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Development of taxonomy for deck officers' non-technical skills (NTS) and analysing training needs for human element, leadership and management (HELM) course

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August 2014

IAMU
International Association of Maritime Universities

This report is published as part of the 2013 Research Project in the 2013 Capacity Building Project of International Association of Maritime Universities, which is fully supported by The Nippon Foundation.

Published by the International Association of Maritime Universities (IAMU) Secretary's Office
Toranomon 35 Mori Building 7F, 3-4-10 Toranomon, Minato-ku,
Tokyo 105-0001, JAPAN
TEL : 81-3-5408-9012 E-mail : info@iamu-edu.org URL : http://www.iamu-edu.org

ISBN978-4-907408-06-0

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Contents

Development of taxonomy for deck officers' non-technical skills (NTS) and analysing training needs for human element, leadership and management (HELM) course

Theme: Human element related issues

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Abstract *A review of the maritime accidents conducted in 2006 confirms that human error is the main contributing factor in the maritime accidents. Non-technical skills (NTS) encompass both interpersonal and cognitive skills such as situation awareness, teamwork, decision-making, leadership, managerial skills, communication and language skills. In a crisis situation good NTS allow the deck officers to recognise a problem quickly and manage the situation and team safely and effectively. As a result, the evaluation and grading of deck officers' NTS is a necessary to assure safety and security at sea. This project aims to identify the links between maritime accidents and deck officers' NTS and identify significant criteria and their contributions to their NTS. In this project, firstly, taxonomy of deck officers' NTS is developed by conducting interviews with experts. Secondly, the relative importance of each attribute is calculated by using Analytical Hierarchy Process (AHP) approach. Thirdly, behavioural markers as well as a set of scenarios are developed for the assessment of deck officers' NTS in a ship bridge simulator. Fourthly, samples of volunteer students after completion of their training programmes are selected and their NTS grades in a ship bridge simulator are assessed. Fifthly, samples of volunteer students after completion of their training programmes as well as HELM course are selected and their NTS grades in a ship bridge simulator are assessed. Seventhly, after conducting extensive research and simulator observations and to see whether HELM training has enhanced their NTS grades or not the utility values for the groups with and without the HELM training are assessed. Finally, HELM training effectiveness is evaluated and suggestions are given for further improvement of the course.*

Keyword: *Deck Officers, Non-technical skills, Leadership, Teamwork, Situation awareness, Decision making, Human Element, Leadership and Management (HELM)*

1. Introduction

This project is following the concept of Formal Safety Assessment (FSA). Formal Safety Assessment is defined by UK Maritime and Coastguard Agency (MCA) [1] as: “a structured, systematic five-step methodology, aimed at enhancing maritime safety including the protection of life, health, the marine environment using risk analysis, cost benefit and regulatory influence diagram to facilitate decision making”.

Formal Safety Assessment is a new approach to maritime safety which involve using the techniques of risk and cost-benefit assessment to assist in the decision making process [2]. Based on the formal safety assessment the following five steps are taken to achieve the aims and objectives of this project.

1. Identification of significant criteria and their contribution to the deck officers’ non-technical skills.
2. Assessment of deck officers’ non-technical skills.
3. Options that can improve deck officers’ non-technical skills.
4. Cost - benefit assessment of the options.
5. Decisions on which options to select.

The first aim of this project is to identify the significant criteria that are applicable for the evaluation of deck officers’ non-technical skills through interviews with experienced merchant navy officers at management level. It is worth mentioning that Non-Technical Skills (NTS) encompass both interpersonal and cognitive skills such as situation awareness, teamwork, decision-making, leadership, managerial skills, communication and language skills. In a crisis situation good NTS allow the deck officers to recognise a problem quickly and manage the situation and team safely and effectively. This project will create a set of scenarios within a ship bridge simulator through which it will be possible to evaluate and grade non-technical skills of the deck officers. The second aim of this project is to develop a method which will enable trainers to quantitatively assess non-technical skills and identify further training requirements. Evaluation of a deck officer’s NTS grade enables and facilitates maritime educators to assess the effectiveness of their training programmes.

Based on the STCW requirements, HELM (Human Element, Leadership and Management) training course need to be consisting of: 1) Knowledge of shipboard personnel management and training; 2) Knowledge of related international maritime conventions and recommendations, and national legislation; 3) Ability to apply task and workload management, including: a) Planning and co ordination, b) Personnel assignment, c) Time and resource constraints, and d) Prioritization; 4) Knowledge and ability to apply effective resource management: a) Allocation, assignment, and prioritization of resources, b) Effective communication on board and ashore, c) Decisions reflect consideration of team experiences, e) Assertiveness and leadership, including motivation, and f) Obtaining and maintaining situation awareness; 5) Knowledge and ability to apply decision-making techniques: a) Situation and risk assessment, b) Identify and generate options, c) Selecting course of action, and d) Evaluation of outcome effectiveness; and 6) Development, implementation, and oversight of standard operating procedures.

The structure of this article is as follows. The identification of significant criteria is conducted by reviewing the marine accidents reports and literature review in section 2. In section 3, firstly,

taxonomy of the deck officers' non-technical skills is developed and validated through interviews with experienced merchant navy officers at management level. Secondly, the relative importance of each attribute is calculated using Analytical Hierarchy Process (AHP) approach. Thirdly, behavioural marker systems are developed for the assessment of deck officers' non-technical skills in a ship bridge simulator. Finally to aggregate the qualitative data evidential reasoning (ER) algorithm is introduced. In section 4, firstly, the methodology is explained and applied for assessment of students' non-technical skills. Secondly, a set of scenarios are developed and samples of volunteer students after completion of their training programmes are selected. Based on the developed scenarios and behavioural marker assessment frameworks their qualitative characteristics are assessed subjectively in a ship bridge simulator and aggregated by using ER. Furthermore, by using the same technique, samples of volunteer students after completion of their training programmes as well as HELM course are selected and their NTS grades in a ship bridge simulator are assessed. The utility values for the groups with and without the HELM training are assessed and the HELM training effectiveness is evaluated. In section 5, control options are suggested and cost benefit analysis is carried out using decision tree and Bayesian networks. The section 5 follows with the section conclusion and recommendations.

2. Literature Review

A review of the maritime accidents databases from UK, USA, Norway and Canada conducted by Professor Michael Barnett *et al.* [3] confirms that human error is the main contributing factor in the maritime accidents. This study illustrate that major maritime accidents are not caused by technical problems but by failure of crew to respond to the situation appropriately. The summary of their study is listed as follows [3, 4]:

1. While the total number of accidents is declining, human error continues to be dominant factor in 80 to 85% of maritime accidents.
2. Failures of situation awareness and situation assessment overwhelmingly dominate.
3. Human fatigue and task omission seem closely related to failures of situation awareness.

Accidents in maritime industry are not new and a major contributing factor to most of these accidents is human error. In 1997 Protection and Indemnity (P&I) club reported that human error was responsible for 58% of all claims made. This figure has not reduced since but the other major contributing cause to accidents, the technical failures, has reduced by two thirds since then [5]. Significant levels of protection are built into modern technical systems, but as hardware and software have become increasingly reliable, the human contribution to accidents has become ever more apparent [6]. Human error cannot possibly be eliminated altogether but measures can be taken to reduce it. Analysis in a number of industrial sectors has indicated that up to 80% of accident causes can be attributed to human factors [6].

The most well-known marine accidents occurred recently are: Herald of Free Enterprise in 1987, recording 188 fatalities; Exxon Valdez in 1989, with extensive sea pollution of 37,000 tons of crude oil; Scandinavian Star in 1990 with 158 fatalities; Estonia in 1994, with 900 fatalities; Erika at the end of 1999 with up to 25,000 tons of oil spill; Samina Express in 2000 with 80 fatalities; Prestige in 2002 with 63,000 tons of oil pollution; Tasman Spirit in 2003 with 28,000 tons of oil pollution; and Costa Concordia in 2012 with 32 fatalities [7].

After the investigation of Herald of Free Enterprise accident in 1987, analysts were unable to blame the flag, as vessel carried British flag; ship's age as she was only seven years old; classification society; as ship was classed by Lloyd Register; crew's nationality, as all crew members were British. During the accident weather was very good, sea conditions were calm and the location of accident was only few minutes away from Belgian port Zeebrugge. As a result, the significant factor was "human error" [7]. Many court decisions about marine accidents had come to same conclusion: "80% of all marine accidents are due to human error" [8]. The Maritime Transportation Research Board in US also estimated that 80% of accidents were due to "human error". It has also been recognised that "human error" is found in both the ship and office management [7].

RINA [9] suggested that human factor is the root cause of about 60 to 80 percent of serious maritime casualties. Serious casualties are often preceded by less noticeable accidents involving human error in the form of misconduct, omission, lack of competence, under-estimation of hazardous situations, preparedness, communication and responsibility which are crucial factors in the attempt to reduce maritime casualties [7].

Warsash Maritime Centre in UK has developed Crew Resource Management (CRM) course to address the non-technical aspects of ship operations. The course curriculum is dedicated to social and cognitive aspects of seafarer's performance. The course contents are focused to those skills assumed to be essential in assisting in the detections and management of errors in the crisis. Barnett *et al.* [3] believe that one week's course provided by a training college is not enough to fix the "problem employee".

The concept of non-technical skills generated from aviation industry when National Transportation Safety Board in USA investigated number of airline accidents in 1960s and 1970s. As a result of the following accident, the concept of Cockpit/Crew Resource Management (CRM) was established [10, 11]:

"On December 28, 1978, as a result of a relatively minor landing gear problem, a United Airlines DC-8 was in a holding pattern while awaiting landing at Portland, Oregon. Although the first officer knew the aircraft was low on fuel, he failed to express his concerns convincingly to the captain. The plane ran out of fuel and crashed, killing 10".
First generation of CRM course was delivered in 1981 and it has evolved into the fifth generation today. Fifth generation of CRM outlines the fact that human errors are inevitable and CRM can be seen as a set of error countermeasures with following three lines of defence:

1. The avoidance of error.
2. The trapping incipient errors before they are committed.
3. Mitigating the consequences of those errors that occur and are not trapped.

Various other safety critical industries, such as Anaesthesia, nuclear powers, fire fighters and surgeons has followed the footsteps of aviation industry's efforts into non-technical skills training and developed specific nontechnical skills models that are suitable for their own domain. The need for the training and assessment of non-technical skills (i.e. team working, leadership and management, situation awareness, and decision making) is established in the maritime industry recently by making Human Element Leadership and Management (HELM) course compulsory in 2012.

3. Development of taxonomy for deck officers' non-technical skills

The aim of this section is to develop taxonomy for deck officers' non-technical skills by the help of collecting data from experienced deck officers. Within this section the term 'non-technical skills' is used to describe senior deck officers' attitude and behaviours in crisis situations which are not directly related to technical skills used to navigate a ship or to use the bridge equipment. This includes social and cognitive skills to deal with crisis situation and thus would cover skills and behaviours relating to teamwork, leadership, decision making, situation awareness and workload management. In a research conducted at Aberdeen University by conducting anaesthetists' non-technical skills [12] importance is given to good non-technical skills. As a result, by enabling anaesthetists to be fully aware of the situation and able to anticipate the problem or deal with unexpected occurrences the chances of problem occurring is reduced. Same could be applied to the maritime industry as good non-technical skills allow the deck officer to recognise the problem quickly and manage the situation and team safely and effectively.

While there are skills taxonomies and behavioural marker systems being used in training and assessment in other safety critical industries around the world, in maritime industry, skills taxonomy is relatively a new concept and it is important to develop skills taxonomies first.

3.1 Cognitive Task Analysis (CTA)

Researchers use different methods of task analysis to design and evaluate systems, equipment and training, as it allows the tasks being carried out to be broken down into their constituent activities [13]. As a result, task analysis is a key component for investigating the training requirements. The purpose of Cognitive Task Analysis (CTA) is to capture the way the mind works. A researcher who is carrying out a CTA study is usually trying to understand and describe how the participants view the work that they are doing and how they make sense of events. If people are making mistakes in the workplace, the CTA study should explain what accounts for their mistakes [14].

Since many of the skill required for deck officers in the crisis situations are cognitive, it is necessary to conduct CTA. Based on Seamster *et al.* [15] "CTA identifies and describes the cognitive structures (e.g. knowledge-base and representation skills) and processes (e.g. attention, problem solving and decision making) underlying job expertise, and the knowledge and skills required for similar job components."

Crandall *et al.* [14] has identified following three primary aspects of CTA:

- Knowledge elicitation.
- Data analysis.
- Knowledge representation.

For a successful CTA study each of the above aspect is crucial. Many researchers equate CTA with first aspect, knowledge elicitation, because traditionally this has received most attention. But Crandall [14] argues that a good analysis of data is necessary otherwise collection of data become meaningless.

3.1.1 Knowledge Elicitation

Knowledge elicitation is the set of methods used to obtain information about what people know and how they know it: the judgement, strategies, knowledge and skill that underline the performance. One way of classifying CTA knowledge elicitation is by the way data is collected. Four ways to collect data are listed as follows [14]:

1. Self-reports (i.e. people talk about or record their behaviour and strategies).
2. Direct observation of performance or task behaviours.
3. Automated collection of behavioural data.
4. Interviews.

3.1.1.1 Self-Reports

These methods vary from highly structured formats, such as surveys and questionnaires, to open ended formats such as diaries and logs. Clearly, self-report formats have an advantage (i.e. for the data collection, presentation of an interviewer or skilled data collector is not essential). The quality of data generated by questionnaires obviously depends in part on the instrument itself. A questionnaire method was considered inappropriate for the purpose of this project as data required is qualitative and would require using exploratory technique to probe for information clarification.

3.1.1.2 Direct Observations

Direct observations can be conducted either at workplace or in the simulated environment. If on-site observations are feasible, CTA researchers are strongly recommended to take advantage of this opportunity. There are insights and types of information that it is simply not possible to get any other way. Observations provide opportunities for discovery and exploration of what the actual work demands are; what sorts of strategies skilled workers have developed for coping; how work flows across the environment, the team, and the shift; and communication and coordination issues [16].

3.1.1.3 Automated Collection of Behaviour Data

Endsley [17] developed Situation Awareness Global Assessment technique (SAGAT) to assess situation awareness which is based on de Groot's strategy for comparing chess players at different skill levels. De Groot method was to have a chess player study a game in progress and then unexpectedly remove all pieces. The players would then be asked replace all the pieces. De Groot found that more skilled players were more accurate in reconstructing the board than novice players. Similarly, the SAGAT method uses 'time freezing' in the midst of the aviation pilots' simulated session by switching all the instruments off and pilots are asked to reconstruct the instrument values.

3.1.1.4 Interview

There are a number of different approaches to interviewing; the most appropriate for this project would be structured interviews or semi-structured interview [18]. The disadvantages with structured interviews are that interviewer has to know which questions need to be asked and the responses are then restricted by the question, there is no flexibility to investigate further. In a semi-structured interview there is more flexibility for the interviewer to investigate the issue that arise during the interview and questions can be adapted to individual circumstances. In this approach the interviewer needs to have fair degree of understanding about the subject area to be able to know when to probe further and what to ask [19]. Within this project since the interviewer is a Master Mariner with 20

years seafaring, teaching and training experience in maritime industry, this would not pose too much of problem.

3.2 Interview Process

To develop taxonomy for deck officers' non-technical skills, the interviews were conducted with experienced deck officers at management level to help identify the key skills to be included in the taxonomy. The interview follows a semi-structured format using methods developed for analysing cognitive tasks. Thus the aim of the interview was to identify the non-technical aspect of deck officers' task in crisis situations on the bridge of a ship and the skills needed for this (e.g. team working skills) and not to make judgements about individual performance. There was no right or wrong answers to any part of the interview.

The interview was divided into three parts:

Part 1: Performance example – The interviewee was asked to describe a real case from his own experience that was particularly challenging and possibly difficult for someone as a senior deck officer. The example can be a real critical incident, near miss, or a normal case where the experience and non-technical skills were significant outcome. The interviewee was asked in the advance if he could think of this example before the interview. Furthermore this case was discussed to identify the most significant non-technical skills components.

Part 2: Distinguishing skills – The interviewee was asked to think of the skills and attributes he/she considers to be characteristic of the effective performance in the crisis situations on the bridge of a ship.

Part 3: Weighting task – The interviewee was asked to assign a number (intensity of importance) for the non-technical skills elements.

To assist in collecting the information, with interviewee's agreement, a digital voice recording device was used. This reduces the amount of time that had to be spent making notes and so allow better discussions to develop. The voice recorded files was permanently deleted once audio was transcribed.

All the given information were held in confidence and were de-identified to ensure participants and any other individuals are not recognisable; results were prepared at a group summary level only. The interview took place in private room at an agreed place and time.

3.2.1 Pilot Interview

To support development of the interview schedule, a pilot interview was undertaken with a senior deck officer. This took place at a fairly early stage to help make minor changes to the interview questionnaire (Appendix 1-3). This questionnaire was adopted from the study of 'identification and measurement of anaesthetists' non-technical skills' [19]. The pilot interview recordings was analysed by the research partners to make sure that necessary information were being obtained from the interviews.

3.2.2 Identifying Participants

It was compulsory for the volunteered participants to hold a master mariner certificate of competency and at least ten years of seagoing experience for the interview. Fletcher *et al*. [19] argues that those people who are very interested in human factors being more inclined to volunteer and this might lead to potential biases. However, given the sensitivity of the information being discussed, it would be unethical to interview unwilling participants.

3.2.3 Ethical Approval

Liverpool John Moores University Research Ethics Committee guidelines were followed and formal approval obtained before conducting interviews with subject experts. Interview Participant Information Sheet sample is shown in Appendix 4 and Participant Consent Form sample is shown in Appendix 5.

3.3 Justification of the Proposed Taxonomy

Based on literature review and by help of experienced deck officers via interviews, as shown in Table 1, taxonomy for deck officers' non- technical skills is illustrated. The elements of non-technical skills taxonomy are justified in the following sub section.

Table 1. Taxonomy for deck officers' non-technical skills

Category	Element
1. Teamwork	Team-building and maintaining Considering others Supporting others Communication Information Sharing
2. Leadership and Managerial Skills	Use of authority and assertiveness Providing and maintaining standards Planning and co-ordination Work load management Prioritisation Task delegation Initial Crisis Management
3. Situation Awareness	Awareness of bridge systems Awareness of external environment Awareness of time Situation Assessment
4. Decision Making	Problem definition and diagnosis Option generation Risk assessment and option selection Outcome review

3.3.1 Teamwork

The need for people to work together as a team and to work in coordinated ways to achieve objectives which contribute to the overall aims of their organisation has become increasingly important as organisations have grown in size and become more complex [20]. Because of the rapidly changing organisational environments and structure, teams are the best way to enact organisational strategy.

Organisations with team-based structure can respond quickly and effectively in the modern fast-changing environment [21].

Team working is very important for the most work settings but is especially important in higher risk industries such as aviation, nuclear power industry, firefighting and maritime. Teams typically must function effectively from the moment they are established to achieve their team task. Team members must have a common understanding of how they will be expected to work together during the manoeuvring of a ship [22]. For instance, on board a ship, effective operation is highly dependent on the level of team performance involving skills such as communication, co-ordination, co-operation and control [23].

3.3.1.1 Team-building and maintaining

Team building is the deliberate process of facilitating the development of an effective and close group, "a process by which members of a group diagnose how they work together and plan changes which will improve their effectiveness" [24]. On board ships teams are built during the course of work.

3.3.1.2 Considering others

In the Crew Resource Management course of the aviation industry considering others is defined as: "acceptance of others and understanding their personal condition" [6]. Considering others and supporting others could be grouped together as one element, since in practice both aspects are very closely interrelated, but for the sake of clarity these concepts were separated as a person may request support and consideration comes from managers without any demand.

Chief Officer's consideration towards crews' mental states and feelings is very important on board and especially during crisis situations. Considering proper rest periods and breaks for the crew in busy periods would improve their efficiency.

3.3.1.3 Supporting others

Team support refers to broad spectrum of behaviours such as emotional team support, information team support, instrumental team support and appraisal team support. Emotional team support refers to sympathetic understanding of another's emotional pain. Information team support refers to team members' exchange of necessary information. Instrumental team support focuses on practical task support that team members offer each other. Appraisal support refers to helping each other in making sense of any problem situation [25].

As teams become the common work unit in today's organisations and the value of supportive discretionary behaviour in those teams is crucial [26]. Researchers now believe that support from one's colleagues is a major means of enhancing team performance, reducing job stress and promoting member's satisfaction [25]. West [27] during his research found that the more team members provide support to each other, the greater the improvement in team members' mental health and team performance.

Superior officers' support may be available in many forms on board such as a new sailor being bullied by others and he approaches chief officer for support or second officer needs master's support in the appraisal stage of the passage planning.

3.3.1.4 Communication

One of the core skill central to effective and safe production and performance in any high-risk industry is communication. Yusof [28] believes that the purposes of communication in a group work are mainly in regulating, controlling, motivating, expressing feeling and conveying information. Blundell [29] believes that most conflicts and crisis that happen inside an organisation are particularly caused by lack of transparent communication among members of the organisation.

The Canadian Transportation and Safety Board (CTSB) reviewed 273 incidents between 1987 and 1992 with vessels in Canadian pilotage waters. They have found that 42% of the incidents are due to misunderstanding between pilot and master or the officer of watch or lack of communication [30].

Yusof [28] believes that the purposes of communication in a group work are mainly in regulating, controlling, motivating, expressing feeling and conveying information. Blundell [29] believes that most conflicts and crisis that happen inside an organisation are particularly caused by lack of transparent communication among members of the organisation. The importance of organisational communication should be looked by superior management team. This should be done by various encompassing dimensions including psychological and neurological, social, cultural and ethical concerns of every staff under their supervision and this is even more critical for the organisation's team building process [31].

3.3.1.5 Information Sharing

Information gathered by one team member can be transferred to other team members through feedback, help, advice or explanation. Exchange of information between team members brings information source together and manipulates it into new information structures [32].

Distributing information from different sources among bridge team members (such as ship's position, tidal stream, available depth or traffic) is called Information Distribution Process [33]. Information sharing or knowledge sharing within teams may occur via the advice-seeking behaviour of team members. A master on the bridge needs information about traffic or vessel's drift to become more competent in handling the task [34].

Based on subsection 3.3.1 team working elements and behavioural markers, as shown in Table 2, are illustrated.

