# Non-technical skills: the vital ingredient in world maritime technology?

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## SYNOPSIS

The significance of human factors in commercial shipping operations is now universally recognized. But, in comparison with our appreciation of technology, the application of our knowledge concerning human performance, and the factors that shape and influence it, remains relatively neglected, and certainly unexploited, in the safe conduct of maritime operations. This paper opens with a review of recent accident analyses and case studies to highlight the importance of non-technical skills in contributing to maritime casualties. The paper provides an overview of recent innovative developments in simulator-based non-technical skills training and assessment, through which the following issues are addressed:

- What are the non-technical skills of resource management?
- Which pedagogical theories underpin the development of these skills?
- Which instructional techniques are appropriate to the development of non-technical skills?
- How may the effectiveness of such training be evaluated?
- What other factors affect the successful development of non-technical skills?

## INTRODUCTION

A recent review[1] of the accident databases from the USA, UK, Canada, Australia and Norway confirms that human error continues to be the dominant factor in maritime accidents. The following conclusions were drawn:

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Professor Mike Barnett is Head of the Maritime Research Centre at Southampton Solent University, which incorporates the Warsash Maritime Centre, which he joined in 1985. His current post encompasses responsibility for the management of research and welfare of postgraduate researchers. Mike is a Chartered Marine Scientist, Fellow of the Nautical Institute, Fellow and current Vice-President of IMarEST and a Council Member. He is an inaugural member of the Maritime Advisory Board of CHIRP and sits on the MCA Research Advisory Committee.

David Gatfield joined Warsash Maritime Centre in 1996 and is a Senior Lecturer and Unit Manager of the Machinery Space Simulator at Warsash Maritime Centre. After serving at sea as a Marine Engineering Officer, he was appointed Technical Superintendent with Shell Tankers. He is currently conducting research for a PhD in behavioural markers for the assessment of competence in crisis management. David is an Associate Member of IMarEST and a Member of its Council.

Claire Pekcan is a Master of Science qualified occupational psychologist who has been working as a Senior Research Fellow at Southampton Solent University since 2003. Claire started her career in maritime research and education in 1996 working at Warsash Maritime Centre as a Researcher. Claire has directed her own company, which specialised in preparing safety management guidance to the UK ports industry, and has worked as a principal consultant for an engineering risk management organisation.

1 While the total number of accidents is declining, human error continues to be a dominant factor in 80 to 85% of maritime accidents.

2 Failures of situational awareness and situation assessment overwhelmingly dominate.

3 Human fatigue and task omission seem closely related to failures of situation awareness.

In their review of 150 accident reports from the website of the Australian Transportation Safety Bureau (ATSB), causal factors were classified in root cause groupings, which included a situational awareness group (27.5%), management group (24.5%), a risk group (30%) and a non-human error group (15%). Although the authors acknowledge that these root cause groupings are subject to interpretation, the results correlate well with the UK Marine Accident Investigation Branch (MAIB) database. However, the management group refers almost entirely to onboard management factors, with only 4.5% of these factors being ascribed to organisational influences, such as the level of manning or business management.

As this study illustrates, the majority of accidents and incidents are *not* caused by technical problems but by the failure of the crew to respond appropriately to the situation. Most maritime professionals would probably agree with Helmreich[2] that in order to ensure safe and efficient operations there is a need to understand the behaviours of effective error detection and management. However, while other safety critical industries[3] [4] and the military[5] have heeded this message and have been training and assessing resource management skills as a way of ensuring that errors are effectively detected and managed, the shipping industry continues to lag behind. Historically, maritime training has focussed on the development of technical and procedural skills. Until recently, providing solutions to the problems of developing non-technical skills and the optimal use of crew resources has been neglected in maritime training.

The only mandatory requirements in the maritime domain for the development of the non-technical skills of resource management are those of the International Maritime Organization's (IMO) Seafarer's Training, Certification and Watchkeeping Code[6]. 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 emergencies. 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[7]. 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.

The following section reviews three case studies to illustrate how our understanding of human error allows us to gain insights into the root causes of maritime casualties. The first case illustrates both failures in system understanding by the onboard engineers and poor communications between teams. The second case is a classic example of loss of situational awareness by both the onboard deck and engineering teams. The third case illustrates how the root cause of onboard violations may be related to organisational culture. It also indicates the sharp distinction between potential remedies for future prevention depending on whether one interprets this type of accident as a failure in individual competence or the results of predisposing factors within the organisational culture. All three cases indicate that in any accident, there are likely to be multiple root causes.

