understanding of naturalistic decision making suggests that there are at least two specific training requirements for the development of situational awareness and decision making skills. Firstly, there is a need to enrich the individual's mental models of systems, situations and the cues by which they recognise them, and secondly, to develop a general critical thinking skill which resolves conflicting information and tests the assumptions on which decisions are based.

An innovative CRM training course is currently being developed at Warsash. The course uses a number of forms of simulation, including role playing exercises and full mission simulator exercises, which combine both bridge and engine room teams to develop the skills of communication, team co-ordination and management and leadership development.

In setting an agenda for future maritime research in this area, the following issues are suggested for consideration:

- If the direct training of resource and crisis management skills is pursued, to what extent will such skills, learned in a simulated environment, transfer to the real world?
- What are the optimum training environments to ensure effective transfer?
- How can these non-technical skills be assessed most effectively, both at the level of the individual and at the level of the team?
- What behavioural markers, both at individual and team level, predict safe performance?
- In multi-national environments, how may cultural factors be characterised and what is the impact on overall safety performance of cultural differences?

- We know that organisational factors also play a significant part in accident causation but how can their significance, frequency and impact be established?
- How does organisational culture impact on accident causation?
- Finally, what are the metrics that enable the status of an organisation's safety management system to be determined?

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BIOGRAPHY

Risk Management training: the development of simulator-based scenarios from the analysis of recent maritime accidents

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