Table 2. Team working elements and behavioural markers

Element	Very Good Practice	Good Practice	Acceptable Practice	Poor Practice	Very Poor Practice
Team building and aintaining	Fully encourages input and feedback from others	Sufficiently encourages input and feedback from others	Just enough encouragement of input and feedbacks from others	Little encouragement of input and feedbacks from others	Keeps barriers between team members
Considering others	Take notice of the suggestions of other team members	Take substantial notice of the suggestions of other team members	Take moderate notice of the suggestions of other team members	Takes little notice of the suggestions of other team members	Ignores suggestions of other team members
	Considers condition of other team members into account	Sufficiently considers the condition of other team members	Moderate consideration of the condition of other team members	Little consideration of the condition of other team members	Does not take account of the condition of other team members
	Provide detailed personal feedback	Provide sufficient personal feedback	Provide just enough personal feedback	Provide little personal feedback	Show no reaction to other team members
Supporting others	Provide ample help to other team members in demanding situation	Provide sufficient help to other team members in demanding situation	Provide adequate help to other team members in demanding situation	Provide minimal help to other team members in demanding situation	Do not help other team members in demanding situation
	Offers very good assistance	Offers good assistance	Offers enough assistance	Offers little assistance	Does not offer assistance
Communication	Establish total atmosphere for open communication	Establish substantial atmosphere for open communication	Establish moderate atmosphere for open communication	Establish little atmosphere for open communication	Blocks open communication
	Communicates very effectively	Communicates substantially effective	Communicates moderately effective	Communicates little effective	Ineffective communication
Information sharing	Shares information among all team members	Shares relevant information among all team members	Shares moderate information among all team members	Shares little information among all team members	Does not share information properly among all team members

3.3.2 Leadership and Managerial Skills

Fiedler [35] defines team leader as: "a person who is appointed, elected, or informally chosen to direct and co-ordinate the work of others in a group". Leadership is all about encouraging team members to work together; assigning tasks and assessing performance of team members; developing team knowledge and awareness; improving team members' skills and abilities; continuously motivating team members; planning and organisation of the tasks; and establishing positive team atmosphere [36]. Team leaders are present in all work settings, including business, industry, health care, military, aviation and maritime. The team leader is responsible to build an effective team in order to maximise task performance by ensuring safe and efficient team functioning [6].

One of the best examples of poor leadership is the Titanic disaster. Capt. Edward J. Smith was persuaded by White Star Line official to proceed on faster speed to arrive in New York a day early. Capt. Smith ordered to light up the last two boilers to bring speed to 22 knots. He did not add extra lookout watching for icebergs through a known ice field when the ship hit the iceberg and 1500 people lost their lives. It was the poor leadership of the Capt. Smith who counted too much on impressive strategy, structure and technology.

3.3.2.1 Use of Authority and assertiveness

Flin [37] describes 'Use of Authority and Assertiveness' as creating proper challenge response atmosphere. The authority of a master on board a ship should be adequately balanced with assertiveness and other bridge team members' participation. If the situation requires, decisive actions are expected [37] such as in pilotage waters when master of a ship doubts any of pilot's actions.

3.3.2.2 Providing and maintaining standards

Master as a leader must comply with standard operating procedures for task completion. If situation requires, it may be necessary to deviate from the standard procedures. Such deviation should take place with consultation with other bridge team members. Any deviation from standard procedures should be mutually supervised by the bridge team members [37]. Captain of Costa Concordia did not maintain the standard operating procedures on 13th Jan 2012 and decided to change his original voyage plan without the agreement of the company and local authority and passed the vessel too close to the Giglio Island, Italy. As a result the cruise ship grounded on the rocks of Le Scole with 32 persons lost their lives and 60 injured [38].

3.3.2.3 Planning and co-ordination

An appropriate system of organised task sharing and delegation needs to be established to avoid fluctuation of workload and to achieve high performance. A ship master needs to make sure that the whole bridge team members understand the goals, plans and intentions to communicate well. This will make sure a good co-ordination among the team members in all activities [37].

Comprehensive planning is required to make safe passage from loading port to the discharging port. Over the years it has been observed that many ships involved in groundings, collisions and other contact incidents due to poor passage planning or deviating from the planned passage. Passenger vessel Balmoral, carrying 213 passengers and 19 crewmembers, grounded on Dagger Reef, Gower Peninsular, on 18th October 2004, in fine weather and good visibility. The reason for the grounding was established that master deviated from planned track and took the vessel even closer to a land [39].

3.3.2.4 Workload Management

A major element of workload management is scheduling the workload appropriately. This will be done at the planning stage and identify when high workload periods will occur. Mismanagement of workload will degrade bridge team performance. As a result, tasks need to be evenly distributed among the other bridge team members. A good leader will need to identify and resolve the signs of stress and fatigue so that performance is not affected [37].

MV Cosco Hong Kong grounded over Lixin Pai reef, in South China Sea, in 2009, as a result of increased workload on OOW. The vessel was on a passage from Xiamen to Nansha, China at a speed of 21 knots when she encountered a large number of fishing vessels in the Dadanwei Shuidao channel. Even with the presence of lookout/helmsman, the OOW manoeuvred the vessel by using autopilot to the south of the track to keep clear of the fishing traffic. In doing so he overlooked the presence of the Lixin Pai reef, over which the charted depth was only 3.1m, which was highlighted as a danger on the paper chart in use [40]. Although OOW should have used helmsman to steer the vessel and he should have concentrated on the other tasks but due to poor workload management he manoeuvred the vessel by using the auto pilot.

3.3.2.5 Prioritisation

Primary tasks such as harbour approaches are classified as those tasks that need to be carried out by experienced crew. Secondary tasks are classified as routine maintenances jobs. Secondary operational tasks are prioritised to retain sufficient resources for primary bridge duties [37]. For instance, ship's crew should not be engaged in heavy duties before port approaches; accordingly, priority should be given to retain sufficient rested crew members to be available for approaches duties.

3.3.2.6 Task Delegation

When tasks are delegated by a team leader then a person is made responsible to perform one particular task. On a bridge of a ship, master needs to make sure that the tasks are delegated properly. If tasks are not delegated properly, then omissions will happen and it will lead to a crisis. On port approaches and for the successful operation appropriate tasks need to be delegated to various team members based on their expertise. For instance OOW1, OOW2, helmsman, lookout and master are designated respectively to looking after the navigation of ship and plotting the position, to dealing with all communications, for steering, lookout duties, and look after the traffic and overall command.

3.3.2.7 Initial Crisis Management

The crisis is a situation which materialises unexpectedly and decisions are required urgently within a short period of time. In a crisis situation the sense of loss of control builds quickly and routine tasks become increasingly difficult. The leader should be able to identify specific threats and respond it accordingly.

There are some initial procedure given in the Bridge Procedure Guide for the expected emergencies on ships such as steering failure, engine failure, collision, grounding, flooding, man overboard and etc. Doubt is a particular indication of a crisis and experienced deck officer must be able to identify the cues of crisis building.

Based on subsection 3.3.2 leadership and managerial skills' elements and behavioural markers, as shown in Table 3, are illustrated.

Table 3. Leadership and managerial skills' elements and behavioural markers

Element	Very Good Practice	Good Practice	Acceptable Practice	Poor Practice	Very Poor Practice
Use of Authority and assertiveness	Takes full initiative to ensure crew involvement and task completion	Takes substantial initiative to ensure crew involvement and task completion	Takes moderate initiative to ensure crew involvement and task completion	Takes little initiative to ensure crew involvement and task completion	Hinders or withholds crew involvement.
	Takes full control if situation requires	Takes substantial control if situation requires	Takes moderate control if situation requires	Takes little control if situation requires	Does not show initiative for decision
	Totally reflects on suggestions of others	Substantially reflects on suggestions of others	Moderately reflects on suggestions of others	Shows little reflection on suggestions of others	Ignores suggestions of others
Providing and Maintaining standards	Demonstrates complete will to achieve top performance	Demonstrate sufficient will to achieve top performance	Demonstrate moderate will to achieve top performance	Demonstrate little will to achieve top performance	Does not care for performance effectiveness
Planning and Co-ordination	Completely encourages crew participation in planning and task completion	Substantially encourages crew participation in planning and task completion	Moderately encourages crew participation in planning and task completion	Shows little Encouragement to crew participation in planning and task completion	Does not encourage crew participation in planning and task completion
	Plan is well clearly stated and confirmed	Plan is clearly stated and confirmed	Plan is fairly stated and confirmed	Plan is briefly stated and confirmed	Plan is not clearly stated and confirmed
	Well clearly states goals and boundaries for task completion	Clearly states goals and boundaries for task completion	Fairly states goals and boundaries for task completion	Briefly states goals and boundaries for task completion	Goals and boundaries remain unclear
Workload Management	Completely notifies signs of stress and fatigue	Substantially notifies signs of stress and fatigue	Moderately notifies signs of stress and fatigue	Shows Little notification of signs of stress and fatigue	Ignores signs of fatigue
	Allots good time to complete tasks	Allots sufficient time to complete tasks	Allots just enough time to complete tasks	Allots little time to complete tasks	Allots very little time to complete tasks
Prioritisation	Demonstrate very good prioritisation of tasks	Demonstrate good prioritisation of tasks	Demonstrate average prioritisation of tasks	Demonstrate little prioritisation of tasks	Demonstrate no prioritisation of tasks
Task delegation	Delegates all tasks in a very good manner	Delegates all tasks in a good manner	Delegates all tasks in an acceptable manner	Delegates all tasks in a poor manner	Delegates all tasks in a very poor manner
Initial crisis management	Identifies initial crisis situation very quickly and respond accordingly	Identifies initial crisis situation quickly and respond accordingly	Identifies initial crisis situation after some time and respond accordingly	Identifies initial crisis situation quite late and respond accordingly	Does not identify initial crisis situation

3.3.3 Situation Awareness

Endsley [41] defines Situation Awareness as: "the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning and the projection of their status in the near future".

It has been widely established and accepted that situation awareness is a contributory factor to many accidents and incidents in safety industries. The importance of situation awareness in assessing and predicting operator competence in complex and stressed environment has become increasingly apparent. The concept first emerged as a topic of interest within military aviation domain during the First World War when it was identified as a critical asset for military aircraft crews. It only began to receive attention in the late 80s when SA-related research began to emerge within the aviation and air traffic control domains [42].

During the evening of 11th February MV Boxford collided with fishing vessel, Admiral Blake, in the English Channel while on passage from Antwerp, Belgium to Gioia Tauro, Italy. The accident happened at 1839hrs when chief officer went to check container lashing on deck and left master in command. Master was busy checking the emails, discussing room repairs with fitter and checking log entries of fire and boat drills. Deck cadet was performing lookout duties and reported fishing vessel, crossing from starboard to port side. Master was overworked in last 36 hours had misinterpreted the situation as fishing vessel was being overtaken. So he only altered 10 degrees starboard and returned to discuss the repairs. But later vessel collided with the fishing vessel with no casualties [43].

3.3.3.1 Awareness of Bridge Systems

Active knowledge of mode and state of bridge systems, such as radar, ARPA, ECDIS, GPS, and echo sounder, need to be maintained. Any changes in the systems' state need to be considered such as unexpected depth from the echo sounder or unexpected appearance of land feature on the radar [37]. In the case of Royal Majesty grounding, bridge team members failed to recognise GPS position failure due to faulty antenna for more than 34 hours. Chief Officer, navigating officer, and second officers were plotting GPS positions based on DR during that time. The echo sounder alarm settings were not changed from harbour settings of zero metre and hence did not warn the problem in advance [44].

3.3.3.2 Awareness of external environment

To avoid a crisis situation, a bridge team member required to have active knowledge of current and estimated position of the ship, weather information as well as traffic. This information must be shared among other bridge team members and necessary action need to be taken to prevent consequences [37]. MV Maersk Newport sailed Le Havre for Algeciras on 10th November 2008 into force 9 winds with rough seas. Despite the forecasted poor weather no specific weather checks and measures been carried out. The port anchor chain lashing arrangement failed because neither extra lashing arrangement was fitted nor windlass brake was sufficiently tightened [45].

3.3.3.3 Awareness of time

To avoid a crisis situation, a bridge team member needs to have sense of available time and thinking ahead to consider future conditions and contingencies [37]. In collision avoidance scenario, the rules (International Regulations for Preventing Collision at Sea) state that action taken to avoid collision shall be made in ample time. In a collision case between MV Hyundai Dominion and Sky Hope, watch

officers of the both ships spent valuable time on arguing the responsibilities of the action by text messaging facility on AIS until finally they passed each other at a range of 0.2nm. [46].

3.3.3.4 Situation assessment

Situation assessment is the evaluation and interpretation of information gathered from variety of sources (including ship's position, course, speed, radar traffic, weather and etc.). After conducting proper situation assessment of a changing situation, bridge team members must be able to recognise possible future problems. On 17th October 2006, MV Maersk Dover, which was en route from Dover to Dunkerque, passed just one cable astern of MV Apollonia. OOW on Maersk Dover observed MV Apollonia at 1.9nm at 040° on her starboard bow, only when he was called by deep sea pilot on board Apollonia. OOW on Maersk Dover did not do proper situation assessment and initially made a succession of small alterations of course to starboard using autopilot and then ordered the helmsman to begin hand steering to avoid collision [47].

Based on subsection 3.3.3 situation awareness elements and behavioural markers, as shown in Table 4, are illustrated.

Table 4. Situation awareness elements and behavioural markers

Element	Very Good Practice	Good Practice	Acceptable Practice	Poor Practice	Very Poor Practice
Awareness of bridge systems	Fully monitors and report changes in systems' states	Substantially monitors and report changes in systems' states	Moderately monitors and report changes in systems' states	briefly monitors and report changes in systems' states	Do not monitors changes in systems' states
Awareness of external environment	Collects full information about environment (own ship's position, traffic and weather)	Collects sufficient information about environment (own ship's position, traffic and weather)	Collects average information about environment (own ship's position, traffic and weather)	Collects little information about environment (own ship's position, traffic and weather)	Does not collect information about environment (own ship's position, traffic and weather)
	Shares complete key information about environment with team members	Shares sufficient key information about environment with team members	Shares average key information about environment with team members	Shares little key information about environment with team members	Does not share key information about environment with crew
Awareness of time	Fully discuss time constraints with other team members	Substantially discuss time constraints with other team members	Moderately discuss time constraints with other team members	Briefly discuss time constraints with other team members	Does not discuss time constraints with other CM
Situation Assessment	Makes full assessment of changing situation	Makes substantial assessment of changing situation	Makes moderate assessment of changing situation	Makes little assessment of changing situation	Does not make an assessment of changing situation

3.3.4 Decision Making

Good decision making is an essential skill for successful operation in any high-risk organisation. If one can learn to make timely and well-considered decisions, then he can often lead his team to spectacular and well deserved success.

In aviation decision making is defined as: “The process of reaching a judgement or choosing an option” [37]. Although this definition is labelled as aeronautical decision making but this may be a universal definition for all high risk industries. Like an aeroplane pilot a ship’s master also make different types of decisions at different situations.

3.3.4.1 Problem definition and diagnosis

A decision maker should collect all the necessary information to determine the nature of a situation by considering all explanations for the observed problem [37]. Some examples are: close quarter situation in congested waters and encountering fog in an area of heavy traffic.

3.3.4.2 Option generation

Option generation is a critical link in the decision making process [48]. In a crisis situation, a decision maker will need to generate several options and analysing each of them prior to make a decision. A decision maker will formulate different approaches to deal with a problem. This will depend on available time and information [37]. In a situation of close quarter in congested waters an OOW needs to generate the options (i.e. alteration of the vessel’s course or reduction of the vessel’s speed).

3.3.4.3 Risk Assessment and option selection

The business dictionary defines risk assessment as “the identification, evaluation and estimation of the levels of risk involved in a situation, their comparison against benchmarks or standards and determination of an acceptable level of risk”. A decision maker needs to evaluate the level of the risk and choose the best option. For instance in situation of close quarter in congested water an OOW need to choose a best option from the generated options.

3.3.4.4 Outcome review

A decision maker needs to consider the effectiveness of the chosen option against the current plan, once the course of action has been implemented [37]. On board a ship any decision taken by an officer in charge must be reviewed for the outcome. He or she needs to run a forecast simulation in his or her mind regarding the effectiveness of his or her decision.

Based on subsection 3.3.4, decision making elements and behavioural markers, as shown in Table 5, are illustrated.

Table 5. Decision making elements and behavioural markers

Element	Very Good Practice	Good Practice	Acceptable Practice	Poor Practice	Very Poor Practice
Problem definition and diagnosis	Gather all information to identify problem	Gather sufficient information to identify problem	Gather just enough information to identify problem	Gather little information to identify problem	Failure to diagnose the problem
	Review all casual factors with other crew members	Review enough casual factors with other crew members	Review some casual factors with other crew members	Review very few casual factors with other crew members	No discussion of probable cause
Option generation	States all alternative option	States enough alternative option	States some alternative option	States very few alternative option	Does not search for information
	Asks crew members for all options	Asks crew members for enough options	Asks crew members for some options	Asks crew members for very few options	Does not ask crew for alternatives
Risk Assessment and option selection	Considers and shares all estimated risk of alternative options	Considers and shares substantial estimated risk of alternative options	Considers and shares just enough estimated risk of alternative options	Inadequate discussion of limiting factors with crew	No discussion of limiting factors with crew
	Confirms and states all selected options/agreed action	Confirms and states enough selected options/agreed action	Confirms and states some selected options/agreed action	Confirms and states very few selected options/agreed action	Does not inform crew of decision path being taken
Outcome review	Complete checking of outcome against plan	Substantial checking of outcome against plan	Average checking of outcome against plan	Little checking of outcome against plan	Fails to check selected outcome against plan

3.4 Analytical Hierarchy Process (AHP)

Based on the literature reviews as presented in section 3.3 and by help of the collected data from experienced deck officers via interviews as presented in Appendices 1 - 5, a decision making model, as shown in Fig. 1, is illustrated and approved. Furthermore, data presented by the interview, as shown in Appendix 6, are carefully reviewed and a weight is assigned to each criterion by using a mathematical decision making method called Analytical Hierarchy Process (AHP). The process of evaluating a weight of a criterion is presented in the following subsection.

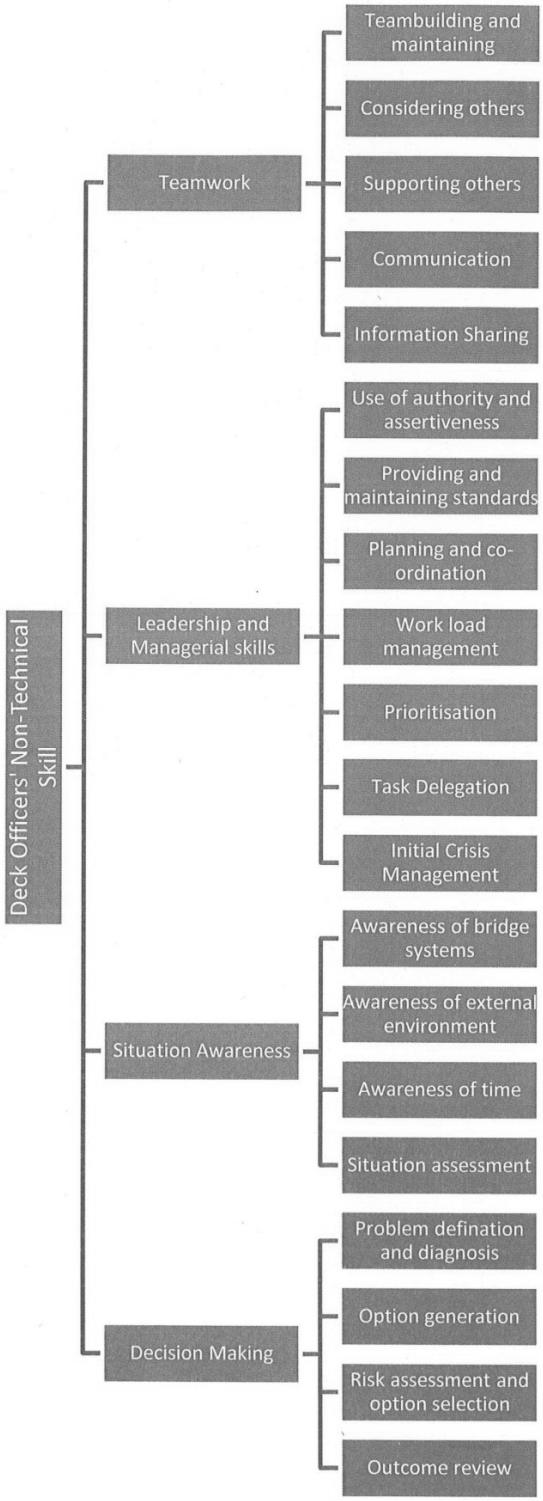

Fig 1. Taxonomy for Deck officers' non-technical skills

3.4.1 AHP method

The Analytic Hierarchy Process (AHP) is pioneered by Saaty [49] and is often referred to Saaty method. The method is popular and widely used in decision making and rating tasks. It is specially used in military decision making but is not restricted to military problems [50]. It is a multi-criteria decision making (MCDM) method that helps the decision maker to make right decision in the complex situation [51]. Saaty [49] describes case application ranging from choice of career through to the planning a port development [50]. To make a comparison, numbers (i.e. intensity of importance) are assigned by the experts. Intensity of importance indicates that how many times more important one element is over another element with respect to what they are compared with. Based on Saaty [52], as shown in Table 6, the scales are illustrated.

Table 6. Comparison scale

Intensity of Importance	Definition	Explanation
1	Equal Importance	Two activities contribute equally to the objective.
2	Weak or slight	
3	Moderate importance	Experience and judgement slightly favour one activity over another.
4	Moderate Plus	
5	Strong importance	Experience and judgement strongly favour one activity over another.
6	Strong Plus	
7	Very strong	An activity is favoured very strongly over another; its dominance demonstrated in practice.
8	Very, very strong	
9	Extreme importance	The evidence favouring one activity over another is of the highest possible order of affirmation.

A number was assigned to each category and element of the non-technical skills taxonomy (Fig. 1) through interviewees (i.e. part 3 of the interview process as explained in the section 3.2). Using AHP to calculate the relative importance of each attribute require a careful review of its principles and background [53]. When considering a group of attributes for evaluation, the main objective of the technique is to provide judgements on the relative importance of these attributes and to ensure that the judgements are quantified to an extent that permits quantitative interpretation of the judgement among these attributes [54].