## THREE CASE STUDIES IN HUMAN ERROR.

### Case Study 1: The grounding of the Hanjin Dampier[8]

The circumstances

At 1032 on 25 August 2002, the Korean flag bulk carrier *Hanjin Dampier* departed from the port of Dampier, Western Australia. A pilot was conducting the navigation of the ship, which was loaded with iron ore and had a displacement of 233 158 tonnes with draughts of 17.94 m forward and 18.10 m aft. At 1127, two of the ship's three main generators stopped, leaving only one generator running and connected to the main switchboard. At 1152, the third generator's circuit breaker tripped open. With the total loss of power to the main switchboard the main engine stopped and the ship lost steering. The rudder had stopped at 10° to starboard. As the ship slowed, it started to turn to starboard towards shallow water. The emergency generator failed to start automatically and, as a result, steering was not restored for some four minutes. At 1202, *Hanjin Dampier* touched bottom. The ship suffered only minor damage to the bottom shell plating, but the consequences of this incident could have been a lot worse.

The Analysis

- There would have been no incident if there had been no loss of electrical power on the vessel. Water had entered the port diesel oil storage tank through a broken manhole gasket. This water was then transferred, during a normal fuel transfer operation, to the diesel oil settling tank.

- However, due to the engineers' use of an incorrect sized gravity disc in the diesel oil purifier, and their incorrect setting of the purifier's fuel outlet line back pressure, the water in the diesel fuel in the diesel oil settling tank was passed to the diesel oil service tank. From here the water reached the three diesel generator engines, leading the to the loss of electrical power on the vessel. The emergency generator then failed to start automatically upon the loss of the main source of electrical power, due to a faulty starting battery. Had the emergency generator restored power automatically to the emergency switchboard within the 45 seconds required by the SOLAS regulations, the ATSB concluded that it was likely that the grounding would have been avoided.

- The report states that numbers one and two generators tripped off the main switchboard, and stopped, at about 1128. At this time the ship was still in the buoyed channel, and being fully laden she had little room for manoeuvre, the open sea still being more than an hour and a quarter away. Given his uncertainty regarding what had caused the first two generator shut downs, and his awareness of the ship's critical navigation situation, the Chief Engineer should have discussed the situation more fully with the Master. This would have given the Master the opportunity to form a contingency plan, in consultation with the pilot, to mitigate the risk to the ship. With number three generator continuing to supply power for a further 24 minutes, there was adequate time at this point in the passage to stop the ship either in the channel, or after it had cleared the channel in deeper water, and to call for tug assistance. In the event, the Chief Engineer did not communicate the gravity of the generator problem to the Master and this failure of communication directly contributed to the grounding.

- The lack of effective communication between the Chief Engineer and Master meant that the bridge team were unaware of the risk to the vessel after the first two generators had stopped and thus precluded the possibility that they could take pre-emptive action to reduce the level of risk to the vessel. The ATSB report makes the following statement:

  *"Had there been more effective communication between the Chief Engineer and Master at the critical time after the first two generators had shut down, it is likely that the grounding of Hanjin Dampier could have been averted."*

**Case Study 2: The Grounding of the "Green Lily".**[9]

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 Coastguard helicopter rescued the ten remaining crewmembers but the winch man, 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)

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. 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.

**Case Study 3: The Collision of the "Diamant" and the "Northern Merchant".[10]**

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.

The Analysis

- This case is similar to previous collisions 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 solution to such problems, specifically, the ability of operator training to provide solutions to this type of problem. The actors in this case were all experienced and professional officers who knew the collision regulations 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 on board. 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.

## CREW RESOURCE MANAGEMENT TRAINING

At the Maritime Centre in Warsash, courses are now being developed that address some of the issues raised by the cases above. One such course, the Crew Resource Management (CRM) course, is almost entirely concerned with teaching human behavioural or non-technical aspects of ship operations. Technical aspects of ship operation, such as ship navigation or power generation, are not covered as separate items. Rather, the course curriculum is devoted to social and cognitive aspects of seafarers’ performance, i.e. it is devoted to those skills thought to be important in assisting in the detection and management of errors.

A further novel approach of the Warsash course is the incorporation of human behaviour research findings in the training philosophy. Recognition primed decision-making theory[11] [12] suggests that there is a generic metacognitive skill that can be developed to be applied to handle any unpredictable situation. One aspect of this theory that is put into practice on the course is the enrichment of mental models through the building of repertoire patterns. Another aspect is the development of critical thinking skills through the practice of specific techniques in simulated scenarios[13].

### The ABC of Learning

On the full mission simulator courses run at Warsash Maritime Centre, a team of researchers and lecturers is working together to ensure three things:

1 that students learn the types of attitudes, behaviours and cognitions that have deep significance for their effectiveness on board ship;

2 that the course lecturers concentrate on what the students do by designing learning sessions that get the students engaged; and

3 that the students learn through observation of, reflection on, and critical analysis of, their own behaviour.

Taking as a starting point the aviation industry’s model for CRM training as outlined in CAP 737[14], the resource management courses at Warsash Maritime Centre aim to:

1 enhance the operational safety of the client company’s vessels

2 reduce the likelihood of an incident to a vessel

3 reinforce the client company’s vision and mission

The philosophy underpinning the management course is very much student centred as opposed to lecturer centred, and thus represents a course that seeks to add value to the participating officers through attitude, behaviour, and cognitive change. The instructional system or process employed at Warsash to bring about these changes draws on theories of learning identified in the foregoing. However, just allowing the students to ‘behave’ on the course with the lecturers providing no more than feedback (consequences) would be unlikely to beget the safety behaviours associated with effective error detection and management. The students need to be presented with new ways of thinking, new techniques, and new ways of behaving that will facilitate their abilities to handle problem situations.

In the language of behaviour based safety management, these new ways of thinking and behaving are the antecedents to safe behaviour. However, antecedents, such as lectures, safety rules, procedures, instructions, toolbox talks, and risk assessments, are ineffective in bringing about change on their own.

Krause[15] explains,

> *“Many well-intentioned safety programs fail because they rely too much on antecedents – things that come before behaviour…All too often these same antecedents have no powerful consequences backing them up.”*

In the same way, training courses that concentrate on instruction (antecedents) where the emphasis is on what the teacher teaches and not on how the student learns, are unlikely to bring about behaviour change. As Krause states:

*"both antecedents and consequences influence behaviour, but they do so differently:*

- *consequences influence behaviour powerfully and directly*
- *antecedents influence behaviour indirectly and serve to predict consequences."*

The authors maintain that both antecedents and consequences are important and thus have designed the crew resource management course in accordance with Antecedent-Behaviour-Consequence (ABC) principles. The course provides the opportunity for the students to practice the behaviour (B) that has been learnt in the lectures (A) and through the debrief session after an exercise receive feedback on their actions (C).

Antecedents

The aims of the crew resource management course are met by emphasising skills that will increase shipboard officers' abilities to act responsibly to health, safety, and environmental concerns. Table I below identifies the types of skills that are taught on the CRM course.

**Table I. Crew Resource Management Skills Taught at Warsash Maritime Centre**

| *SOCIAL SKILLS* | *COGNITIVE SKILLS* |
|---|---|
| **Co-operation** | **Situation Awareness** |
| Open communication | Situation assessment |
| Consideration for others | Risk assessment |
| Team working | |
| **Leadership and Managerial Skills** | **Decision Making** |
| Situational leadership | Problem diagnosis |
| Assertiveness | Option generation |
| Planning and coordinating | Option selection |

Within the Warsash training course, the lecturer inputs are descriptions and explanations of the following:

- models of human error
- error chain analysis
- effective communication
- cultural awareness
- interpersonal influence
- situational leadership
- situation awareness and the rule of three
- critical thinking techniques for decision-making in a crisis

In accordance with the theories of learning presented above, the course begins with teacher led instruction. However, the students are not subjected to transmissions of information, rather syndicate groups, question and answer sessions, and case study analysis are an integral part of the lectures to ensure that the students are engaging with the material. The intention is to develop the students' independence in preparation for the simulator exercises that begin in the middle of the week and occupy all of the time in the last two days of the course. These teacher led activities are antecedent to student-centred activities described under the behaviours section below.