Riahi [55] has used Saaty's quantified judgements on pairs of attributes A_i and A_j represented by an n-by-n matrix D.

The entries a_{ij} are defined by the following entry rules.

Rule 1: If $a_{ij} = \alpha$, then $a_{ji} = 1/\alpha$, $\alpha \neq 0$.

Rule 2: If A_i is judged to be of equal relative importance as A_j, then $a_{ij} = a_{ji} = 1$.

$$D = \begin{bmatrix} 1 & a_{12} & \dots & a_{1n} \\ 1/a_{12} & 1 & \dots & a_{2n} \\ \dots & \dots & \dots & \dots \\ 1/a_{1n} & 1/a_{2n} & \dots & 1 \end{bmatrix}$$

Where, i, j = 1, 2, 3, …, n and each a_{ij} is relative importance of attribute A_i to attribute A_j.

Having recorded the quantified judgments of comparison on pair (A_i, A_j) as the numerical entry a_{ij} in the matrix D, what is left is to assign to the "n" contingencies (A_1, A_2, …, A_n) a set of numerical weights (w_1, w_2, …, w_n) that should reflect the recorded judgements. Generally weights w_1, w_2,…, w_n can be calculated by using the following equation:

$$\omega_k = \frac{1}{n} \sum_{j=1}^{n} \frac{a_{kj}}{\sum_{i=1}^{n} a_{ij}} (k = 1, 2, 3, \dots, n) \quad (1)$$

Where, a_{ij} represents the entry of row i and column j in a comparison matrix of order n.

The weight vector of the comparison matrix will provide the priority order but it cannot confirm the consistency of the pairwise judgement. The AHP provides a measure of the consistency of the pairwise comparisons by computing a consistency ratio (CR) [55]. The CR is devised in such a way that a value of less than 0.10 is deemed consistent in the pairwise judgement. A decision maker should review the pairwise judgements if the resultant value is more than 0.10.

The CR value is calculated according to the following equations:

$$CR = \frac{CI}{RI} \quad (2)$$

$$CI = \frac{\lambda_{max} - n}{n - 1} \quad (3)$$

$$\lambda_{max} = \frac{\sum_{j=1}^{n} [(\sum_{k=1}^{n} w_k a_{jk})/w_j]}{n} \quad (4)$$

Where, CI is the consistency index, RI is the average random index (Table 7), n is the matrix order and λ_{max} is the maximum weight value of the n-by-n comparison matrix D.

Table 7. Value of RI versus matrix order [53]

n	RI
1	0
2	0
3	0.58
4	0.9
5	1.12
6	1.24
7	1.32
8	1.41
9	1.45
10	1.49

3.4.2 Numerical Example

Following numerical example shows the method of evaluation of weights of main criteria (i.e SA, DM, LS and TW) by an anonymous expert judgement (Table 8).

$$D = \begin{bmatrix} a_{11} & a_{12} & a_{13} & a_{14} \\ a_{21} & a_{22} & a_{23} & a_{24} \\ a_{31} & a_{32} & a_{33} & a_{34} \\ a_{41} & a_{42} & a_{43} & a_{44} \end{bmatrix}$$

The matrix for main criterion is obtained from the Table 8 as follows;

$$\begin{array}{c} \\ SA \\ DM \\ LS \\ TW \end{array} \begin{bmatrix} SA & DM & LS & TW \\ 1 & 1 & 1/3 & 2 \\ 1 & 1 & 1 & 3 \\ 3 & 1 & 1 & 3 \\ 1/2 & 1/3 & 1/3 & 1 \end{bmatrix}$$

Weights of main criteria are calculated using equation 1:

$$\omega_1 = \frac{1}{n}\left(\frac{a_{11}}{(a_{11}+a_{21}+a_{31}+a_{41})} + \frac{a_{12}}{(a_{12}+a_{22}+a_{32}+a_{42})} + \frac{a_{13}}{(a_{13}+a_{23}+a_{33}+a_{43})} + \frac{a_{14}}{(a_{14}+a_{24}+a_{34}+a_{44})}\right)$$

$$\omega_1 = \frac{1}{4}\left(\frac{1}{(1+1+3+0.5)} + \frac{1}{(1+1+1+0.3333)} + \frac{0.3333}{(0.3333+1+1+0.3333)} + \frac{2}{(2+3+3+1)}\right)$$

$$\omega_1 = 0.207260$$

Table 8. Anonymous expert judgements

A. Goal: Evaluating weights of the following main criteria for non-technical skills by the AHP method

1. Situation Awareness

How important is 'Situation Awareness' compared to	Unimportant								Equally Important	Important						
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Decision Making									x								
Leadership							x										
Teamwork										x							

2. Decision Making

How important is 'Decision Making' compared to	Unimportant								Equally Important	Important						
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Leadership									x								
Teamwork											x						

3. Leadership

How important is 'Leadership' compared to	Unimportant								Equally Important	Important						
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Teamwork											x						

$$\omega_2 = \frac{1}{n}\left(\frac{a_{21}}{(a_{11}+a_{21}+a_{31}+a_{41})} + \frac{a_{22}}{(a_{12}+a_{22}+a_{32}+a_{42})} + \frac{a_{23}}{(a_{13}+a_{23}+a_{33}+a_{43})} + \frac{a_{24}}{(a_{14}+a_{24}+a_{34}+a_{44})}\right)$$

$$\omega_2 = \frac{1}{4}\left(\frac{1}{(1+1+3+0.5)} + \frac{1}{(1+1+1+0.3333)} + \frac{1}{(0.3333+1+1+0.3333)} + \frac{3}{(2+3+3+1)}\right)$$

$$\omega_2 = 0.297538$$

$$\omega_3 = \frac{1}{n}\left(\frac{a_{31}}{(a_{11}+a_{21}+a_{31}+a_{41})} + \frac{a_{32}}{(a_{12}+a_{22}+a_{32}+a_{42})} + \frac{a_{33}}{(a_{13}+a_{23}+a_{33}+a_{43})} + \frac{a_{34}}{(a_{14}+a_{24}+a_{34}+a_{44})}\right)$$

$$\omega_3 = \frac{1}{4}\left(\frac{3}{(1+1+3+0.5)} + \frac{1}{(1+1+1+0.3333)} + \frac{1}{(0.3333+1+1+0.3333)} + \frac{3}{(2+3+3+1)}\right)$$

$$\omega_3 = 0.388447$$

$$\omega_4 = \frac{1}{n}\left(\frac{a_{41}}{(a_{11}+a_{21}+a_{31}+a_{41})} + \frac{a_{42}}{(a_{12}+a_{22}+a_{32}+a_{42})} + \frac{a_{43}}{(a_{13}+a_{23}+a_{33}+a_{43})} + \frac{a_{44}}{(a_{14}+a_{24}+a_{34}+a_{44})}\right)$$

$$\omega_4 = \frac{1}{4}\left(\frac{0.5}{(1+1+3+0.5)} + \frac{0.3333}{(1+1+1+0.333)} + \frac{0.3333}{(0.3333+1+1+0.3333)} + \frac{1}{(2+3+3+1)}\right)$$

$$\omega_4 = 0.106755$$

The weight values are 0.207260 (ω1), 0.297538 (ω2), 0.388447 (ω3) and 0.106755 (ω4). Consistency ratio is calculated by using equations 2-4.

Based on equation 4, λ_{max} is calculated as follows:

$\omega_{1x} = (1 \times 0.207260) + (1 \times 0.297538) + (0.333333 \times 0.388447) + (2 \times 0.106755) = 0.847790$
$\omega_{2x} = (1 \times 0.207260) + (1 \times 0.297538) + (1 \times 0.388447) + (3 \times 0.106755) = 1.21351$
$\omega_{3x} = (3 \times 0.207260) + (1 \times 0.297538) + (1 \times 0.388447) + (3 \times 0.106755) = 1.62803$
$\omega_{4x} = (0.5 \times 0.20726) + (0.33 \times 0.297538) + (0.33 \times 0.388447) + (1 \times 0.106755) = 0.43905$

$$\lambda_{max} = \frac{\left(\frac{0.847790}{0.207260}\right) + \left(\frac{1.21351}{0.297538}\right) + \left(\frac{1.62803}{0.388447}\right) + \left(\frac{0.43905}{0.106755}\right)}{4} = 4.118196$$

The mean value for λ_{max} is 4.118196. If any of the λ_{max} turns out to be less than n, which is 4 in this case, then there is an error in the calculation, which require a thorough check.

The CI is calculated as follows:

$$CI = \frac{\lambda_{max} - n}{n - 1} = \frac{4.118196 - 4}{4 - 1} = 0.03939$$

Based on Table 8, the random index (RI) is 0.9. As a result, the CR value is calculated as follows:

$$CR = \frac{CI}{CR} = \frac{0.03939}{0.9} = 0.04376$$

The CR value for the main criteria is 0.04376. CR value of less than or equal to 0.1 indicates that judgements are acceptable [49]. As a result, the consistency of pair-wise comparisons for main criteria is acceptable. The same technique is applied to obtain weights of sub-criteria and to check the consistency of the expert opinions.

3.4.3 Geometric Mean Method

Experts' judgement can be aggregated by using the geometric mean method [56].

$$GeometricMean_{ij} = [e_{1ij}.e_{2ij}.e_{3ij} \dots e_{kij}]^{\frac{1}{k}} \quad (5)$$

Where, e_{kij} is the k^{th} expert judgement on pair of attributes A_i and A_j.

3.5 Data Collection

Data was collected by conducting interviews with 12 experienced senior deck officers both in UK and Malmo, Sweden (Appendix 6). Only eight participants' results were considered for the following study as the remaining four participants' data was inconsistent (i.e. CR was greater than 0.1). Table 9 shows the weights of all elements of the non-technical skills.

Table 9. Weights of the main and sub-criteria

Category	Element
1. Teamwork (0.1914)	Team-building and maintaining (0.2066) Considering others (0.1860) Supporting others (0.1831) Communication (0.2436) Information Sharing (0.1807)
2. Leadership and Managerial Skills (0.2878)	Use of Authority and assertiveness (0.1579) Providing and maintaining standards (0.0857) Planning and co-ordination (0.1437) Work load management (0.1280) Prioritisation (0.1255) Task delegation (0.1316) Initial Crisis Management (0.2276)
3. Situation Awareness (0.2863)	Awareness of bridge systems (0.2433) Awareness of external environment (0.2375) Awareness of time (0.1860) Situation Assessment (0.3332)
4. Decision Making (0.2346)	Problem definition and diagnosis (0.2447) Option generation (0.2069) Risk assessment and option selection (0.2426) Outcome review (0.3058)

3.6 Evidential Reasoning Algorithm

The theory of evidence was first generated by Dempster [57] and further developed by Shafter [58]. It is often referred to as Dempster-Shafter (D-S) theory of evidence. The D-S theory was originally used for information aggregation in expert systems as an approximate tool. Subsequently it has been used in decision making under uncertainty. In continuously researching and practising process, based on the D-S theory, the ER (Evidential Reasoning) algorithm has been developed. The algorithm can be analysed and explained as follows [55]:

Let *R* represents a set with five linguistic terms (i.e. very poor, poor, average, good and very good) with their associated belief degrees (i.e. β) and be synthesised by two subsets R_1 and R_2 from two different assessments. Then, for example, *R*, R_1 and R_2 can separately be expressed by:

$$R = \{\beta^1 Very\ Poor, \beta^2 Poor, \beta^3 Average, \beta^4 Good, \beta^5 Very\ Good\}$$

$$R_1 = \{\beta_1^1 Very\ Poor, \beta_1^2 Poor, \beta_1^3 Average, \beta_1^4 Good, \beta_1^5 Very\ Good\}$$

$$R_2 = \{\beta_2^1 Very\ Poor, \beta_2^2 Poor, \beta_2^3 Average, \beta_2^4 Good, \beta_2^5 Very\ Good\}$$

Suppose that the normalised relative weights of two assessments in the evaluation process are given as w_1 and w_2 ($w_1 + w_2 = 1$). w_1 and w_2 can be estimated by using an AHP technique. Suppose that M_1^m

and M_2^m (m = 1, 2, 3, 4, 5) are individual degrees to which the subsets R_1 and R_2 support the hypothesis that the evaluation is confirmed to the five linguistic terms. Then, M_1^m and M_2^m are obtained as:

$$\boldsymbol{M_1^m = w_1 \beta_1^m}$$

$$\boldsymbol{M_2^m = w_2 \beta_2^m}$$

(6)

Suppose that H_1 and H_2 are the individual remaining belief values unassigned for M_1^m and M_2^m (m = 1, 2, 3, 4, 5). Then H_1 and H_2 are expressed as:

$$\boldsymbol{H_1 = \bar{H}_1 + \tilde{H}_1}$$

$$\boldsymbol{H_2 = \bar{H}_2 + \tilde{H}_2}$$

(7)

Where $\bar{H}_n$ (n = 1, 2) represent the degree to which the other assessor can play a role in the assessment, and $\tilde{H}_n$ (n = 1, 2) is caused by the possible incompleteness in the subsets R_1 and R_2. $\bar{H}_n$ (n = 1 or 2) and $\tilde{H}_n$ (n = 1, 2) are described as:

$$\boldsymbol{\bar{H}_1 = 1 - w_1 = w_2}$$

$$\boldsymbol{\bar{H}_2 = 1 - w_2 = w_1}$$

$$\boldsymbol{\tilde{H}_1 = w_1 (1 - \sum_{m=1}^{5} \beta_1^m)}$$

$$\boldsymbol{\tilde{H}_2 = w_2 (1 - \sum_{m=1}^{5} \beta_2^m)}$$

(8)

Suppose that $\beta^{m\prime}$ (m = 1, 2, 3, 4 or 5) represents the non-normalised degree to which the reliability evaluation is confirmed to each of the five linguistic terms as a result of the synthesis of the judgements produced by assessors 1 and 2. Suppose that H'_U represents the non-normalised remaining

belief unassigned after the commitment of belief to the five linguistic terms because of the synthesis of the judgements produced by assessors 1 and 2. The ER algorithm is stated as:

$$\beta^{m'} = K(M_1^m M_2^m + M_1^m H_2 + M_2^m H_1)$$

$$\overline{H'}_U = K(\bar{H}_1 \bar{H}_2)$$

$$\widetilde{H'}_U = K(\tilde{H}_1 \tilde{H}_2 + \tilde{H}_1 \bar{H}_2 + \tilde{H}_2 \bar{H}_1)$$

$$K = (1 - \sum_{T=1}^{5} \sum_{\substack{R=1 \\ R \neq T}}^{5} M_1^T M_2^R)^{-1}$$

(9)

After above aggregation, the combined degrees of belief are generated by assigning $\overline{H'}_U$ back to five linguistic terms using the normalisation process:

$$\beta^m = \frac{\beta^{m'}}{1 - \overline{H'}_U} \qquad (m = 1,2,3,4,5)$$

$$H_U = \frac{\widetilde{H'}_U}{1 - \overline{H'}_U}$$

(10)

Where, H_U is the unassigned degree of belief representing the extent of incompleteness in the overall assessment. The above gives the process of combining two subsets. If three subsets are required to be combined, the result obtained from the combination of any two subsets can be further synthesised with the third subset using the above algorithm. In a similar way, the judgements of multiple assessors of lower-level criteria in the chain system (i.e. components or subsystems) can be combined.

4.6.1 Numerical example

As an example, based on Evidential Reasoning algorithm two quantitative data (e.g. *R_1 and R_2)* are aggregated as follows:

R_1 stands for 'Problem definition and diagnosis' (sub criteria of decision making) assessed for a team performance (Appendix 7)

R_2 stands for 'Option generation' (sub criteria of decision making) assessed for a team performance (Appendix 7)

	Very Poor	Poor	Average	Good	Very Good	Weight (w_n)
R_1	0	0.5	0	0.5	0	0.2447
R_2	0.5	0.5	0	0	0	0.2069

$w_1 + w_2 = 0.2447 + 0.2069 = 0.4516$

Normalised weights $w_1 = 0.2447 \times 2.21435 = 0.54185$

Normalised weights $w_2 = 0.2069 \times 2.21435 = 0.45815$

$$\beta_1^1 = 0, \quad \beta_1^2 = 0.5, \quad \beta_1^3 = 0, \quad \beta_1^4 = 0.5, \quad \beta_1^5 = 0$$

$$\beta_2^1 = 0.5, \quad \beta_2^2 = 0.5, \quad \beta_2^3 = 0, \quad \beta_2^4 = 0, \quad \beta_2^5 = 0$$

$$M_1^1 = w_1\beta_1^1 = 0.54185 \times 0 = 0$$

$$M_1^2 = w_1\beta_1^2 = 0.54185 \times 0.5 = 0.27093$$

$$M_1^3 = w_1\beta_1^3 = 0.54185 \times 0 = 0$$

$$M_1^4 = w_1\beta_1^4 = 0.54185 \times 0.5 = 0.27093$$

$$M_1^5 = w_1\beta_1^5 = 0.54185 \times 0 = 0$$

$$M_2^1 = w_2\beta_2^1 = 0.45815 \times 0.5 = 0.22908$$

$$M_2^2 = w_2\beta_2^2 = 0.45815 \times 0.5 = 0.22908$$

$$M_2^3 = w_2\beta_2^3 = 0.45815 \times 0 = 0$$

$$M_2^4 = w_2\beta_2^4 = 0.45815 \times 0 = 0$$

$$M_2^5 = w_2\beta_2^5 = 0.45815 \times 0 = 0$$

$$\bar{H}_1 = 1 - w_1 = 1 - 0.54185 = 0.45815$$

$$\bar{H}_2 = 1 - w_2 = 1 - 0.45815 = 0.54185$$

$$\tilde{H}_1 = w_1\left(1 - \left(\beta_1^1 + \beta_1^2 + \beta_1^3 + \beta_1^4 + \beta_1^5\right)\right) = 0.54185\left(1 - (0 + 0.5 + 0 + 0.5 + 0)\right) = 0$$

$$\tilde{H}_2 = w_2\left(1 - \left(\beta_2^1 + \beta_2^2 + \beta_2^3 + \beta_2^4 + \beta_2^5\right)\right) = 0.45815\left(1 - (0.5 + 0.5 + 0 + 0 + 0)\right) = 0$$

$$H_1 = \bar{H}_1 + \tilde{H}_1 = 0.45815 + 0 = 0.45815$$

$$H_2 = \bar{H}_2 + \tilde{H}_2 = 0.54185 + 0 = 0.54185$$

$$K = (1 - \sum_{T=1}^{5} \sum_{\substack{R=1 \\ R \neq T}}^{5} M_1^T M_2^R)^{-1}$$

$$K = (1 - \sum_{T=1}^{5} (M_1^T M_2^1 + M_1^T M_2^2 + M_1^T M_2^3 + M_1^T M_2^4 + M_1^T M_2^5))^{-1}$$

$$\begin{aligned} K = (1 - [&(M_1^1 M_2^2 + M_1^1 M_2^3 + M_1^1 M_2^4 + M_1^1 M_2^5) + (M_1^2 M_2^1 + M_1^2 M_2^3 + M_1^2 M_2^4 + M_1^2 M_2^5) \\ &+ (M_1^3 M_2^1 + M_1^3 M_2^2 + M_1^3 M_2^4 + M_1^3 M_2^5) \\ &+ (M_1^4 M_2^1 + M_1^4 M_2^2 + M_1^4 M_2^3 + M_1^4 M_2^5) \\ &+ (M_1^5 M_2^1 + M_1^5 M_2^2 + M_1^5 M_2^3 + M_1^5 M_2^4)])^{-1} \end{aligned}$$

$$K = 1.2288$$

$$\bar{H}_{U'} = K\,(\bar{H}_1 \bar{H}_2) = 0.3050$$

$$B^{1'} = K(M_1^1 M_2^1 + M_1^1 H_2 + M_2^1 H_1) = 0.1289$$

$$\beta^1 = \frac{B^{1'}}{1 - \bar{H}_{U'}} = 0.18547$$

$$B^{2'} = K(M_1^2 M_2^2 + M_1^2 H_2 + M_2^2 H_1) = 0.3857$$

$$\beta^2 = \frac{B^{2'}}{1 - \bar{H}_{U'}} = 0.55496$$

$$B^{3'} = K(M_1^3 M_2^3 + M_1^3 H_2 + M_2^3 H_1) = 0$$

$$\beta^3 = \frac{B^{3'}}{1 - \bar{H}_{U'}} = 0$$

$$B^{4'} = K(M_1^4 M_2^4 + M_1^4 H_2 + M_2^4 H_1) = 0.1805$$

$$\beta^4 = \frac{B^{4'}}{1 - \bar{H}_{U'}} = 0.25971$$

$$B^{5\prime} = K\left(M_1^5 M_2^5 + M_1^5 H_2 + M_2^5 H_1\right) = 0$$

$$\beta^5 = \frac{B^{5\prime}}{1 - \bar{H}_{U\prime}} = 0$$

Following result is obtained from the above calculations:

	Very Poor	Poor	Average	Good	Very Good
$R_{12} = R_1 \oplus R_2$	18.547%	55.496%	0	25.971%	0

The calculation is repeated for R_3 and R_4 and then again repeated to aggregate the R_{12} (i.e. $R_1 \oplus R_2$) and R_{34} (i.e. $R_3 \oplus R_4$) to find the final value of the 'decision making' element of the group.

4. Assessment of students' non-technical skills in a ship bridge simulator

Some industries, such as aviation and anaesthesia, have conducted extensive research identifying domain specific non-technical skills, training methods and behavioural marker systems for the assessment. Aviation industry is considered to be pioneer in discovering the importance of non-technical skills and researching and developing courses like crew resource management to supplement the main training. The first comprehensive CRM (Cockpit Resource Management) programme was initiated and developed by United Airlines in 1981 in the US and the course called Command, Leadership and Resource Management [59]. The CRM programmes are extensively used in aviation industry and there is evidence that these programmes have positively influenced pilots' attitude and behaviour.

The system of anaesthesia non-technical skills was developed in a project conducted by University of Aberdeen Industrial Psychology Research Centre and the Scottish Clinical Simulation Centre. The system includes the main non-technical skills linked with good anaesthetic practice [60].

The International Convention on standards of Training, Certification and Watch keeping (STCW) sets qualification standards for masters, officers and watch keeping personnel on seagoing merchant ships. The STCW was officially adopted by Conference at the IMO in 1978 to standardise the qualifications required for masters, officers and watch personnel on seagoing merchant ships. In January 2006, in the 37th session of STW Sub-Committee it was decided to review the STCW Convention to ensure it meets the new challenges facing the shipping industry today and in the years to come. At its 38th session of Sub-Committee, following detailed discussion, it was agreed that the present structure of the Convention had more than adequately served its purpose and there was no need to review it in great detail. It was also agreed to include non-technical skills elements in the training of the deck and engineering officers [61]. The aim of this section is to analyse the effectiveness of HELM training course as proposed by the STCW 2010 and implemented by MNTB (Merchant Navy Training Board).

4.1 Methodology

Simulation training is becoming an integral part of maritime training as it provides obvious advantages such as realistic environment. The simulation training allows trainees to make mistakes and then learn from their errors in a safe environment. This provides trainers the ability to train and assess technical and non-technical skills [62].

The methodology is divided into the following four steps:

1. Behavioural marker systems will be developed for the assessment of deck officers' non-technical skills in a ship bridge simulator.
2. A set of scenarios will be developed and a sample of students after completion of their training programme will be selected. Based on the developed scenarios their qualitative characteristics (situation awareness, decision making, etc.) will be assessed subjectively in a bridge simulator.
3. All input data will be aggregated by using an evidential reasoning algorithm.
4. A utility value will be assigned to each group performance for the purpose of comparisons. Utility values will be used to compare the performance of the groups with and without non-technical skills training.

4.2 Behavioural Marker Systems (Step 1)

Behavioural marker systems are used for training and assessments of the participants in the simulators and were first developed in the aviation industry [63]. Later on other safety critical industries such as anaesthesia and nuclear power generation have developed their own behavioural marker systems.

Klampfer and Jochum [64] propose the following for designing good behaviour marker systems:

- Validity: in relation to performance outcome.
- Reliability: inter-ratter reliability, internal consistency.
- Sensitivity: in relation to levels of performance.
- Transparency: the observer understands the performance criteria against which they are being rated, availability of reliability and validity data.
- Usability: easy to train, simple framework, easy to understand, domain appropriate language, sensitive to ratter workload, easy to observe.
- Can provide a focus for training goals and needs.
- Baseline for performance criteria are used appropriately for experience level of a ratter.
- Minimal overlap between components.

Klampfer and Jochum [64] further suggest that behavioural marker systems are limited because they "cannot capture every aspect of performance and behaviour" due to the:

- Limited occurrence of some behaviours such as conflict resolution.
- Limitation of human observers such as distraction or overload (e.g. in complex situations, or when observing large teams)

In developing behavioural markers systems for scrub practitioners' non-technical skills (SPLINTS system) Mitchell *et al*. [65] established the following design criteria:

- Focus on the skills that are observable from behaviour.
- Be set as hierarchical structure with three levels of description; category, element, and behaviour.
- Use active verbs for skills and understandable language for definitions.
- Show a simple structure and layout with a rating scale that fits on one page that it can be easily used.

The behavioural marker assessment framework must, as far as possible, be designed to ensure that it is capable of capturing the fullest context of environment in which the assessment is taking place [66].

A review of behaviour marker systems available in other safety critical industries was conducted in this section. Behavioural marker systems provide a valuable tool for measuring or rating performance based on observation and rating behaviour. This allows an individual's or team's skills to be assessed in their real context, preferably in simulator. To allow for this assessment to be structured and to ensure it is clear which behaviour and skill are being rated, behavioural marker systems were designed in the form of structured lists or taxonomies. In the area of non-technical skills assessment, behavioural marker systems are an important tool for ensuring objectivity of performance assessment since they specify clearly the skills being assessed, and good and poor practice are indicated.

To confirm which skills and behaviours are important for the deck officers interviews were conducted with experienced deck officers. The aim of the interviews was to collect the information from experienced deck officers to determine the significant elements for the deck officers' non-technical skills.

The initial taxonomy and behavioural marker systems had 26 elements and 4 categories. Based on the experts 'opinions during the interviews and since some elements such as "conflict resolution" were non-observable; six elements out of 26 elements were removed from the taxonomy as well as behavioural markers.

Based on section 3.3 justification of the proposed taxonomy, as shown in Tables 2-5, a procedure for assessing the teamwork, leadership, situation awareness and decision making in a ship bridge simulator is developed. As a result the Tables (2-5) were used as behavioural marker assessment frameworks and they were used during non-technical skills observations in a ship bridge simulator. There are five levels of performance in the behavioural marker systems ranging from very good practice to very poor practice. By using the behavioural markers an assessor is able to rate the students' performance in a ship bridge simulator. All assessments are shown in Appendices 7-18.

4.3 Scenarios and Simulator Assessments (Step 2 and 3)

Scenarios were developed and the students were divided into two groups. First group had not gained the non-technical skills training and the second group had obtained non-technical skills training through the approved HELM training short course. The students were assessed using behavioural marker systems (Tables 2-5) in a ship bridge simulator. The students were divided in sub groups and were assessed by executing the following scenarios:

4.3.1 Scenario 1

A vessel is alongside the jetty in Southampton or Algeciras. Each team will pilot a vessel (i.e. own vessel) and maintain all the records as agreed by the members. Each team will need to manoeuvre own vessel with use of a bow thruster (team is not allowed to use tug boats). There will be a number of inbound as well as outbound vessels during the departure. There will be a grounded vessel in the vicinity of NAB tower with salvage operation underway and requests for a wide berth (Southampton only).

Just after passing Fawley Terminal in Southampton or coming out of the breakwater in Algeciras, Gyro No. 1 will commence to drift at a rate of 1°/sec. Based on the position of each vessel at time of passing; there will be the possibility of interaction with large inbound containerships.

The exercise will require effective teamwork, situation awareness, leadership, and decision making skills.

4.3.2 Scenario 2

Exercise is set in the approaches to Bosphorus, Turkey. Master commences exercise in debrief room and will be called to bridge when required. Equipment needs to be tested and checklists need to be completed prior to exercise. The vessel will proceed to an anchorage for bunkering.

There will be a number of vessels in the concerned area (anchored, approaching, overtaking and numerous ferries crossing). The strong tide setting will make it hard to steer. Exercise will continue

until the vessel is alongside a jetty. As time permits the vessel will proceed through the Bosphorus towards the Black Sea.

A number of south bound vessels, strong cross currents and ferry operations will require strict adherence to and monitor of the passage plan as well as collision avoidance manoeuvres. The exercise will require effective teamwork, situation awareness, leadership, and decision making skills.

4.3.3 Scenario 3

The exercise will commence with handover/ takeover of a watch. A Third Officer (3/O) from each of the three bridges will commence the exercise as an Officer of the Watch (OOW). Instructor will act as a lookout and will be on a walkie-talkie / telephone. Sufficient time will be given to the trainees prior to the commencement of the exercise such that they are able to check all the equipment and familiarise themselves with the pre-prepared passage plan.

A delegate from each of the three bridges will be in the role of Second Officer and he will proceed to the bridge for takeover of the watch. The handover/ takeover will take place using the appropriate procedure and checklists. When agreement is reached, each relieved OOW will return to the debrief room and will take up the role as a Chief Officer (C/O) in an assigned bridge.

Bridge 1 will be situated in such a way that in the initial 20 minutes of running the exercise it will be just in visual range of a target showing a strobe light (normally fitted on a life raft). This target will have no or very poor radar returns. The target will be detected if radar controls are set appropriately. Another target to the north (i.e. distressed vessel) will provide a weak radar return but will not be in the visual range. Bridges 2 and 3 will be in the VHF range of Bridge 1.

The exercise is based on a scenario set in the GMDSS sea area A2 (i.e. medium frequency range). Delegate assignment will be in ranks of master, chief officer (C/O) and third officer (3/O) / lookout for all three bridges.

The exercise will progress in the anticipation that the OOW on Bridge 1 will identify a life raft, summon the Master and instigate a search and rescue plan. In the event that the OOW does not take the appropriate action, the virtual lookout (i.e. instructor) will call the bridge and report the sighting. The exercise will then be conducted in line with delegates' response; one of the bridges will be tasked with the OSC (On Scene Commander) role. There will be minimum intervention by MRCC (Maritime Rescue Coordination Centre). There will be other vessels in the area. A warship to the west will be in MF range and has an operational helicopter. A fishing vessel to the north will offer assistance and has benefit of low freeboard. Her position will be such that EPIRB (Emergency Position-Indicating Radio Beacon) position of the causality can be checked if utilised immediately. The exercise will test all the non-technical skills of the delegates involved.

4.4 Students' Performance

The students' non-technical skills are assessed by executing each scenario in a bridge simulator. The behavioural markers are shown in Appendices 7 - 18.

4.4.1 Performance of Group 1 / Scenario 1– without HELM training

The group was formed in the beginning of the NAEST (Navigation aids, equipment and simulator

training) course and teambuilding element was evident. The passage plan was already prepared a day before the exercise. The group tested all bridge equipment and completed the check lists. The exercise started when the bridge team was ready. Initially they had some doubts about departing the berth without tugs. The use of bow thrust helped them to depart without any problems. The vessel was manoeuvred slowly and left the berth and headed towards channel. The vessel speed was about 8 knots in the channel. The master was overall in charge, C/O and OOW were performing navigation and communication duties respectively. At one point the vessel grounded and then re-floated quickly. The gyro started drifting but bridge team considered that vessel was drifting due to tide/current. OOW suggested that the drifting is due to the gyro failure but master did not investigate it further and it was assumed that vessel was drifting due to heavy current. Master only realised the gyro failure once the large alteration of the vessel's course was observed (i.e. about half an hour after the initial drift). Immediately action was taken by switching to gyro 2 and controlling the situation.

Gyro failure during the exercise was the key moment and it was expected that bridge team would identify and take corrective measures immediately. The group poor performance was due to lack of situation awareness of the team and then master's over reliance on C/O information and not taking the control of the situation by himself.

The students' behavioural data are tabulated in Tables A7.1, A7.2, A7.3 and A7.4 in Appendix 7. As a result, after feeding the input data to the model (i.e. Fig. 1), and by using ER algorithm the output set, as shown in Table 10 and Fig. 2, is evaluated.

Table 10. ER results of group 1

Very Poor	35.39%
Poor	33.71%
Average	28.05%
Good	2.85%
Very Good	0.0%

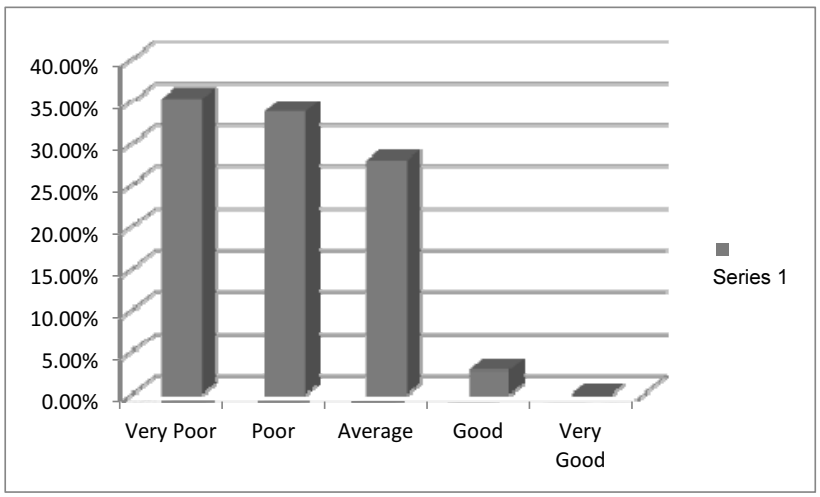

Fig. 2. ER results of group 1

4.4.2 Performance of Group 2 / Scenario 2 (Thursday 18/04/2013) – without HELM training

This was an exercise with number of vessels in area (anchored, approaching and overtaking) with numerous ferry crossing. The vessel was passing through Dardanelle's TSS (Traffic Separation Scheme). At one point own vessel was in the opposite lane of the TSS due to the strong current. There was a tug on starboard side being overtaken. The target was not initially picked up on the radar but later on picked up visually. No immediate action was taken by the students. When the tug was less than one mile the master of own ship started to alter the vessel's course in successions of 5° to port and ship nearly went into opposite lane for the second time in this exercise. As a result the target only passed one cable ahead of the own ship. Immediately after passing the tug the own vessel collided with a fishing vessel which was not observed in the panic of clearing the tug.

This team has shown that the effect of training and procedures will be relinquished as a result of panic. The group has shown poor non-technical skills and there was very weak leadership and teamwork. The group has also shown lack of situation awareness.

The students' behavioural data are tabulated in Tables A8.1, A8.2, A8.3 and A8.4 in Appendix 8. As a result, after feeding the input data to the model (i.e. Fig. 1) and by using ER algorithm the output set, as shown in Table 11 and Fig. 3, is evaluated.

Table 11. ER results of group 2

Very Poor	10.52%
Poor	70.0%
Average	19.49%
Good	0.0%
Very Good	0.0%

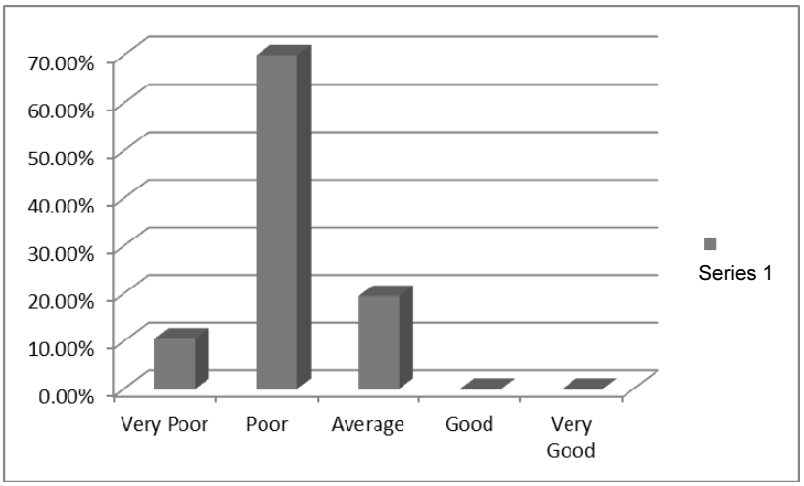

Fig. 3. ER results of group 2

4.4.3 Performance of Group 3 / Scenario 3 – without HELM training

Exercise set in the Western approaches to English Channel. Exercise started with OOW on the bridge and after some time C/O arrived on the bridge to take over the watch. After OOW left the bridge C/O was alone on the bridge. Restricted visibility encountered after about 30 minutes. Master informed and fog signal activated. Soon after that survival craft sighted and position noted. Master carried out Williamson Turn to recover the casualties from the life raft. SECURITY message transmitted on ch.16 (but not on 2182). At the end of the turn, survival craft sighted and vessel stopped. Half an hour after the sighting Mayday Relay message received from Falmouth Coastguard as they got information from sunken vessel's EPIRB. Three more vessels in the area responded and joined the search and rescue operations. After consultation with Falmouth Coastguard own vessel assumed on scene commander (OSC) role. Own vessel recovered five persons from the life raft out of twelve. One of the five rescued persons was badly wounded. The Master contacted warship Halifax (which was in the area and offered assistance) for medical evacuation. Halifax informed the master that helicopter will be arriving in 30 minutes. Three more persons rescued by one of the other vessels. Another vessel sighted two more survivors in the water. Helicopter was diverted towards the two survivors in the water. As per instruction of OSC, after some time injured person on the own vessel became unconscious and required evacuation. As per Falmouth Coastguard all four vessels proceeded to rendezvous position to start parallel search.

The students' behavioural data are tabulated in Tables A9.1, A9.2, A9.3 and A9.4 in Appendix 9. As a result, after feeding the input data to the model (i.e. Fig. 1) and by using ER algorithm the output set, as shown in Table 12 and Fig. 4, is evaluated.

Table 12. ER results of group 3

Very Poor	4.15%
Poor	35.02%
Average	60.83%
Good	0.0%
Very Good	0.0%

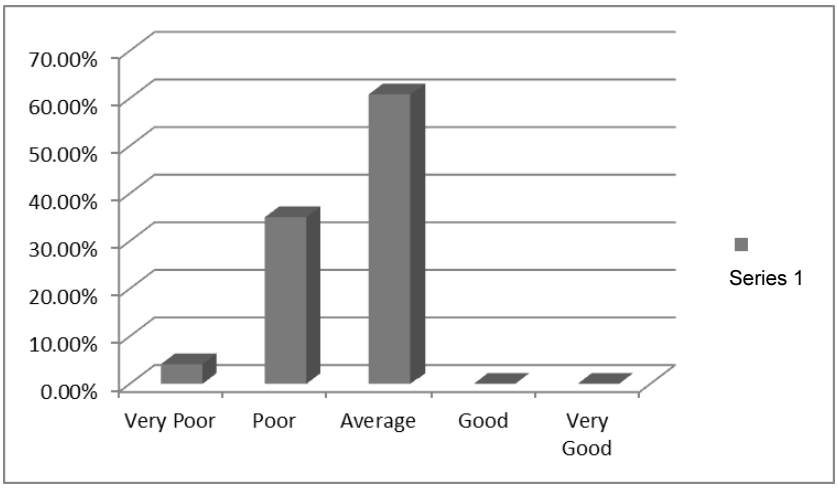

Fig. 4. ER results of group 3

4.4.4 Performance of Group 4 / Scenario 1 – without HELM training

The group was formed in the beginning of the course and teambuilding element was evident. The passage plan was already prepared a day before the exercise. Exercise started with vessel berthed in Gibraltar and there was restricted visibility. There was a pilot on board and he helped to manoeuvre the vessel. 15 minutes after the pilot departure, vessel made contact with head on vessel just outside the harbour. The target was not plotted on the ARPA. Port Control was informed and gyro started to drift at this stage. Clues of gyro drift were ignored as binoculars visual channel was showing true heading which was different from actual heading. It was considered that the error is due to heavy current. Although OOW1 informed the master regarding gyro failure, master ignored him. Gyro drift problem was detected 45 minutes after its initial failure.

The students' behavioural data are tabulated in Tables A10.1, A10.2, A10.3 and A10.4 in Appendix 10. As a result, after feeding the input data to the model (i.e. Fig. 1) and by using ER algorithm the output set, as shown in Table 13 and Fig. 5, is evaluated.

Table 13. ER results of group 4

Very Poor	47.66%
Poor	44.89%
Average	7.45%
Good	0.0%
Very Good	0.0%

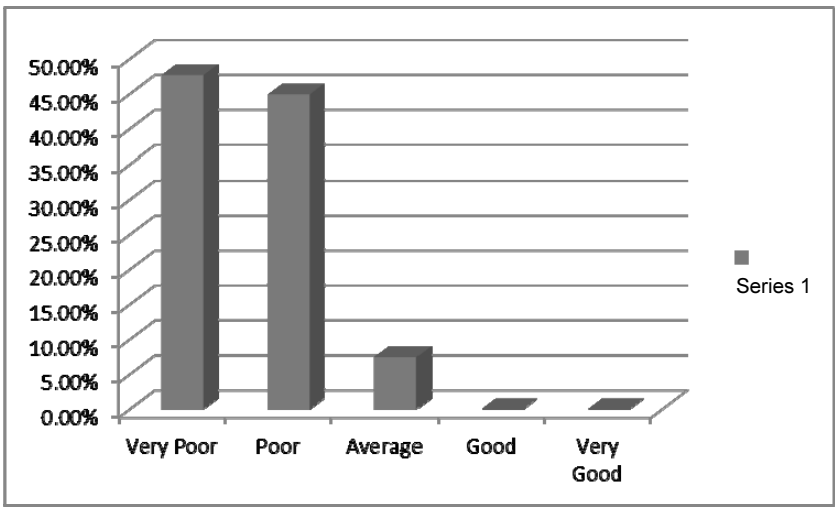

Fig. 5. ER results of group 4

4.4.5 Performance of Group 5 / Scenario 2 – without HELM training

Exercise started in Dardanelle's TSS. Half an hour later a vessel ahead of the own vessel went aground and the own vessel had to reduce its speed. After some time vessel re-floated but by then the own

vessel could not control steering and moved into opposite lane as a result of panic. There was a vessel coming down in opposite lane and it passed on port side very closely and consequently the own vessel lost steering control and touched the breakwater on starboard side and grounded. 15 minutes after grounding, vessel re-floated and proceeded. Due to heavy currents vessel experienced difficulties in steering throughout.

The students' behavioural data are tabulated in Tables A11.1, A11.2, A11.3 and A11.4 in Appendix 11. As a result, after feeding the input data to the model (i.e. Fig. 1) and by using ER algorithm the output set, as shown in Table 14 and Fig. 6, is evaluated.

Table 14. ER results of group 5

Very Poor	7.26%
Poor	46.58%
Average	45.59%
Good	0.57%
Very Good	0.0%

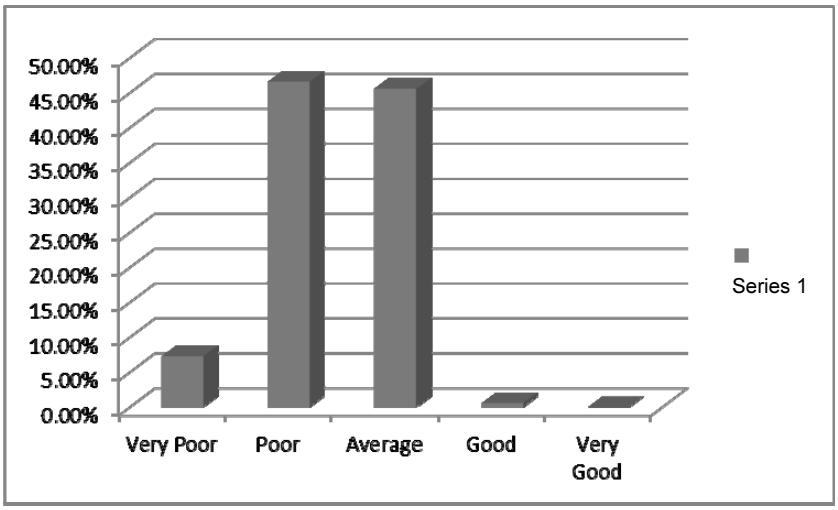

Fig. 6. ER results of group 5

4.4.6 Performance of Group 6 / Scenario 3 – without HELM training

Exercise set in the Western approaches to English Channel. Exercise started with OOW1 on the bridge and after some time OOW2 arrived on the bridge for taking over the watch. After OOW1 left the bridge OOW2 was alone on the bridge. Restricted visibility encountered after about 30 minutes, Master informed and fog signal activated. Soon after that distress message received on DSC and Mayday Relay received from Falmouth Coastguard on RT (Radio Telephony); own vessel reported to Falmouth Coastguard and requested to proceed to distress position. Master summoned on the bridge

and altered the vessel's course to distress position with estimated time of arrival in 40 minutes, master delegated tasks very well. Passenger Ferry Mukran assigned On Scene Commander (OSC) role.