Behaviours

There have been a number of training programs produced that aim to improve the higher order cognitive skills of the students within specific context[16] [17] [18]. These techniques have been adapted at Warsash to try and improve the students' social skills such as communication and co-operation.

Some of the techniques used are:

- having students justify their solutions to one another
- having students evaluate other students solutions
- allowing students to make and correct errors

Other studies have been directed at trying to generate training techniques to improve general problem solving skills that would be transferable into different contexts of application[19] [20]. These techniques, listed below, have also been adapted at Warsash to improve the students' cognitive and metacognitive skills:

- considering multiple sides of an issue (lateral thinking)
- considering consequences
- selecting goals and planning strategies
- prioritizing factors involved in a situation
- generating and evaluating evidence
- using perceptual rather than logical thinking
- extensive practice of solving problems
- teaching the use of heuristic strategies
- use of graphical representations to show the structure of problems

In effect, the lecturing staff are making the most use of learning through social interaction, and are attempting to capitalise on the range of experiences and learning styles within the group. As the course progresses, the teacher decreases the structure and control of the classes as students develop their ideas, which they are then eager to test out in the simulators. This latter phase of learning is further developed through the Consequences aspects of the course.

## Consequences

> *"Debriefing is the key to the entire learning process, during which trainees' knowledge and attitudes are applied, tested, analysed and synthesised."* [21]

A student-centred debriefing technique has been shown to be more effective because students learn better through self-discovery and self-analysis than by lecture. The student-centred debriefing technique draws upon students' professional expertise and motivation to perform well, and it helps the lecturer understand the students' performance.

Until students have the opportunity to reflect on that which they have experienced during a simulator exercise, it is doubtful that any real learning will take place. The 'debrief' integrates the simulation experience into the learning environment. Debriefing is the critical phase of learning, where the individual begins to understand events experienced. These accommodations of new information form the essence of meaning. Students learn to tie things together, to connect part to part to whole.

However, students may, or may not, process their newly acquired information correctly. Through the debriefing process, the lecturer can ensure that new learning is processed in the correct manner. The debriefing process should provide feedback to the lecturer on the students' value of, and understanding of, the simulation. It also provides feedback to the students about the consequences of their behaviours. Lecturers need to ascertain whether the students' experiences matched those of the real world and whether they believed the experiences were useful.

For example, in the "total ship simulation" exercises during the CRM course, in which the bridge and engine control room simulators are linked, a lack of communication between the engine room and the bridge has been observed on many occasions. The first communication between Master and Chief Engineer following a total loss of electrical power on the vessel is often when the Master calls the Chief to ask whether a problem exists.

This is despite the fact that in the exercise scenario used, as in the case of the *Hanjin Dampier*, the Chief Engineer is already very well aware that there is something seriously wrong with the supply of electrical power to the vessel. During the debriefs of such exercises, Master's will sometimes say that if the Chief Engineer had only given him a few minutes warning of the possibility of a blackout, he could have placed the vessel in a much safer situation. With these debriefs being conducted with the whole ships team, including both deck and engineering departments, a powerful learning point can be taken away by the engineering officers.

The ATSB report of the *Hanjin Dampier* case made the recommendation that ship owners and managers should consider resource management training for engineering officers. It is the authors' experience that the most effective resource management training occurs when both the bridge team and the engine room team receive resource management training together. In this way, the non-technical skills that are required for safe operations are practiced by the whole ships team and not just the deck department. By using this combined method of training, both the inter and intra team non-technical skills onboard can be enhanced, and incidents such as the *Hanjin Dampier* should not be repeated.

In summary, the team behind the CRM course being run at Warsash have designed the course to ensure that non-technical skills are not only taught but are also learnt. This has entailed designing the course to contain the types of knowledge that has significance for effective performance, structuring the sessions such the students are engaged, and gradually introducing simulation exercises so that the level of student autonomy has developed sufficiently to make extended abstract learning possible. However, it has to be borne in mind that crew resource management training, even if well designed, is not a panacea for human error prevention.

## LIMITATIONS OF CRM TRAINING

There is now a general acceptance of the core concepts for the non-technical or resource management skills required for competence in shipboard operations. Furthermore, there is also an acceptance that the behaviours associated with these skills are context specific. For example, Helmreich *et al*[22] suggests that the optimal implementation of resource management skills is dependent upon the cultural context in which they are applied.