Search pattern advised by OSC and own vessel proceeded to delegated search position. Vessel started parallel search once she arrived at the search position. After 90 minutes a target sighted 4 nm on the starboard beam. OSC informed and altered the vessel's course towards the target with speed of 21.5 knots.

After approaching the life raft, the bosun informs that there are no signs of life in the life raft. The ship crew was unable to launch rescue boat due to heavy weather.

The students' behavioural data are tabulated in Tables A12.1, A12.2, A12.3 and A12.4 in Appendix 12. As a result, after feeding the input data to the model (i.e. Fig. 1) and by using ER algorithm the output set, as shown in Table 15 and Fig. 7, is evaluated.

Table 15. ER results of group 6

Very Poor	0.00%
Poor	28.11%
Average	31.02%
Good	37.24%
Very Good	3.62%

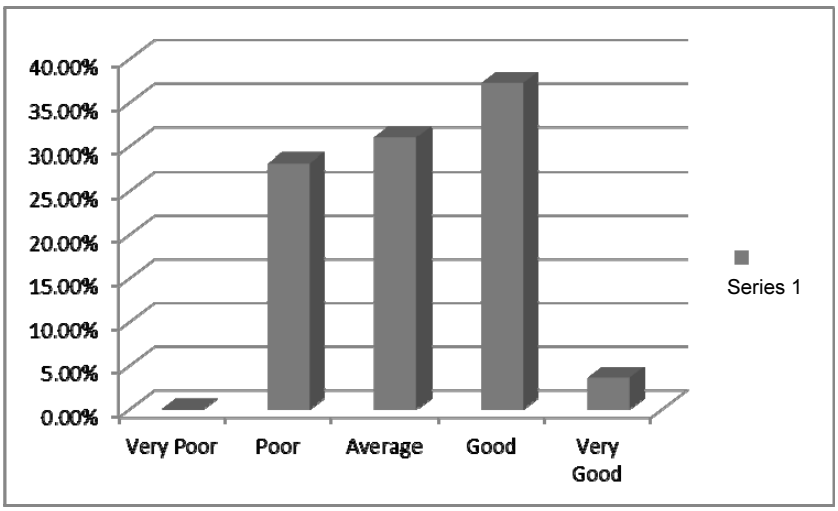

Fig. 7. ER results of group 6

4.4.7 Performance of Group 7 / Scenario 1– with HELM training

The group was formed in the beginning of the course and teambuilding element was evident. The passage plan was already prepared day before the exercise. Vessel was alongside in the port of

Algeciras. Visibility was less than one mile. The group tested all bridge equipment and completed the check lists. The exercise started when the bridge team declared ready. Initially they had some doubts about departing the berth without tugs when they were told no tugs are available. The use of bow thrust helped them to depart without any problems. The vessel was manoeuvred slowly and left the berth and headed towards channel. Chief Officer assumed to have pilot exemption certificate so he manoeuvred the vessel in the beginning and then master took over. Change of command from pilot to master was not clearly defined. After coming out of harbour the plan was adjusted to avoid oncoming traffic. Helm order miscommunication took place with no incident happening (Master gave helm order starboard 20°, helmsman responded port 20°). The error was not picked up by the master. Engine room requested the reduction of the speed to slow ahead due to some problems in engine room. This was followed and problem rectified very soon. Overall group performance found to be average with some good practices in situation awareness and team working.

The students' behavioural data markers are tabulated in Tables A13.1, A13.2, A13.3 and A13.4 in Appendix 13. As a result, after feeding the input data to the model (i.e. Fig. 1) and by using ER algorithm the output set, as shown in Table 16 and Fig. 8, is evaluated.

Table 16. ER results of group 7

Very Poor	1.58%
Poor	20.53%
Average	64.17%
Good	13.73%
Very Good	0.00%

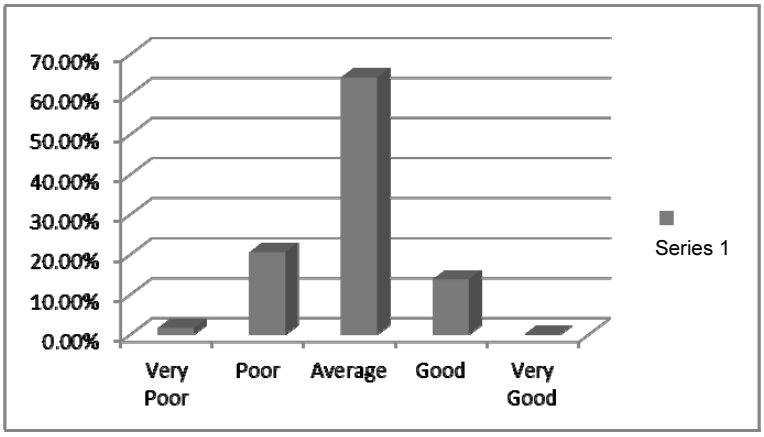

Fig. 8. ER results of group 7

4.4.8 Performance of Group 8 / Scenario 2 – with HELM training

Exercise started in the middle of Dardanelles TSS. Master passed control to Chief Officer who assumed to have pilotage exemption certificate. Master did not show any leadership qualities

throughout the exercise. A vessel ahead of the own vessel was proceeding at 7.5 knots so the own vessel reduced its speed and preferred not to overtake. Due to heavy currents it was difficult to steer and while helmsman performed hard port on the steering the rudder stuck there. Instructor advised and by using limit switch the problem was rectified. Half an hour into exercise the vessel went out of control and ran aground. At one point the own vessel passed with a short distance to an anchored naval vessel. The vessel went out of control again and went into inshore traffic zone on the opposite lane and then collided with shore and grounded.

The students' behavioural data are tabulated in Tables A14.1, A14.2, A14.3 and A14.4 in Appendix 14. As a result, after feeding the input data to the model (i.e. Fig. 1) and by using ER algorithm the output set, as shown in Table 17 and Fig. 9, is evaluated.

Table 17. ER results of group 8

Very Poor	46.37%
Poor	47.21%
Average	6.42%
Good	0.00%
Very Good	0.00%

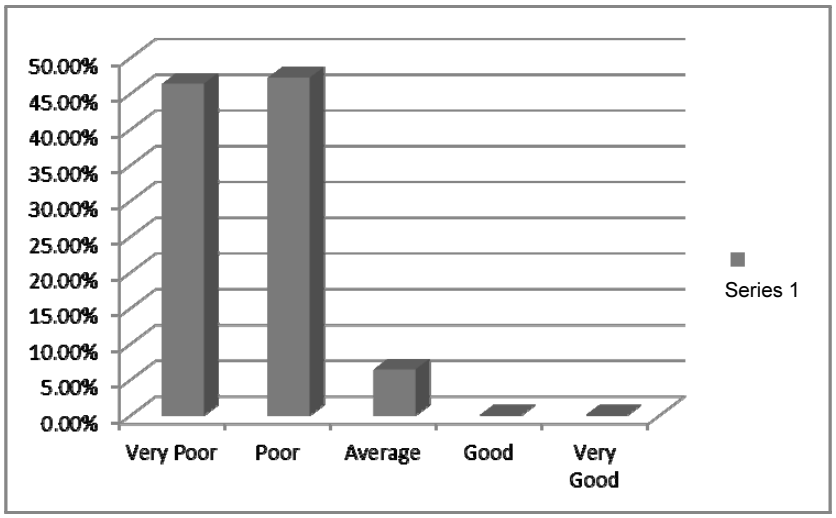

Fig. 9. ER results of group 8

4.4.9 Performance of Group 9 / Scenario 3 –with HELM training

Exercise set in the Western approaches to English Channel. Exercise started with OOW on the bridge. Half an hour into exercise OOW sighted a life raft and called master. The OOW also sighted a vessel with visible smoke. After few minutes second life raft was sighted and engine stopped. (No distress relay sent and rescue party was not prepared.) After 15 minutes of the sighting of the first life raft and the vessel with visible smoke a VHF distress relay sent without MAYDAY prefix. After another 15 minutes 2182 message sent regarding life raft sighting (2182 KHz is the international calling and

distress frequency). OOW decided to be OSC without consulting with the master. Tasks were delegated 45 minutes after first sighting and rescue party prepared. Own vessel diverted to the first life raft to rescue. Bridge team has relinquished second life raft and only focus on the first life raft. Distress relayed by Falmouth Coastguard received and the own vessel was informed that there are thirteen persons on board the fishing vessel which caught fire. Five persons were rescued from the life raft and eight persons were unaccounted for.

The students' behavioural data are tabulated in Tables A15.1, A15.2, A15.3 and A15.4 in Appendix 15. As a result, after feeding the input data to the model (i.e. Fig. 1) and by using ER algorithm the output set, as shown in Table 18 and Fig. 10, is evaluated.

Table 18. ER results of group 9

Very Poor	4.93%
Poor	78.27%
Average	16.80%
Good	0.00%
Very Good	0.00%

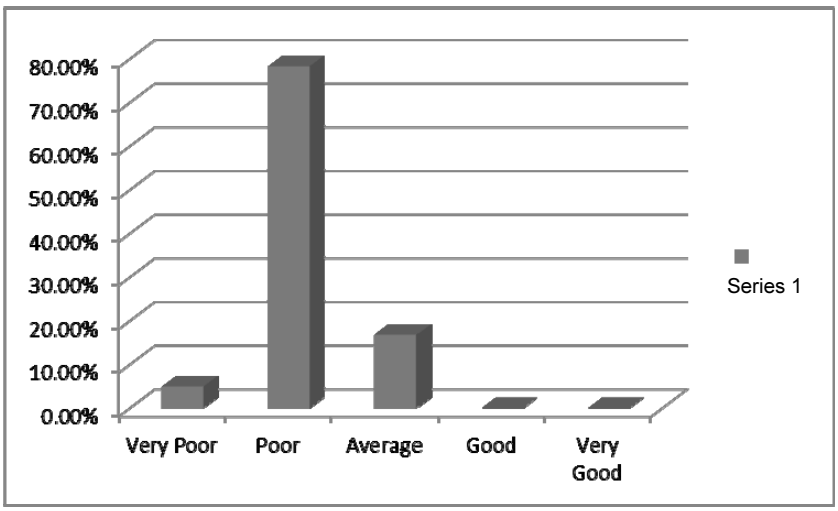

Fig. 10. ER results of group 9

For the purpose of this project and to widen the research area it was decided to collect data from other maritime institutes in the UK. Only one institute has positively responded to the request. Section 4.4.10 - 4.4.12 are the observation reports of another UK maritime institutes with different scenarios.

4.4.10 Performance of Group 10– with HELM training

The exercise set in Storebaelt TSS. The exercise starts with a vessel ahead of the own vessel which was being overtaken. Own vessel's speed was 15.4 knots and the speed of other vessel was 15.0 knots. One vessel was crossing from port to starboard and another vessel was crossing from starboard to port. The own vessel altered its course to Starboard 10°. Engine room was required 15 minutes' notice to changeover from heavy fuel oil to diesel oil; however, master only gave notice to the engine room as per marked on the planned chart. 20 minutes into exercise a vessel was observed in starboard bow. Own vessel altered its course to 25° starboard in successions. One hour into exercise GPS (Global Positioning System) malfunctioned. All three bridge team members actually thought that with GPS failure they are not able to plot a position by radar. Only one of the students was able to plot the position with radar. One and half hour in to the exercise the own vessel finally reached to the destination and managed to drop the anchor.

It was a poor to average teamwork throughout the exercise. In summary, the students' lack of anticipation skills and inability to adapt to the changing situation was observed. Not using the radar for fixing a position immediately after GPS failure was due to the lack of technical skills, as a result and due to the panic, control of the situation was lost. The students' behavioural data are tabulated in Tables A16.1, A16.2, A16.3 and A16.4 in Appendix 16. As a result, after feeding the input data to the model (i.e. Fig. 1) and by using ER algorithm the output set, as shown in Table 19 and Fig. 11, is evaluated.

Table 19. ER results of group 10

Very Poor	1.30%
Poor	45.13%
Average	48.93%
Good	3.33%
Very Good	0.0%

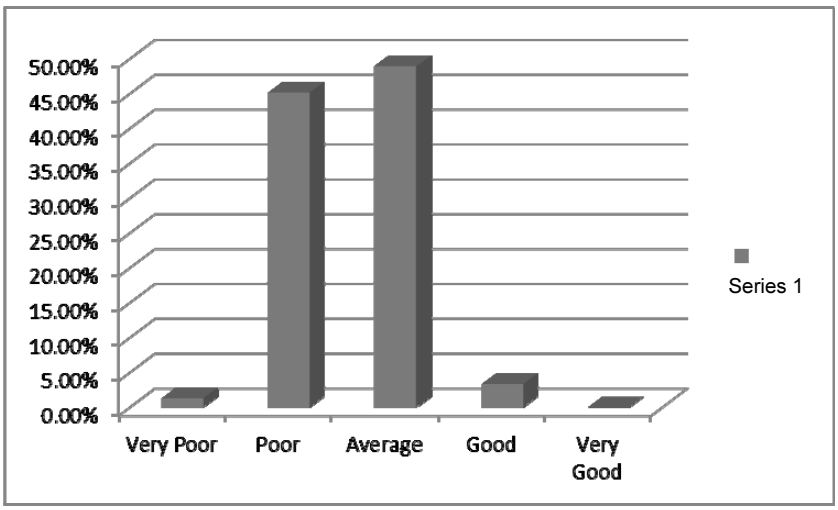

Fig. 11. ER Results of group 10

4.4.11 Performance of Group 11– with HELM training

This was a restricted visibility exercise. There were several targets in the 12 miles rage scale. The target on starboard bow altered its course to port and gave a very close CPA (Closest Point of Approach) to the own ship so the master of the own ship decided to alter the vessel's course 20° to starboard to increase CPA to 9 cables. After 20 minutes of first alteration another target appeared on the starboard bow with risk of collision. Mater first considered reduction of vessel's speed but then he altered the vessel's course 8° to starboard. There was a target behind own ship which was going to clear in 3 minutes after the alteration and master announced that he will reduce the vessel's speed after three minutes. The master reduced the vessel's speed and also made a succession of small alteration of the vessel's course to starboard. Once vessels cleared, the own vessel made a broad alteration of course to port to come back to its original course. The exercise was stopped at this stage.

In general, the group performance was found to be average with some good elements such as team working. The performances of students were found to be poor in situation awareness and situation assessment and average in leadership. The students' behavioural data are tabulated in Tables A17.1, A17.2, A17.3 and A17.4 in Appendix 17. As a result, after feeding the input data to the model (i.e. Fig. 1) and by using ER algorithm the output set, as shown in Table 20 and Fig. 12, is evaluated.

Table 20. ER results of group 11

Very Poor	0.0%
Poor	35.01%
Average	49.74%
Good	11.92%
Very Good	0.0%

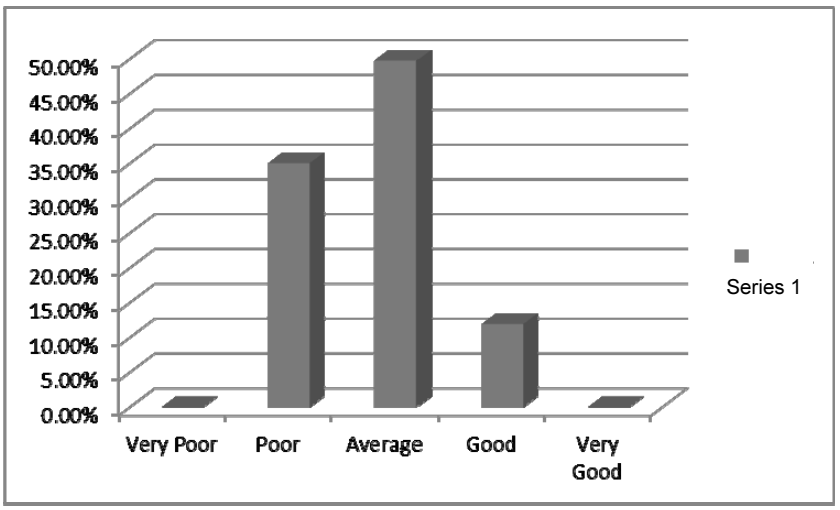

Fig. 12. ER results of group 11

4.4.12 Performance of Group 12– with HELM training

The exercise set in Singapore Strait with the own vessel in west bound lane. Exercise started with a vessel crossing from starboard with risk of collision. The own vessel reduced its speed to dead slow ahead and altered its course to 10° starboard and then 20° to starboard to avoid collision. After clearing the target vessel the own vessel returned to its course slowly. Once back on its original course another target vessel was observed on starboard bow with the risk of collision. This time Master increased the vessel's speed to pass ahead of the target vessel and as a result the target vessel passed very close to the astern of the own vessel. Later on the own vessel reduced its speed to half ahead to let the MV Souter Bay to overtake which was overtaking the own vessel with CPA of 1.4 cables. The own vessel further reduced its speed to dead slow ahead to let MV Tyne Trader to overtake. The master of own vessel called VTIS (Vessel Traffic Information System) and informed them regarding the vessel's speed reduction. The vessel's speed increased to slow ahead 15 minutes after reduction. Five minutes after increasing the vessel's speed to slow ahead the own vessel altered its course to port for safe passing of a vessel. Five minutes after that master ordered hard starboard which he was informed that steering is not taking effect and helmsman assumed the steering failure. Master did not investigate further and assumed the case and called for engineers. During this process the own vessel luckily escaped other vessel by inches. Engineers inspected the steering gear and informed that steering is working properly. By this time vessel was heading in the opposite direction of the traffic lane. Master ordered hard starboard to take a turn from starboard side whereas there was more clear area on the port side. While altering the vessel's course to starboard the own vessel luckily escaped another vessel by very narrow margin.

In general, the group performance was found to be poor. The performances of students were found to be poor in situation awareness, situation assessment, and leadership. Practically for achieving an effective steering the vessel's speed needs to be more than certain limits. However, during the exercise the team has announced the steering failure without paying any attention to the vessel's speed. This was due to lack of technical skills. The lack of anticipation resulted in poor decisions made by master such as turning the vessel to starboard side whereas there was much clear room on the port side. The students' behavioural data are tabulated in Tables A18.1, A18.2, A18.3 and A18.4 in Appendix 18. As a result, after feeding the input data to the model (i.e. Fig. 1) and by using ER algorithm the output set, as shown in Table 21 and Fig. 13, is evaluated.

Table 21. ER results of group 12

Very Poor	28.03%
Poor	42.60%
Average	25.02%
Good	01.69%
Very Good	0.0%

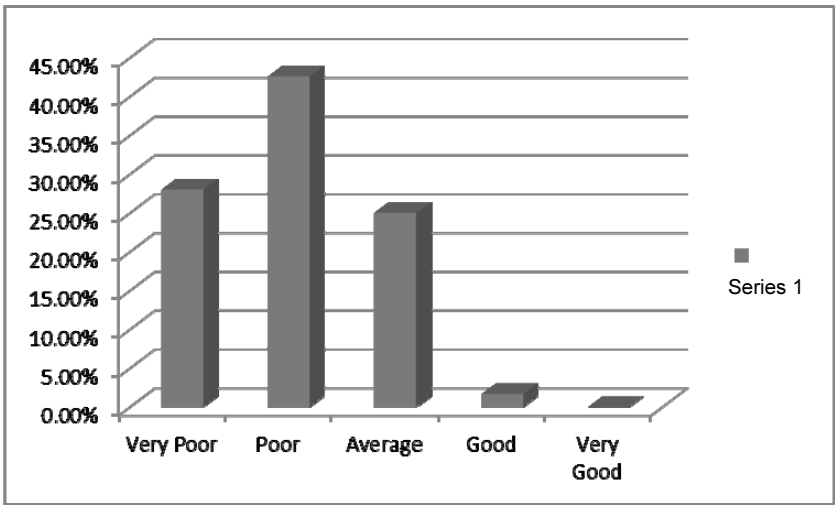

Fig. 13. ER results of group 12

4.5 Obtaining Utility Value (Step 4)

The main aim of using a utility approach is to obtain a single crisp number for the final output result or goal in order to rank them. Let the utility of an evaluation grade H_n be denoted by $u(H_n)$ and $u(H_{n+1}) > u(H_n)$ if H_{n+1} is preferred to H_n; $u(H_n)$ can be estimated using the decision marker's preferences. If no preference information is available, it could be assumed that the utilities of evaluation grades are equidistantly distributed in a normalised utility space. The utilities of evaluation grades that are equidistantly distributed in a normalised utility space are calculated as follows:

$$\mu(H_n) = \frac{V_n - V_{min}}{V_{max} - V_{min}} \tag{11}$$

Where V_n is the ranking value of the linguistic term H_n that has been considered, V_{max} is the ranking value of the most-preferred linguistic term H_N *and* V_{min} is the ranking value of the least-preferred linguistic term H_l.

The utility of the top level or general criterion S(E) is denoted by *u(S(E))*. If $\beta_H \neq 0$ (i.e. the assessment is incomplete, $\beta_H = 1 - \sum_{n=1}^{N} \beta_n$) there is belief interval $[\beta_n, (\beta_n + \beta_H)]$, which provides likelihood that *S(E)* is assessed to H_n. Without loss of generality, suppose that the least-preferred linguistic term having the lowest utility is denoted by $u(H_l)$ and the most-preferred linguistic term having the highest utility is denoted by $u(H_N)$. Then the minimum, maximum and average utilities are defined as follows [55]:

$$u_{min}\left(S(E)\right) = \sum_{N=2}^{N} \beta_n u(H_n) + (\beta_l + \beta_H) u(H_l)$$

$$u_{max}\left(S(E)\right) = \sum_{n=1}^{N-1} \beta_n u(H_n) + (\beta_N + \beta_H) u(H_N)$$

$$u_{average}\left(S(E)\right) = \frac{u_{min}\left(S(E)\right) + u_{max}\left(S(E)\right)}{2}$$

(12)

Obviously if all the assessments are complete, then $\beta_H = 0$ and the maximum, minimum and average utilities of S(E) will be the same. Therefore, *u(S(E))* can be calculated as:

$$u\left(S(E)\right) = \sum_{n=1}^{N} \beta_n u(H_n)$$

(13)

The above utilities are used only for characterising an assessment and not for criteria aggregation [55].

4.5.1 Numerical example

In view of the fact that the output sets for the goal were characterised by five linguistic terms, the highest preference is given to very good (i.e. 5) and lowest preference is given to very poor (i.e. 1). As a result:

$$u(H_n) = \frac{V_n - V_{min}}{V_{max} - V_{min}}$$

$$u(H_5) = \frac{5-1}{5-1} = 1$$

$$u(H_4) = \frac{4-1}{5-1} = \frac{3}{4} = 0.75$$

$$u(H_3) = \frac{3-1}{5-1} = \frac{2}{4} = 0.5$$

$$u(H_2) = \frac{2-1}{5-1} = \frac{1}{4} = 0.25$$

$$u(H_1) = \frac{1-1}{5-1} = 0$$

The output set for group 1, as shown in Table 10, was evaluated as:

{(0.3539, Very Poor), (0.3371, Poor), (0.2805, Average), (0.0285, Good), (0, Very Good)}

As a result:

β_1	=	*0.3539*
β_2	=	*0.3371*
β_3	=	*0.2805*
β_4	=	*0.0285*
β_5	=	*0.000*
Total		*1.000*

Since the assessments are complete, the equation 13 can be used:

$$u(S(E)) = \sum_{n=1}^{N} \beta_n u(H_n)$$

$$u(S(E)) = \beta_1 u(H_1) + \beta_2 u(H_2) + \beta_3 u(H_3) + \beta_4 u(H_4) + \beta_5 u(H_5)$$

$$u(S(E)) = (0.3539 \times 0) + (0.3371 \times 0.25) + (0.2805 \times 0.5) + (0.0285 \times 0.75) + (0 \times 1)$$

$$u(S(E)) = 0.2459$$

4.6 Comparing the Students' Performance With and Without Helm Training

After conducting extensive simulator observations a comparison is made between average performance of the groups with and without HELM training. To do this, utility values of each group are used and a mean of the each group is calculated to compare the average group performance.

Table 22 shows the utility values of all groups and their respective ranking. Table 23 shows rank wise sequence of all groups. Table 24 compares the average utility value of the groups with and without HELM training.

Table 22. Utility values of all groups

		Utility Value	Rank
Group 1	Without HELM Training	0.2459 (24.59%)	10
Group 2	Without HELM Training	0.2724 (27.24%)	8
Group 3	Without HELM Training	0.3917 (39.17%)	4
Group 4	Without HELM Training	0.1459 (14.59%)	12
Group 5	Without HELM Training	0.3487 (34.87%)	6
Group 6	Without HELM Training	0.5409 (54.09%)	1
Group 7	With HELM Training	0.4751 (47.51%)	2
Group 8	With HELM Training	0.1501 (15.01%)	11
Group 9	With HELM Training	0.2797 (27.97%)	7
Group 10	With HELM Training	0.3888 (38.88%)	5
Group 11	With HELM Training	0.4423 (44.23%)	3
Group 12	With HELM Training	0.2576 (25.76%)	9

Table 23. Ranking of all groups

Rank			**Utility Value**
1	**Group 6**	Without HELM Training	0.5409 (54.09%)
2	**Group 7**	With HELM Training	0.4751 (47.51%)
3	**Group 11**	With HELM Training	0.4423 (44.23%)
4	**Group 3**	Without HELM Training	0.3917 (39.17%)
5	**Group 10**	With HELM Training	0.3888 (38.88%)
6	**Group 5**	Without HELM Training	0.3487 (34.87%)
7	**Group 9**	With HELM Training	0.2797 (27.97%)
8	**Group 2**	Without HELM Training	0.2724 (27.24%)
9	**Group 12**	With HELM Training	0.2576 (25.76%)
10	**Group 1**	Without HELM Training	0.2459 (24.59%)
11	**Group 8**	With HELM Training	0.1501 (15.01%)
12	**Group 4**	Without HELM Training	0.1459 (14.59%)

Table 24. Average utility values

Without HELM Training	**With HELM Training**
0.2459 (24.59%)	0.4751 (47.51%)
0.2724 (27.24%)	0.1501 (15.01%)
0.3917 (39.17%)	0.2797 (27.97%)
0.1459 (14.59%)	0.3888 (38.88%)
0.3487 (34.87%)	0.4423 (44.23%)
0.5409 (54.09%)	0.2576 (25.76%)
Average = 32.4%	**Average = 33.2%**

Based on Table 24, the average utility value of groups with the HELM training is only improved by 0.8%. It was evident during the observations that the students with the HELM training did not apply the non-technical skills which were taught during the course. Generally students were found weak in situation awareness and decision making. Lack of anticipation resulted in poor decisions. In some instances task delegation was not clear which resulted in tasks omission. In some instances leadership was quite weak such as the chief officer was actually controlling the master.

Feedback from students regarding the course and the body language of the students showed that they only enjoyed parts of the course where sessions were interactive. It seemed difficult for students to adapt to new concept of non-technical skills with topics like situation awareness, decision making, leadership, teamwork and communication.

4.7 Analysis of Students' Academic Performance

It was decided to analyse the students' academic performance to see whether there is any link between their academic performance and their non-technical skills or not. To do this AHP approach is used to obtain the weights:

	Master	C/O	OOW
Master	1	2	3
C/O	1/2	1	2
OOW	1/3	1/2	1

Following weights are obtained from AHP calculations:

Master	=	w_1	=	0.5396
C/O	=	w_2	=	0.2970
OOW	=	w_3	=	0.1634

Following equation is used to achieve group's average academic marks:

$$A_R = \sum_{i=1}^{4} W_i R_i = w_1 R_1 + w_2 R_2 + w_3 R_3 \quad (14)$$

Where,

A_R stands for Average academic marks of the group

R_i stands for Average academic marks of i^{th} student

W_i stands for the weight of the i^{th} person's role in the ship bridge simulator

Group 1's results are as follows;

$A_R = (0.5396 \times 74) + (0.2970 \times 73.22) + (0.1634 \times 65.88)$

$A_R = 72.4415$

The results obtained from equation 14 for each individual group were compared with the utility value obtained for the same group in section 4.6.

It can be seen from Table 25 and Fig. 14 that there is no link between students' academic marks and their non-technical skills. Group four, for instance, their utility value is lowest and their academic marks are second highest.

Table 25. Utility value of a group versus their academic marks

	Utility Value	**Average Academic Marks (A_R)**
Group 1	0.2459 (24.59%)	72.4415
Group 2	0.2724 (27.24%)	69.1997
Group 3	0.3917 (39.17%)	69.6401
Group 4	0.1459 (14.59%)	71.3070
Group 5	0.3487 (34.87%)	67.7628
Group 6	0.5409 (54.09%)	68.0092
Group 7	0.4751 (47.51%)	69.1886
Group 8	0.1501 (15.01%)	64.2523
Group 9	0.2797 (27.97%)	68.9911

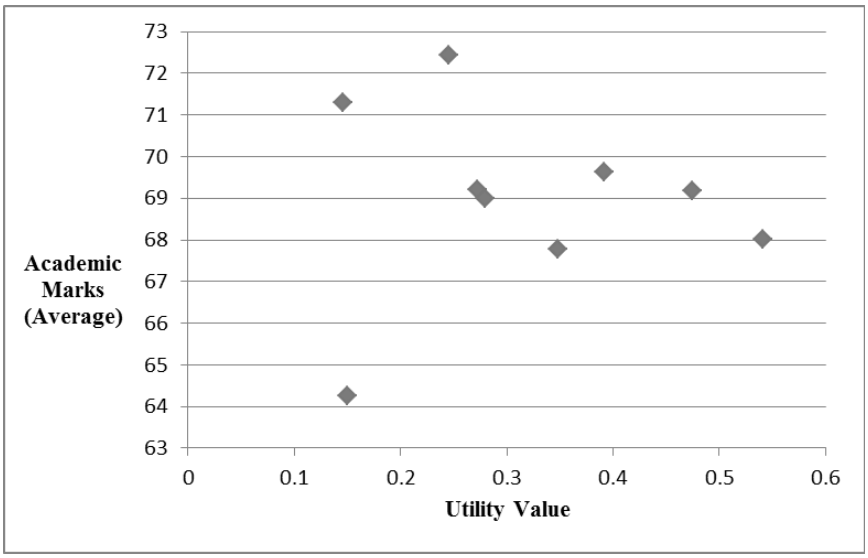

Fig.14. Utility value of a group versus their average academic marks

The measure which is most widely used to gauge the strength of the relationship between pair of data is called sample correlation, represented by *r*. The sample correlation is a measure of how closely the points on a scatter plot lie on a straight line. If the points lie exactly on a straight line with positive slope, *r = 1*, whereas with a negative slope, *r = -1*. More the points scatter about the line the closer *r* is to 0. When r = 0 there is no linear relationship between the points although they might form some other pattern [67].

The sample correlation is calculated as follows:

$$r = \frac{S_{xy}}{\sqrt{S_{xx} S_{yy}}} \tag{15}$$

Where;

$$S_{xx} = \sum x^2 - \frac{(\sum x)^2}{n}$$

$$S_{yy} = \sum y^2 - \frac{(\sum y)^2}{n}$$

$$S_{xy} = \sum xy - \frac{\sum x \sum y}{n}$$

Table 26. Sample correlation values

Utility Value = x	Average academic result = y	x^2	y^2
0.2459	72.4415	0.0605	5247.7709
0.2724	69.1997	0.0742	4788.5985
0.3917	69.6401	0.1534	4849.7435
0.1459	71.3070	0.0213	5084.6882
0.3487	67.7628	0.1216	4591.7906
0.5409	68.0092	0.2926	4625.2513
0.4751	69.1886	0.2257	4787.0624
0.1501	64.2523	0.0225	4128.3581
0.2797	68.9911	0.0782	4759.7719
$\sum x$ = 2.8504	$\sum y$ = 620.7923	$\sum x^2$=1.0500	$\sum y^2$=42863.0418

$$S_{xx} = \sum x^2 - \frac{(\sum x)^2}{n} = 1.0500 - \frac{(2.8504)^2}{9} = 0.1472$$

$$S_{yy} = \sum y^2 - \frac{(\sum y)^2}{n} = 42863.0418 - \frac{(620.7923)^2}{9} = 42.6996$$

$$S_{xy} = \sum xy - \frac{\sum x \sum y}{n} = 196.5727 - \frac{1769.5064}{9} = -0.0391$$

Therefore;

$$r = \frac{S_{xy}}{\sqrt{S_{xx} S_{yy}}} = \frac{-0.0391}{\sqrt{0.1472 \; x \; 42.6996}} = -0.0156$$

The sample correlation between students' academic marks and their non-technical skills (i.e. utility value) is found to be -0.0156, which means there is no linear relationship between the two.

5. Control Options and Cost Benefit Analysis for Improving HELM Training Course

Within This section the possible options for improving the HELM training course will be discussed. Furthermore, a cost benefit analysis will be carried out by using decision tree method to work out whether there will be any benefits of applying such methods to the maritime industries or not.

5.1 HELM Training Course Improvement

In section 4.6, it has been proven that the present HELM training course is ineffective and it is essential to explore the possible options or methods for improving the HELM training course. One way of doing this is to analyse the other safety critical industries models of non-technical skills training [22, 68].

Aviation's CRM is conducted in the flight simulator whereas deck officers' or marine engineers' HELM course is delivered in combination of classroom and bridge simulator or can be delivered solely in the classroom with group activities and case studies. Based on the policy makers decision it is not compulsory for maritime institutes to deliver the HELM course in a ship bridge simulator whereas in aviation simulation remains an important part in the CRM training [22].

In aviation much of the non-technical skills theoretical knowledge is covered in the initial training and it is not repeated when delegates attend CRM course. Whereas in maritime domain HELM course is a five days course with everything included. Furthermore, if any institute is delivering the HELM course without bridge simulator exercises then there is no practical flavour included in the course.

In maritime industry presently training institutes seem responsible for conducting such training and the HELM course is only one off training. In aviation this responsibility is given to the operators. The aviation's CRM course is repeated every three years, or when individual changes aircraft or company. When course is repeated it is focused on the weak areas within individual or the company [22]. In maritime industry the responsibility of delivering HELM course need to be shifted to shipping companies and each individual shipping company will need to design a specific HELM course based on their requirement.

A workshop was conducted with students after the completion of their HELM training course. The following remarks have been received from students:

- Simulation training is not sufficient within the HELM training course and more time needs to be allotted for simulators exercises.
- Instead of having a short course with the duration of five days, the course needs to be incorporated into the entire programme of the study.
- Introducing the case studies on maritime accidents during the HELM training course will help to identify the gap of knowledge in bridge team managements.
- Parts of the course where sessions are interactive such as simulator exercises are very useful.

In the present structure of the HELM course students do not have any prior underpinning knowledge of the subject and everything is done in 35 hours of specified course time. As a result underpinning knowledge of non-technical skills need to be integrated into the main course and then extensive simulator training need to be conducted carefully thought exercises developed to cover each skill and

element of the non-technical skills. The present idea of delivering underpinning knowledge within five days of the course may not be very effective as it does not give enough time to students to study the non-technical skills material.

Based on the above investigations, instead of having a short HELM course with duration of five days, it is suggested that a module to be introduced into the main course by teaching 3 to 4 hours per week over 10 to 12 weeks. This will provide opportunity to the students to absorb the knowledge gradually and effectively. Once the students have completed the non-technical skills module then they will be introduced to simulator exercises that are designed for improvement of their non-technical skills and they are able to learn the practical aspects of the non-technical skills. Though, this option will raise their tuition fee eventually, but, by the help of shipping companies as it will be revealed in subsection 5.2.2 the cost can be justified.

To improve the HELM training course the following objectives need to be considered:

- To enhance crew and management awareness of human factors which could cause or aggravate incidents which affect the safe conduct of ship operations.
- To enhance knowledge of human factors and develop non-technical skills and attitudes which when applied appropriately could extricate a ship operation from incipient accidents and incidents whether perpetrated by technical or human factor failings.
- To use non-technical skills knowledge, skills and attitudes to conduct and manage ship operation and fully integrate these techniques throughout every facets of the organisation culture; this will prevent the onset of incidents and potential accidents.
- To improve the working environment for crews and all those associated with ship operations.

In order for HELM training course to have positive effect on behaviour, as opposed to just increasing knowledge of human factors and attitude, following criteria must be met [22];

- The organisation climate must be conducive to change.
- The individuals must have desire to change.
- The individuals must know what and how to make change.

5.2 Bayesian Networks

A Bayesian network (BN) is a probabilistic graphical model that represents a set of random variables and their conditional dependencies through a directed acyclic graph (DAG). The approach is based on conceptualising a model domain or system of interest as a graph of connected nodes and linkages. In the graph, nodes represent important domain variables and a link from one node to another represents a dependency relationship between the corresponding variables. Given their network structuring, Bayesian networks successfully capture the notation of modularity (i.e. a complex system can be built by combining simpler parts).

Bayesian Networks (BNs) also known as “Bayesian Belief Networks (BBNs)”, “Belief Networks”, “Causal Probabilistic Networks”, “Causal Nets”, “Graphical Probability Networks”, and “Probabilistic Cause-Effect” models are an emerging modelling approach of artificial intelligence research that aim to provide a decision-support framework for problems involving uncertainty, complexity and

probabilistic reasoning [69]. Bayesian networks were first developed at Stanford University in the 1970s [70]. The first world application of Bayesian network was Munin [71]. Since then, Bayesian networks have spread quickly and been used extensively to model many real world problems [72].

The reasons for choosing BNs can be summarised as follows:

- They are graphical models, capable of displaying relationships clearly and intuitively.
- They are directional, thus being capable of representing cause-effect relationships.
- They handle uncertainty through the established theory of probability.
- They can be used to represent indirect causation in addition to direct one.

Due to their Bayesian probability formalism, Bayesian networks provide a rational technique to combine both subjective (e.g. expert opinion) and qualitative (e.g. monitoring data) information [73]. The flexibility nature of Bayesian networks also means that new information can easily be incorporated as it becomes available. Only the conditional probabilities of the affected variable require redetermination. Moreover Bayesian networks are helpful for challenging experts to articulate what they know about the model domain, and to join those influences into dependency network. The graphical nature of Bayesian networks therefore facilitates the easy transfer of understanding about key linkages. In addition, because subjective expert opinions are made explicit in the formal structure of the network, they can be challenged and revised, and can also be directly evaluated to determine whether the results are robust.

5.2.1 Interference Formulism of Bayesian Networks

The basis of reasoning under uncertainty in BNs is called Bayesian interference formulism, which is developed for the task of computing the probability of each value of a node in a BN when other variables' values are known [74]. The uncertainty may be due to imperfect understanding of the domain, incomplete knowledge of the state of the domain at the time where a given task is to be performed, randomness in the mechanism governing the behaviour of the domain, or combination of these. One of the main advantages of BNs is that they allow interference based on observed evidence. The model can be updated in accordance with observation using Bayes rule. For random variables "X_1" and "X_2", as shown in Fig. 15, Bayes rule states:

$$\boldsymbol{P(X_1|X_2) = \frac{P(X_2|X_1)P(X_1)}{\sum_{all..i} P(X_2|X_1 = x_i)P(X_1 = x_i)}} \tag{16}$$

Assume for instance that variable "X_2" is observed to be in state x_j. The probability of a parameter value given the observation is referred to as the posterior probability. This distinguishes it from the prior probability held by the analyst prior to collection and analysis of the observation. By applying Equation 16 to each state of "X_1" the probability distribution "$P(X_1 \mid X_2 = x_j)$" is computed:

$$\boldsymbol{P(X_1|X_2 = x_j) = \frac{P(X_2 = x_j|X_1)P(X_1)}{\sum_{all..i} P(X_2 = x_j|X_1 = x_i)P(X_1 = x_i)}} \tag{17}$$

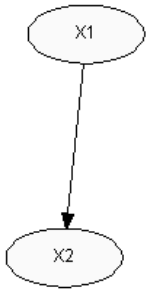

Fig. 15. BN consisting of two nodes

Similar computations may be performed for large networks, allowing users to investigate different scenarios. Manually updating by this method is practical only if the network is small and each node represents only a few states. However, in the 1980s researchers discovered propagation algorithms that make it possible to break the overall graph down into smaller sub-sets within which information flows are largely self-contained [75]. With the introduction of software tools that implement these algorithms it is now possible to use Bayesian networks to solve a complex problem without doing it manually.

5.2.2 Decision tree calculation

The improvement of deck officers' non-technical skills will eventually improve a shipping company's performance and hence will increase the company's profit. The company has to make decision whether to take an action or not to improve the deck officers' performance. The company is uncertain whether the performance of the company's deck officers (i.e. Deck Officers' Performance or DOP) is high, average or low. The cost of an action is C_1. It is believed by taking an action and enhancing the performance of the deck officers (i.e. with average performance) the reliability of the company's vessels will increase and accordingly the profit and net profit associated with an action will be increased. The profit and net profit can be estimated as B_1 and $(B_1 – C_1)$ respectively. Similarly for the deck officers with low performance, the profit and net profit associated with an action can be estimated as B_2 and $(B_2 – C_1)$ respectively. An assessment programme (i.e. Audit) will help the company to determine the company's performance (i.e. CP). The cost of an assessment programme (i.e. Audit) is C_2. Based on the performance data from section 4 (Tables 22-24) and the following rule,

If a group's NTS is less than 0.33, then the performance is Low.
If a group's NTS is between 0.33 and 0.66, then the performance is Average.
If a group's NTS is between 0.66 and 1.0, the performance is High.

Based on above, it can be estimated that 0%, 50% and 50% of the deck officers are with high, average and low performance respectively. Based on expert's opinion the relationship between a company's performance and its employee are shown in Table 27.