However, the maritime training community often finds that the application of CRM style training is limited to a retro-active 'dose' of post incident remedial training. A collision or a grounding is likely to result in bridge teams being prescribed a course of 'treatment' in passage planning; an engine room fire or catastrophic failure is likely to result in engineering officers being prescribed a course of treatment in engine room management.

Quite rightly, the management of shipping companies feel that these potentially life-threatening incidents need to be addressed. The human errors arising from poor judgement, poor situation awareness and procedural violations are unpacked to see what lessons can be learnt. Officers are sent on the courses in the hope that their erroneous behaviour can be un-learnt and replaced with more appropriate behaviour. In effect, training colleges are asked to 'fix' problem employees. The training colleges oblige with a week's course for the "problem employees" but it is unlikely that the course members will ever sail together as a team.

In our rush to fix the "problem employee", we are all in danger of missing the point: different ships, different teams, different individuals, but the same sort of incidents keep occurring. Something more fundamental, more deep rooted than operator error is at fault. In the same way that having a documented safety management system does not make a company safe, having employees attend CRM courses does not make a ship safe. Most company managers fail to ask why this is the case. Training is often seen as an end in itself and little effort is made to follow up the training by seeing how effective it has been on board the vessel itself. Little or no research is done to analyse whether solutions other than training are more appropriate and the training community unwittingly colludes in this self-deception by supplying yet more customised courses.

At Warsash, the research team are attempting to address this thorny issue, if not in whole, at least in part. In an effort to foster behaviour change beyond the usual 'honeymoon phase' of the training intervention, a reflective practitioner[23] initiative has been developed and is being trialled. Before the start of the course proper, course attendees are encouraged to reflect on past experiences, to ascertain where their behaviour is effective and where it is ineffective. At the end of the course, the students are asked to think about what they have learned and how they might apply this new learning in the workplace, i.e. onboard ship. Three month's after they have attended the course, the students will be followed up to establish what they remember, what they have applied and what they believe to be the enablers and constraints to applying what they have learned on board ship. This latter aspect of the reflective practitioner exercise will also enable the research team to establish whether the culture in which the students are attempting to apply their newly learned non-technical skills, is receptive or hostile. In other words, this research will help us to understand the extent to which company culture influences accident likelihood and inhibits safe behaviour.

Three 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. All three case studies 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"* and the *Hanjin Dampier* cases show, can work at an inter-team level too. In addition, as mentioned before, 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 the purposes of assessing competence, both for individuals and for distributed teams, represent interesting challenges to the maritime training and research 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 are 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[24]. The second area of research therefore seeks to address the following questions:

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?

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, as a third area of research, what are the 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 scientific 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.

## 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. Although CRM training has become well established in the maritime curricula, as with civil aviation, there remains a question mark about how effective such training actually might be in improving safety performance. Current research at Warsash is attempting to address this question by determining to what extent will CRM skills, learned in a simulated environment, *transfer* to the real world? Questionnaires are being used at different stages of the learning process to follow up course participants to assess what has been retained from their training after a defined period.

Analysis of recent casualties also suggest that CRM training, although important, may not be a panacea for prevention of accidents and that organisational factors, as well as operator error, must also be taken into account.

Notwithstanding this conundrum, there is much that maritime colleges can do to improve the learning of their students. Whether the courses are simulator-based or not, theories of learning suggest to us that we must tailor our courses to meet the needs of the students. Students need to be given opportunities to be active discoverers rather than passive recipients of knowledge and thus courses dominated by one-way lecturer transmissions are unlikely to be effective. Students also need to be able to interact in a social environment, one in which the teacher gradually reduces control, and one in which students' brave efforts to develop understanding are encouraged. Introducing elements in the course requiring student independence too early can backfire leading students to become defensive and shut down their learning. Students also need to be encouraged and guided in the interpretation of experiences, whether in a classroom discussion or post a simulator exercise. Reflection on experience is a process that has a powerful effect on adults' learning. By encouraging our students to carry this process on beyond the conclusion of the course, we have the potential to get beyond the honeymoon period normally associated with training interventions and bring about lasting attitude, behaviour and cognitive change.

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