Table 27. Conditional probability table

DOP / CP	High (H)	Average (A)	Low (L)
High (H)	0.8	0.1	0.1
Average (A)	0.15	0.8	0.2
Low (L)	0.05	0.1	0.7

Based on Bayes chain rule the following equation can be evaluated;

$$P(CP = H) = P(CP = H|DOP = H) \times P(DOP = H) + P(CP = H|DOP = A) \times (P(DOP = A) + P(CP = H|DOP = L) \times (P(DOP = L)$$

$$P(CP = H) = (0.8 \times 0) + (0.1 \times 0.5) + (0.1 \times 0.5) = 0.1$$

$$P(CP = A) = P(CP = A|DOP = H) \times P(DOP = H) + P(CP = A|DOP = A) \times (P(DOP = A) + P(CP = A|DOP = L) \times (P(DOP = L)$$

$$P(CP = A) = (0.15 \times 0) + (0.8 \times 0.5) + (0.2 \times 0.5) = 0.5$$

$$P(CP = L) = P(CP = L|DOP = H) \times P(DOP = H) + P(CP = L|DOP = A) \times (P(DOP = A) + P(CP = L|DOP = L) \times (P(DOP = L)$$

$$P(CP = L) = (0.05 \times 0.1) + (0.1 \times 0.5) + (0.7 \times 0.5) = 0.4$$

Based on equation 17:

$$P(DOP = H \mid CP = H) = \frac{P(CP = H|DOP = H) \times P(DOP = H)}{P(CP = H)}$$

$$P(DOP = H \mid CP = H) = \frac{0.8 \times 0}{0.1} = 0$$

$$P(DOP = A \mid CP = H) = \frac{P(CP = H|DOP = A) \times P(DOP = A)}{P(CP = H)}$$

$$P(DOP = A \mid CP = H) = \frac{0.1 \times 0.5}{0.1} = 0.5$$

$$P(DOP = L \mid CP = H) = \frac{P(CP = H|DOP = L) \times P(DOP = L)}{P(CP = H)}$$

$$P(DOP = L \mid CP = H) = \frac{0.1 \times 0.5}{0.1} = 0.5$$

$$(DOP = H \mid CP = A) = \frac{P(CP = A|DOP = H) \times P(DOP = H)}{P(CP = A)}$$

$$P(DOP = H \mid CP = A) = \frac{0.15 \times 0}{0.5} = 0$$

$$(DOP = A \mid CP = A) = \frac{P(CP = A|DOP = A) \times P(DOP = A)}{P(CP = A)}$$

$$P(DOP = A \mid CP = A) = \frac{0.8 \times 0.5}{0.5} = 0.8$$

$$(DOP = L \mid CP = A) = \frac{P(CP = A|DOP = L) \times P(DOP = L)}{P(CP = A)}$$

$$P(DOP = L \mid CP = A) = \frac{0.2 \times 0.5}{0.5} = 0.2$$

$$P(DOP = H \mid CP = L) = \frac{P(CP = L|DOP = H) \times P(DOP = H)}{P(CP = L)}$$

$$P(DOP = H \mid CP = L) = \frac{0.05 \times 0}{0.5} = 0$$

$$P(DOP = A \mid CP = L) = \frac{P(CP = L|DOP = A) \times P(DOP = A)}{P(CP = L)}$$

$$P(DOP = A \mid CP = L) = \frac{0.1\ x\ 0.5}{0.4} = 0.125$$

$$P(DOP = L \mid CP = L) = \frac{P(CP = L|DOP = L) \times P(DOP = L)}{P(CP = L)}$$

$$P(DOP = L \mid CP = L) = \frac{0.7 \times 0.5}{0.4} = 0.875$$

A decision tree is a diagram that represents, in a special organised way, the decisions and the main external or other events that influence uncertainty, as well as possible outcomes of all those decision and events. Fig. 16 shows a decision tree representation and solution to this problem. In Fig. 16, squares represent decisions and the lines coming out of each square show all available distinct options that can be selected at the decision analysis point. For instance, as shown in Fig. 16, to perform an assessment programme (i.e. Audit) or not to perform, two lines coming out of "audit square" show all available distinct options (i.e. Yes or No) that can be selected by the manager. In Fig. 16, circles show various circumstances that have uncertain outcomes and the lines that come out of each circle denote a possible outcome of that uncertainty. For instance, as shown in Fig. 16, the "circle R" shows the result of an assessment programme and the line that come out of "circle R" denote possible outcomes of that uncertainty (i.e. a company's performance is high, average or low). Based on the above calculation the probability of each outcome is written on each respective line. Based on Fig. 16, the manager can calculate the overall desirability of those choices. For instance, if manager makes a decision to perform the audit and based on audit's result the company's performance found to be high, then the desirability for taking an action can be calculated as follows:

$$\mathbf{0} \times (\boldsymbol{C_1} + \boldsymbol{C_2}) + \mathbf{0.5} \times [\boldsymbol{B_1} - (\boldsymbol{C_1} + \boldsymbol{C_2})] + \mathbf{0.5} \times [\boldsymbol{B_2} - (\boldsymbol{C_1} + \boldsymbol{C_2})]$$

$$= \mathbf{0.5} \times \boldsymbol{B_1} + \mathbf{0.5} \times \boldsymbol{B_2} - (\boldsymbol{C1} + \boldsymbol{C2}) \tag{18}$$

If the assessment (i.e. evaluated by Equation 18) is lesser than "$-C_2$", then no action has to be taken. Thus:

$$\mathbf{0.5} \times \boldsymbol{B_1} + \mathbf{0.5} \times \boldsymbol{B_2} - (\boldsymbol{C_1} + \boldsymbol{C_2}) < (-\boldsymbol{C_2})$$

$$\mathbf{0.5} \times \boldsymbol{B_1} + \mathbf{0.5} \times \boldsymbol{B_2} < \boldsymbol{C_1} \tag{19}$$

With similar techniques the desirability for the other choices can be assessed. Thus, the three conditions can be summarised as follows:

1. If a company's performance is high and $C_1 > 0.5 \times B_1 + 0.5 \times B_2$, then take no action.
2. If a company's performance is average and $C_1 > 0.8 \times B_1 + 0.2 \times B_2$, then take no action.
3. If a company's performance is low and $C_1 > 0.125 \times B_1 + 0.875 \times B_2$, then take no action.

As an illustrative example, Italian Cruise liner Costa Cruise Line own 27 ships with revenues of 3.1 billion euros in year 2011[76]. One of the Costa Cruise Line ships, Costa Concordia partially sank when it ran aground at Isola del Giglio on 13th January 2012 with loss of 32 lives. The accident mainly

caused by human error [38]. After salvage of Costa Concordia the total cost of the accident was estimated to be $800 million (£480 million) [77]. For the purpose of the following calculations it is assumed that the total loss to the company due to poor performance of the deck officers is £480 million due to the accident. Assume $B_2 = 2 \times B_1$. Thus:

$$\boldsymbol{B_1 + B_2 = £480m}$$

$$\boldsymbol{B_2 = 2 \times B_1}$$

$$\boldsymbol{B_1 = £160m}$$

$$\boldsymbol{B_2 = £320m}$$

The company may decide to improve the non-technical skills of its deck officers by introducing further human element training. This needs evaluation based on the proposed methodology in this project (see 5.1). The cost of evaluation of non-technical skills taxonomy is estimated as £200,000. For 27 ships a company would have 216 deck officers so training cost of deck officers is £216,000 (i.e. 216 × £1000). So the total estimated cost of C_1 is £416,000. The cost of an assessment programme (i.e. C_2) is estimated as £200,000. The assessment programme could be implemented by sending experts on board ships to assess the performance of the deck officers on board such as Line Operations Safety Audit (LOSA) program. During LOSA observation, observer record and code potential threats to safety, how the threats were addressed, and the errors generated, how the errors were managed, and how the observed behaviour could be associated with incidents and accidents [78].

1. £416,000 > 0.5 × 160m + 0.5 ×320m
   £416,000 > £240m = Condition not satisfied
2. £416,000 > 0.8 x 160m + 0.2 × 320m
   £416,000 > £192m = Condition not satisfied
3. £416,000 > 0.125 × 160m + 0.875 × 320m
   £416,000 > £300m = Condition not satisfied

As a result conditions 1, 2 and 3 are not satisfied. Consequently and based on Fig. 16, the expected profit associated with this strategy is calculated as:

$$\boldsymbol{0.1 \times \{-0 \times (C_1 + C_2) + 0.5 \times [B_1 - (C_1 + C_2)] + 0.5 \times [B_2 - (C_1 + C_2)]\} +}$$

$$\boldsymbol{0.5 \times \{-0 \times (C_1 + C_2) + 0.8 \times [B_1 - (C_1 + C_2)] + 0.2 \times [B_2 - (C_1 + C_2)]\} +}$$

$$\boldsymbol{0.4\{-0 \times (C_1 + C_2) + 0.125 \times [B_1 - (C_1 + C_2)] + 0.875 \times [B_2 - (C_1 + C_2)]\} =}$$

$$\boldsymbol{= £239,384,000} \quad (20)$$

Based on Fig. 16, the expected profits associated with taking an action and not performing the assessment programme is calculated as:

$$\mathbf{0} \times (-\boldsymbol{C_1}) + \mathbf{0.5}\ (\boldsymbol{B_1} - \boldsymbol{C_1}) + \mathbf{0.5}\ (\boldsymbol{B_2} - \boldsymbol{C_1}) =$$

$$\mathbf{0.5}\ \boldsymbol{B_1} + \mathbf{0.5}\ \boldsymbol{B_2} - \ \boldsymbol{C_1} = \boldsymbol{£239{,}584{,}000} \quad (21)$$

Based on Equations 20 and 21, the optimal strategy is to take an action immediately.

For the above example and by assuming that the utility function is a linear function of the monetary profit, a BN decision making model, as shown in Fig. 17, is illustrated. In Fig. 17, squares represent decisions and diamonds (i.e. U_1 and U_2) represent utilities. The values for U_1 and U_2 are shown in Tables 28 and 29. In Fig. 17, the expected profits associated with taking an action and performing the audit (i.e. yes) or not performing the audit (i.e. no) are estimated as £239.38m and £239.58m respectively.

Table 28. Values of U_1

Audit	Yes	No
U_1	-£200,000	0

Table 29. Values of U2

Action	Yes			No		
SSP	High	Average	Low	High	Average	Low
U_2	-£0.416m	£159.584m	£319.584m	0	0	0

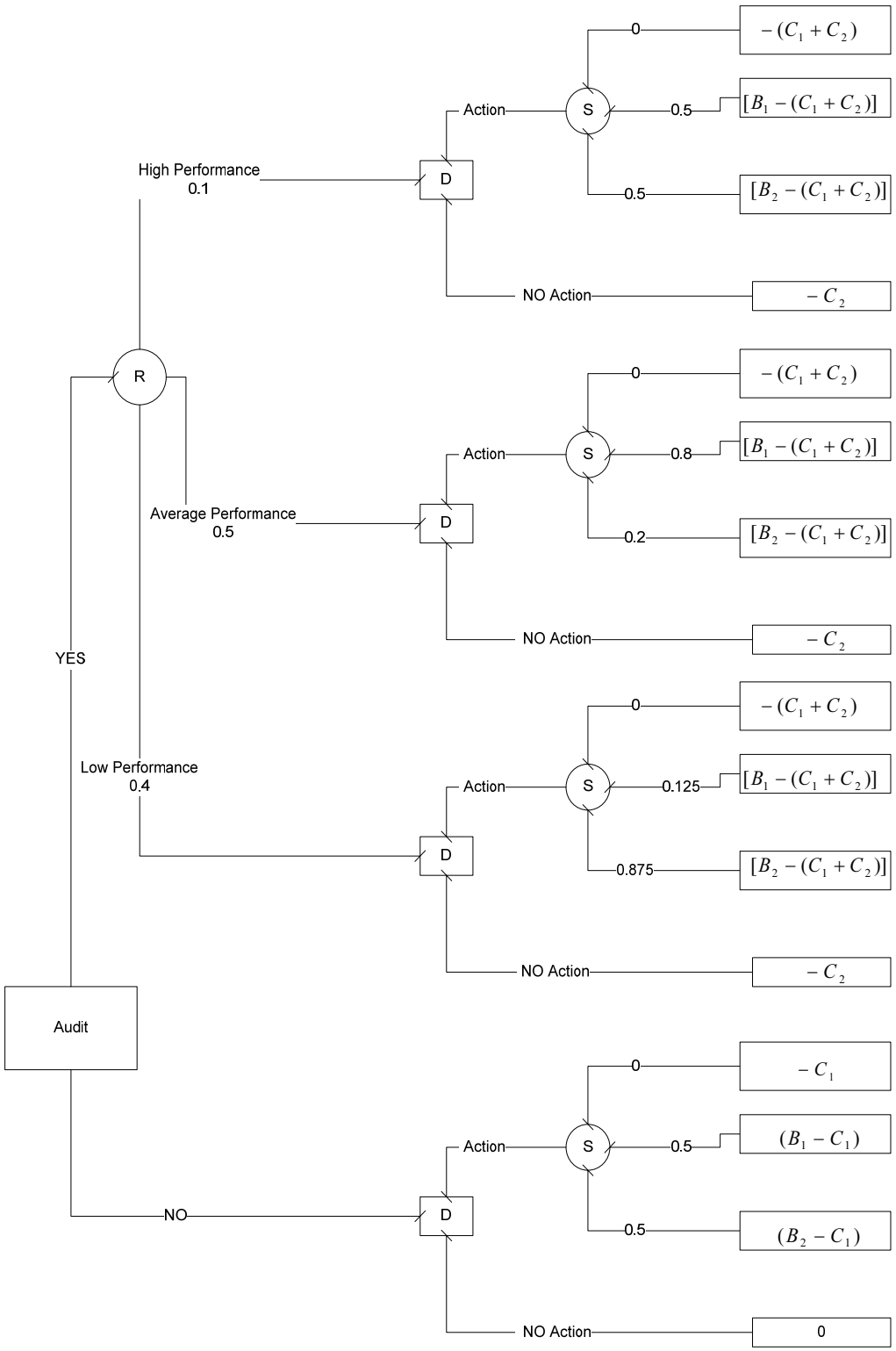

Fig. 16. Decision Tree

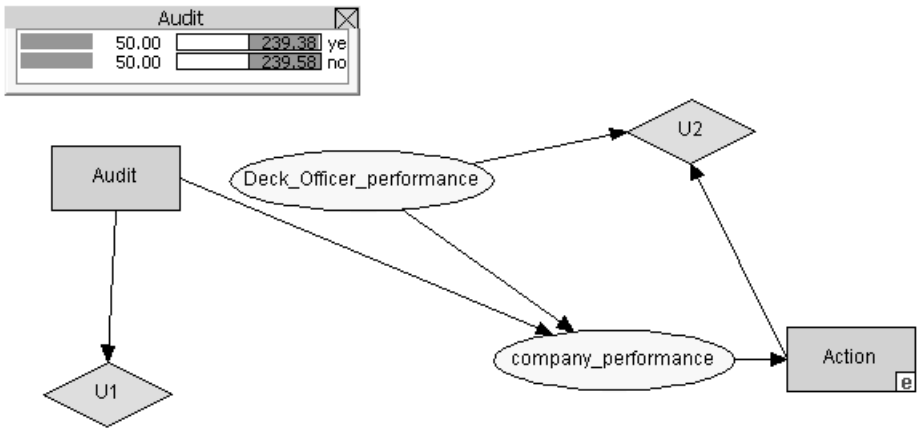

Fig. 17. BN decision making model for measuring the shipping company's profit

5.3 Options

In general the following three options are available:

1. Do not take any action and endure with existing HELM training course.
2. Follow the suggestions in section 5.1 and integrate a module into the main course by teaching 3 to 4 hours per week over 10 to 12 weeks. Once students have completed the non-technical skills module; they need to carry out the practical exercises in a ship bridge simulator where by executing the scenarios they will learn the practical aspects of the non-technical skills.
3. In addition to Option 2, perform an assessment programme by sending experts on board ships to assess the performance of the deck officers on board such as Line Operations Safety Audit (LOSA) programme.

Based on the outcome of this project and since the current HELM training course is only capable of improving the deck officers' non-technical skills by 0.8%. As a result, by choosing option 1 the accidents will continue to happen and industry will bear the cost of $541m annually caused by the human error [79]. Based on the decision tree model as well as BN decision making model It can be concluded that option 2 is the most profitable and feasible option to choose.

6. Conclusion and Recommendations

Within this project in a systematic way the links between maritime accidents and human error are determined. Significant criteria and their contributions to the deck officers' non-technical skills (NTS) are identified and a preliminary model with a hierarchal structure as a taxonomy for the deck officers' non-technical skills has been developed. Furthermore, a novel technique for assessing the deck officers' non-technical skills in a ship bridge simulator is produced. The produced framework is sufficiently flexible and can be used by training organisations involved with maritime, offshore and onshore industries. The methodology that is produced by this project will facilitate trainers in maritime institutes to quantitatively assess performance of their students in a ship's bridge simulator and identify further training requirements.
Based on the remarkable investigation the behavioural marker assessment frameworks for team working, leadership and managerial skills, situation awareness, and decision making are developed. For assessment of a deck officer's NTS in a ship bridge simulator, sets of scenarios that are executable in a ship bridge simulator have been produced. Samples of volunteer students after completion of their training programmes (i.e. STCW Chief Mate Certificate of Competency) with and without HELM training were selected. Based on the: i) developed scenarios, ii) developed behavioural marker assessment frameworks, iii) evidential reasoning algorithm, and iv) utility approach, their NTS grades in a ship bridge simulator have been assessed. After conducting extensive research and simulator observations, the utility values for the groups with and without the HELM training were assessed. Based on the evaluation results, the average utility value for the groups with the HELM training has been found to be only 0.8% above the groups without the HELM training and it has been found that the present HELM training short course is an ineffective training method. Based on the simulator observation, it has been found that that the students with HELM training did not employ the non-technical skills which were taught during the course. Generally students have been found to be weak in situation awareness and decision making due to lack of anticipation. In some of the simulator observation it has been found that some of the tasks are left unattended. In some of the simulator observation it has been found that the degree of some of the student's leadership is quite weak.

With the present structure of the HELM training course, students do not achieve any prior underpinning knowledge of the subject and everything is done within 35hours of the specified course time. As a result, the HELM training course can be improved if: i) underpinning knowledge of non-technical skills is integrated into the main programme of the study, and ii) extensive simulator training with carefully thought exercises to cover each skill and element of the non-technical skills are used.

Based on the investigations and to implement an effective HELM training course: i) a HELM training module needs to be introduced into the main syllabus, ii) the module needs to be delivered 3 to 4 hours every week over 10 to 12 weeks (this will give opportunity to students to grasp the knowledge gradually), iii) once students have completed the non-technical skills module; they need to carry out the practical exercises in a ship bridge simulator where by executing the scenarios they will learn the practical aspects of the non-technical skills, iv) the trainers (by the techniques and methodologies that have been introduced in this project) need to evaluate the trainees' NTS after the completion of the programme of their studies and the assessments need to be recorded and forwarded to their employers (i.e. shipping companies), and v) the HELM training course for an individual needs to be repeated every three years (when the course is repeated it needs to focus on the weak NTS of an individual rather than repeating the same materials). Based on the decision tree model as well as Bayesian

Network (BN) decision making model, it has been revealed that this option is the most profitable and feasible option to choose.

Root causes for human error can be segregated into two categories: preventable, and inevitable. As a result, human errors can be mitigated by the appropriate strategies. Furthermore, the grades of the deck officers' non-technical skills are highly dependent on operational strategies of the ship owner. By improving the deck officers' non-technical skills through constant monitoring of their performance and correction of any deviation on time, the safety of international trade and maritime environment can be enhanced.

For further research activities, firstly, by applying the same methodology that has been proposed in this repot instead of observing students' non-technical skills from one country it would be appropriate to collect more bridge simulator observation data from various nautical institutes across the globe. Secondly, various factors such as: a) time of the training, b) existence of parallel duties of the students, c) personal approach of the instructor who provided the HELM training, and d) integrating non-technical skills underpinning knowledge in the main course need to be tested. Finally, in this research the simulator assessments of the students in a ship bridge simulator were conducted subjectively by assessors based on the developed behaviour marker assessment frameworks. As a result in future a generic overt behavioural markers system for the objective assessment of the deck officers' NTS needs to be developed.

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appendix

Contents

Appendix 1: Introduction Letter for Interview

As part of the project to develop taxonomy for deck officers' non-technical skills, interviews will be conducted with experienced deck officers at management level to help identify the key skills that need to be included in the taxonomy. The interview will follow a semi-structured format using methods that have been developed for analysing the cognitive tasks. Thus the aim of the interview is to find out regarding the non-technical aspect of deck officers' task on the bridge of a ship and the required skills by them. There are no right or wrong answers to any part of the interview. The interview is divided into three parts:

Part 1: Performance example: You will be asked to describe a real case from your own experience that was particularly challenging and possibly difficult for you as a senior deck officer. This can be a real critical incident/near miss or a normal case that just really tested all your skills as a senior deck officer and whether your experience had significant outcomes or not. It would be very helpful if you could think of this example before the interview.

Part 2: Distinguishing skills: You will be asked to think of the skills and attributes you consider to be characteristic of the effective performance on the bridge of a ship.

Part 3: To assign a weight to an element: You will be asked to assign a number that indicates the relative importance of each attribute as shown in Appendix 3.

To assist in collecting the information, with your agreement, a digital voice recording device will be used. This reduces the amount of time that has to be spent making notes and so allow better discussions to develop. The voice recorded files will be permanently deleted once audio is transcribed. All the information you give will be held in confidence and will be de-identified to ensure participants and any other individuals are not recognisable; results will be prepared at a group summary level only. The interview will take place in private room at an agreed place and time convenient to you. If you have any further questions about the interviews or project in general, please contact me. Thank you for your interest in the project, and I look forward to your possible involvement in the study. If you decide to take part we can discuss the practical arrangements and details of the interview nearer the time.

APPENDIX 2: Interview Process

Part 1 – Performance Example

Explain task: You were asked if you could think about a case from your experience in advance.

You will be asked to "walk-through" the case number of times:

- Brief description of case.
- Interviewer repeats back the key aspects to check time frame and understanding.
- Describe the case in more detail focusing on non-technical aspects.
- Interviewer will ask questions where necessary to help understanding.

Re-iterate: not interested in making any judgement about your performance.

Request: as much information as possible but not specific personal details about any bridge team member.

Begin: Thinking of your case, could you possibly please describe it to me from your perspective, starting from the point you first encountered the situation. Please remember to focus on the non-technical aspects. I will probably make some notes to help me and start constructing a time line of events to help our discussion and my understanding.

Interviewee describes the case: I will repeat the case as I have understood it. Please correct me if I have not understood it properly. Interviewer repeats back the event.

Interviewer and interviewee develop timeline:

Question: Can you tell me why you have selected this case? Why was this case so challenging for you?

I would now like you to go through the case again, as you experienced it, giving me a detail of: your decision, communications with colleagues, planning and co-ordination of tasks, etc.

If I think something is particularly important I will ask questions for more information.

Interviewee re-describes the event, interviewer probes as required.

Additional questions:

- Is there anything else you would like to add about non-technical skills in this situation?
- What kind of things could have gone wrong for you in this situation?
- What is your opinion regarding someone with less experience (e.g. a junior deck officer,) might have handled the situation? Can you think of any problems they might have encountered?
- Was there any breakdown in communication?
- What sort of teamwork was there within the bridge?
- Who was in the leadership role?

- What would have happened if the team members had been different (less, more, unknown, experienced)?
- What cues were you using to help understand the situation?
- What information did you use in recognising the situation / making the decision?
- What non-technical skills were you using in dealing with the situation?
- Did you able to draw on any comparisons from previous experience?
- What were your goals during the managements of the case at this time?
- What options were open to you at that moment?
- How did you decide which option to take?
- Was there any influence from the team?
- How did you arrive at your chosen course of action?
- What factors affected your decision?
- What strategy did you use in reaching your decision?
- How did you maintain situation awareness?
- To what extent did some of your situation awareness come from the team?
- What sort of projections were you making into the future?
- What sort of things would you have to be anticipating for?
- What are the major elements you have to keep track of to develop/maintain the big picture?
- What sort of resources did you have available to support you?
- What factors might have influenced your performance?
- What role did the team have on this case?
- What is the importance of the education/training provided to you to deal with such situation?
- What improvement do you want to see in the deck officer training?

Part 2: Distinguishing Skills

I would like you to think about, the types of skills that you believe are required for an experienced deck officer (in terms of non-technical skills) to be distinguishable from an inexperienced deck officer. Kindly let me know these skills will be developed with experience or training.

Question: What kind of non-technical skills are important for a highly reliable deck officer?

Senior deck officer gives examples; interviewer probes/confirms as required

Additional questions:

- How do you think these skills are currently developed?
- How might a trainee gain these vital non-technical skills?
- Do you think there are any differences or similarities between skills needed for normal situation and crisis situation?

Part 3: Weighting Task

Part 3: You will be asked to assign a number that indicates the relative importance of each attribute as shown in Appendix 3.

APPENDIX 3: Questionnaires (AHP Form)

A. Goal: Evaluating weights of the following main criteria for non-technical skills by the AHP method

Situation Awareness

How important is 'Situation Awareness' compared to	Unimportant								Equally Important	Important							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Decision Making																	
Leadership																	
Teamwork																	

Decision Making

How important is 'Decision Making' compared to	Unimportant								Equally Important	Important							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Leadership																	
Teamwork																	

Leadership

How important is 'Leadership' compared to	Unimportant								Equally Important	Important							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Teamwork																	

B. Goal: Evaluating weights of the following criteria for teamwork by the AHP method

Teambuilding and maintaining

How important is 'Team Building and maintaining' compared to	Unimportant								Equally Important	Important							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Considering others																	
Supporting others																	
Communication																	
Information sharing																	

Considering others

How important is 'Considering Others' compared to	Unimportant								Equally Important	Important							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Supporting others																	
Communication																	
Information sharing																	

Supporting others

How important is 'Supporting Others' compared to	Unimportant								Equally Important	Important							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Communication																	
Information sharing																	

Communication

How important is 'Communication' compared to	Unimportant								Equally Important	Important							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Information sharing																	

C. Goal: Evaluating weights of the following criteria for leadership and managerial skills by the AHP method

Use of authority and assertiveness

How important is 'Use of authority and assertiveness' compared to	Unimportant								Equally Important	Important							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Providing and maintaining standards																	
Planning and co-ordination																	
Work load management																	
Prioritisation																	
Task delegation																	
Initial Crisis Management																	

Providing and maintaining standards

How important is 'Providing and maintaining standards' compared to	Unimportant								Equally Important	Important							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Planning and co-ordination																	
Work load management																	
Prioritisation																	
Task Delegation																	
Initial Crisis Management																	

Planning and co-ordination

How important is 'Planning and Co-ordination' compared to	Unimportant								Equally Important	Important							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Work load management																	
Prioritisation																	
Task Delegation																	
Initial Crisis Management																	

Work load management

How important is 'Workload management' compared to	Unimportant								Equally Important	Important							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Prioritisation																	
Task Delegation																	
Initial Crisis Management																	

Prioritisation

How important is 'Prioritisation' compared to	Unimportant								Equally Important	Important							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Task Delegation																	
Initial Crisis Management																	

Task Delegation

How important is 'Task Delegation' compared to	Unimportant								Equally Important	Important							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Initial Crisis Management																	

D. Goal: Evaluating weights of the following criteria for situation awareness by the AHP method

Awareness of bridge systems

How important is 'Awareness of bridge systems' compared to	Unimportant								Equally Important	Important						
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Awareness of external environment																	
Awareness of time																	
Situation assessment																	

Awareness of external environment

How important is 'Awareness of external environment' compared to	Unimportant								Equally Important	Important						
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Awareness of time																	
Situation assessment																	

Awareness of time

How important is 'Awareness of time' compared to	Unimportant								Equally Important	Important						
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Situation assessment																	

Goal: Evaluating weights of the following criteria for decision making by the AHP method

Problem definition and diagnosis

How important is 'Problem definition and diagnosis' compared to	Unimportant								Equally Important	Important						
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Option generation																	
Risk assessment and option selection																	
Outcome review																	

Option Generation

How important is 'Option generation' compared to	Unimportant								Equally Important	Important						
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Risk assessment and option selection																	
Outcome review																	

Risk assessment and option review

How important is 'Risk assessment and option review' compared to	Unimportant								Equally Important	Important						
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Outcome review																	

APPENDIX 4A: Information Sheet (Interview Participant)

LIVERPOOL JOHN MOORES UNIVERSITY

PARTICIPANT INFORMATION SHEET

Development of taxonomy for deck officers' non-technical skills (NTS) and analysing training needs for human element, leadership and management (HELM) course

You are being invited to take part in the above research study. Please read the following information and ask us if there is anything that is not clear or if you would like more information.

1. What is the purpose of the study?

Accidents in maritime industry are not new and a major contributing factor to most of these accidents is human error. Analysis in a number of maritime industrial sectors has indicated that up to 80% of accident causes can be attributed to human factors. Non-technical skills are relatively new concept in maritime industry and thus so far a little research has been conducted in this field.

The objective of the first part of the project is to develop and validate the taxonomy for deck officers' non-technical skills. Within this project the term 'non-technical skills' is used to describe deck officers' attitude and behaviours in crisis situations not directly related to technical skills used to navigate a ship or to use the bridge equipment. Non-technical skills taxonomy is developed from literature review and will be validated by conducting interviews with experts.

Once the model is validated in the first part, a simulator study will be conducted in the second part of the project to assess the deck officers' non-technical skills. The performance of a set of volunteer students, who have completed DipHE Nautical science, will be assessed in three simulated scenarios which would require the students to use their non-technical skills.

The performance of a second set of volunteer students, who have completed DipHE Nautical science and HELM training course, will be assessed with the same method. Afterward the results will be analysed and compared.

2. Do I have to take part?

You are invited to take part in the first part of the study, i.e. interview. This is a voluntary participation and it up to you to decide whether to take part or not. If you would like to participate you will be asked to sign a consent form. During the interview, you are still free to withdraw at any time and without giving a reason. A decision to withdraw will not affect your rights/any future treatment/service you receive.

3. What will happen to me if I take part?

The date and time of the interview will be agreed with you in advance. The interview data will be kept anonymous and you will not be contacted after interview is completed.

4. Are there any risks / benefits involved?

Interview process is a short process and unlikely to cause any risk. There is no specific benefit to an individual but there is overall benefit to the whole maritime industry.

5. Will my taking part in the study be kept confidential?

Yes, taking part in the study will be kept confidential.

APPENDIX 4B: Information Sheet (Simulator Participant)

LIVERPOOL JOHN MOORES UNIVERSITY

PARTICIPANT INFORMATION SHEET

Development of taxonomy for deck officers' non-technical skills (NTS) and analysing training needs for human element, leadership and management (HELM) course

You are being invited to take part in the above research study. Please read the following information and ask us if there is anything that is not clear or if you would like more information.

6. What is the purpose of the study?

Accidents in maritime industry are not new and a major contributing factor to most of these accidents is human error. Analysis in a number of industrial sectors has indicated that up to 80% of accident causes can be attributed to human factors. Non-technical skills are relatively new concept in maritime industry and thus so far a little research has been conducted in this field.

The objective of the first part of the project is to develop and validate the taxonomy for deck officers' non-technical skills. Within this project the term 'non-technical skills' is used to describe deck officers' attitude and behaviours in crisis situations not directly related to technical skills used to navigate a ship or to use the bridge equipment. Non-technical skills taxonomy is developed from literature review and will be validated by conducting interviews with experts.

Once the model is validated in the first part, a simulator study will be conducted in the second part of the project to assess the deck officers' non-technical skills. The performance of a set of volunteer students, who have completed DipHE Nautical science, will be assessed in three simulated scenarios which would require the students to use their non-technical skills.

The performance of a second set of volunteer students, who have completed DipHE Nautical science and HELM training course, will be assessed with the same method. Afterward the results will be analysed and compared.

7. Do I have to take part?

You are invited to take part in the second part of the study, i.e. simulation observations. This is a voluntary participation and it up to you to decide whether or not to take part. If you would like to participate you will be asked to sign a consent form. During the simulation observation you are still free to withdraw at any time and without giving a reason. A decision to withdraw will not affect your rights/any future treatment/service you receive.

8. What will happen to me if I take part?

The date and time of the simulation observation will be agreed with you in advance. There will be three simulation observations the data will be kept anonymous.

9. Are there any risks / benefits involved?

The process is same as you have already attended in the NAEST simulator exercise during the DipHE Nautical Science course so there is no risk in these exercises.

10. Will my taking part in the study be kept confidential?

Yes, taking part in the study will be kept confidential.

APPENDIX 5A: Consent Form (Interview Participant)

LIVERPOOL JOHN MOORES UNIVERSITY

CONSENT FORM

Development of taxonomy for deck officers' non-technical skills (NTS) and analysing training needs for human element, leadership and management (HELM) course

I confirm that I have read and understand the information provided for the above study. I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily. ☐

I understand that my participation is voluntary and that I am free to withdraw at any time, without giving a reason and that this will not affect my legal rights. ☐

I understand that any personal information collected during the study will be anonymised and remain confidential. ☐

I agree to take part in the above interview study. ☐

Name of Participant Date Signature

Name of Researcher Date Signature

APPENDIX 5B: Consent Form (Simulator Participant)

LIVERPOOL JOHN MOORES UNIVERSITY

CONSENT FORM

Development of taxonomy for deck officers' non-technical skills (NTS) and analysing training needs for human element, leadership and management (HELM) course

1. I confirm that I have read and understand the information provided for the above study. I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily. ☐

2. I understand that my participation is voluntary and that I am free to withdraw at any time, without giving a reason and that this will not affect my legal rights. ☐

3. I understand that any personal information collected during the study will be anonymised and remain confidential. ☐

4. I understand that the simulation observations will be video recorded and I am happy to proceed. ☐

5. I agree to take part in the above simulation observation study. ☐

Name of Participant Date Signature

Farhan Saeed
Name of Researcher Date Signature

Appendix 6 – AHP Data

Table A6.1 – Expert 01

A. Goal: Evaluating weights of the following main criteria for non-technical skills by the AHP method

Situation Awareness

How important is 'Situation Awareness' compared to	Less important								Equally Important	More important							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Decision Making								x									
Leadership								x									
Teamwork								x									

Decision Making

How important is 'Decision Making' compared to	Less important								Equally Important	More important							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Leadership										x							
Teamwork										x							

Leadership

How important is 'Leadership' compared to	Less important								Equally Important	More important							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Teamwork										x							

B. Goal: Evaluating weights of the following criteria for teamwork by the AHP method

Teambuilding and maintaining

How important is 'Team Building and maintaining' compared to	Less important								Equally Important	More important							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Considering others									x								
Supporting others									x								
Communication								x									
Information sharing							x										

Considering others

How important is 'Considering Others' compared to	Less important								Equally Important	More important							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Supporting others									x								
Communication								x									
Information sharing									x								

Supporting others

How important is 'Supporting Others' compared to	Less important								Equally Important	More important							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Communication								x									
Information sharing									x								

Communication

How important is 'Communication' compared to	Less important								Equally Important	More important						
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Information sharing											x						

C. Goal: Evaluating weights of the following criteria for leadership and managerial skills by the AHP method

Use of authority and assertiveness

How important is 'Use of authority and assertiveness' compared to	Less important								Equally Important	More important						
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Providing and maintaining standards										x							
Planning and co-ordination								x									
Work load management								x									
Prioritisation							x										
Task delegation									x								
Initial Crisis Management								x									

Providing and maintaining standards

How important is 'Providing and maintaining standards' compared to	Less important								Equally Important	More important							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Planning and co-ordination							x										
Work load management							x										
Prioritisation							x										
Task Delegation								x									
Initial Crisis Management							x										

Planning and co-ordination

How important is 'Planning and Co-ordination' compared to	Less important								Equally Important	More important							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Work load management										x							
Prioritisation										x							
Task Delegation												x					
Initial Crisis Management											x						

Work load management

How important is 'Workload management' compared to	Less important								Equally Important	More important							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Prioritisation										x							
Task Delegation										x							
Initial Crisis Management									x								

Prioritisation

How important is 'Prioritisation' compared to	Less important								Equally Important	More important							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Task Delegation									x								
Initial Crisis Management									x								

Task Delegation

How important is 'Task delegation' compared to	Less important								Equally Important	More important							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Initial Crisis Management									x								

D. Goal: Evaluating weights of the following criteria for situation awareness by the AHP method

Awareness of bridge systems

How important is 'Awareness of bridge systems' compared to	Less important								Equally Important	More important						
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Awareness of external environment										x							
Awareness of time										x							
Situation assessment								x									

Awareness of external environment

How important is 'Awareness of external environment' compared to	Less important								Equally Important	More important						
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Awareness of time										x							
Situation assessment								x									

Awareness of time

How important is 'Awareness of time' compared to	Less important								Equally Important	More important						
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Situation assessment							x										

E. Goal: Evaluating weights of the following criteria for decision making by the AHP method

Problem definition and diagnosis

How important is 'Problem definition and diagnosis' compared to	Less important								Equally Important	More important							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Option generation										x							
Risk assessment and option selection								x									
Outcome review								x									

Option Generation

How important is 'Option generation' compared to	Less important								Equally Important	More important							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Risk assessment and option selection							x										
Outcome review							x										

Risk assessment and option review

How important is 'Risk assessment and option review' compared to	Less important								Equally Important	More important							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Outcome review								x									

Table A6.2 - Expert 02

A Goal: Evaluating weights of the following main criteria for non-technical skills by the AHP method

Situation Awareness

How important is 'Situation Awareness' compared to	Less important								Equally Important	More important							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Decision Making										x							
Leadership								x									
Teamwork											x						

Decision Making

How important is 'Decision Making' compared to	Less important								Equally Important	More important							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Leadership								x									
Teamwork											x						

Leadership

How important is 'Leadership' compared to	Less important								Equally Important	More important							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Teamwork										x							

B. Goal: Evaluating weights of the following criteria for teamwork by the AHP method

Teambuilding and maintaining

How important is 'Team Building and maintaining' compared to	Less important								Equally Important	More important							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Considering others								x									
Supporting others								x									
Communication								x									
Information sharing								x									

Considering others

How important is 'Considering Others' compared to	Less important								Equally Important	More important							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Supporting others										x							
Communication										x							
Information sharing										x							

Supporting others

How important is 'Supporting Others' compared to	Less important								Equally Important	More important							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Communication								x									
Information sharing										x							

Communication

How important is 'Communication' compared to	Less important								Equally Important	More important							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Information sharing										x							

C. Goal: Evaluating weights of the following criteria for leadership and managerial skills by the AHP method

Use of authority and assertiveness

How important is 'Use of authority and assertiveness' compared to	Less important								Equally Important	More important							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Providing and maintaining standards										x							
Planning and co-ordination										x							
Work load management										x							
Prioritisation										x							
Task delegation										x							
Initial Crisis Management										x							

Providing and maintaining standards

How important is 'Providing and maintaining standards' compared to	Less important								Equally Important	More important							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Planning and co-ordination										x							
Work load management										x							
Prioritisation										x							
Task Delegation										x							
Initial Crisis Management										x							

Planning and co-ordination

How important is 'Planning and Co-ordination' compared to	Less important								Equally Important	More important							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Work load management										x							
Prioritisation										x							
Task Delegation										x							
Initial Crisis Management										x							

Work load management

How important is 'Workload management' compared to	Less important								Equally Important	More important							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Prioritisation										x							
Task Delegation							x										
Initial Crisis Management										x							

Prioritisation

How important is 'Prioritisation' compared to	Less important								Equally Important	More important							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Task Delegation										x							
Initial Crisis Management										x							

Task Delegation

How important is 'Task delegation' compared to	Less important								Equally Important	More important							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Initial Crisis Management										x							

D. Goal: Evaluating weights of the following criteria for situation awareness by the AHP method

Awareness of bridge systems

How important is 'Awareness of bridge systems' compared to	Less important								Equally Important	More important							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Awareness of external environment										x							
Awareness of time										x							
Situation assessment										x							

Awareness of external environment

How important is 'Awareness of external environment' compared to	Less important								Equally Important	More important							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Awareness of time								x									
Situation assessment										x							

Awareness of time

How important is 'Awareness of time' compared to	Less important								Equally Important	More important							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Situation assessment									x								

E. Goal: Evaluating weights of the following criteria for decision making by the AHP method

Problem definition and diagnosis

How important is 'Problem definition and diagnosis' compared to	Less important								Equally Important	More important							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Option generation										x							
Risk assessment and option selection										x							
Outcome review									x								

Option Generation

How important is 'Option generation' compared to	Less important								Equally Important	More important							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Risk assessment and option selection									x								
Outcome review									x								

Risk assessment and option review

How important is 'Risk assessment and option review' compared to	Less important								Equally Important	More important							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Outcome review									x								

Table A6.3 - Expert 03

A. Goal: Evaluating weights of the following main criteria for non-technical skills by the AHP method

Situation Awareness

How important is 'Situation Awareness' compared to	Less important								Equally Important	More important							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Decision Making												x					
Leadership									x								
Teamwork									x								

Decision Making

How important is 'Decision Making' compared to	Less important								Equally Important	More important							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Leadership							x										
Teamwork									x								

Leadership

How important is 'Leadership' compared to	Less important								Equally Important	More important							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Teamwork											x						

B. Goal: Evaluating weights of the following criteria for teamwork by the AHP method

Teambuilding and maintaining

How important is 'Team Building and maintaining' compared to	Less important								Equally Important	More important							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Considering others										x							
Supporting others									x								
Communication									x								
Information sharing									x								

Considering others

How important is 'Considering Others' compared to	Less important								Equally Important	More important							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Supporting others								x									
Communication								x									
Information sharing								x									

Supporting others

How important is 'Supporting Others' compared to	Less important								Equally Important	More important							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Communication									x								
Information sharing									x								

Communication

How important is 'Communication' compared to	Less important								Equally Important	More important							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Information sharing									x								

C. Goal: Evaluating weights of the following main criteria for leadership and managerial skills by the AHP method

Use of authority and assertiveness

How important is 'Use of authority and assertiveness' compared to	Less important								Equally Important	More important							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Providing and maintaining standards							x										
Planning and co-ordination								x									
Work load management								x									
Prioritisation									x								
Task delegation									x								
Initial Crisis Management										x							

Providing and maintaining standards

How important is 'Providing and maintaining standards' compared to	Less important								Equally Important	More important							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Planning and co-ordination									x								
Work load management								x									
Prioritisation									x								
Task Delegation									x								
Initial Crisis Management							x										

Planning and co-ordination

How important is 'Planning and Co-ordination' compared to	Less important								Equally Important	More important							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Work load management									x								
Prioritisation										x							
Task Delegation									x								
Initial Crisis Management									x								

Work load management

How important is 'Workload management' compared to	Less important								Equally Important	More important							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Prioritisation										x							
Task Delegation										x							
Initial Crisis Management									x								

Prioritisation

How important is 'Prioritisation' compared to	Less important								Equally Important	More important							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Task Delegation								x									
Initial Crisis Management									x								

Task Delegation

How important is 'Task delegation' compared to	Less important								Equally Important	More important							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Initial Crisis Management								x									

D. Goal: Evaluating weights of the following main criteria for situation awareness by the AHP method

Awareness of bridge systems

How important is 'Awareness of bridge systems' compared to	Less important								Equally Important	More important							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Awareness of external environment									x								
Awareness of time										x							
Situation assessment									x								

Awareness of external environment

How important is 'Awareness of external environment' compared to	Less important								Equally Important	More important							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Awareness of time										x							
Situation assessment									x								

Awareness of time

How important is 'Awareness of time' compared to	Less important								Equally Important	More important							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Situation assessment								x									

E. Goal: Evaluating weights of the following criteria for decision making by the AHP method

Problem definition and diagnosis

How important is 'Problem definition and diagnosis' compared to	Less important								Equally Important	More important						
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Option generation											x						
Risk assessment and option selection									x								
Outcome review									x								

Option Generation

How important is 'Option generation' compared to	Less important								Equally Important	More important						
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Risk assessment and option selection								x									
Outcome review								x									

Risk assessment and option review

How important is 'Risk assessment and option review' compared to	Less important								Equally Important	More important						
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Outcome review									x								

Table A6.4 - Expert 04

A. Goal: Evaluating weights of the following main criteria for non-technical skills by the AHP method

Situation Awareness

How important is 'Situation Awareness' compared to	Less important								Equally Important	More important							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Decision Making										x							
Leadership									x								
Teamwork									x								

Decision Making

How important is 'Decision Making' compared to	Less important								Equally Important	More important							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Leadership											x						
Teamwork											x						

Leadership

How important is 'Leadership' compared to	Less important								Equally Important	More important							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Teamwork										x							

B. Goal: Evaluating weights of the following criteria for teamwork by the AHP method

Teambuilding and maintaining

How important is 'Team Building and maintaining' compared to	Less important								Equally Important	More important							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Considering others									x								
Supporting others									x								
Communication									x								
Information sharing									x								

Considering others

How important is 'Considering Others' compared to	Less important								Equally Important	More important							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Supporting others										x							
Communication										x							
Information sharing										x							

Supporting others

How important is 'Supporting Others' compared to	Less important								Equally Important	More important							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Communication										x							
Information sharing										x							

Communication

How important is 'Communication' compared to	Less important								Equally Important	More important							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Information sharing										x							

C. Goal: Evaluating weights of the following criteria for leadership and managerial skills by the AHP method

Use of authority and assertiveness

How important is 'Use of authority and assertiveness' compared to	Less important								Equally Important	More important							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Providing and maintaining standards									x								
Planning and co-ordination										x							
Work load management										x							
Prioritisation										x							
Task delegation										x							
Initial Crisis Management										x							

Providing and maintaining standards

How important is 'Providing and maintaining standards' compared to	Less important								Equally Important	More important						
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Planning and co-ordination									x								
Work load management								x									
Prioritisation									x								
Task Delegation									x								
Initial Crisis Management								x									

Planning and co-ordination

How important is 'Planning and Co-ordination' compared to	Less important								Equally Important	More important						
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Work load management								x									
Prioritisation									x								
Task Delegation									x								
Initial Crisis Management								x									

Work load management

How important is 'Workload management' compared to	Less important								Equally Important	More important						
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Prioritisation									x								
Task Delegation									x								
Initial Crisis Management								x									

Prioritisation

How important is 'Prioritisation' compared to	Less important								Equally Important	More important						
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Task Delegation									x								
Initial Crisis Management								x									

Task Delegation

How important is 'Task delegation' compared to	Less important								Equally Important	More important						
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Initial Crisis Management								x									

D. Goal: Evaluating weights of the following criteria for situation awareness by the AHP method

Awareness of bridge systems

How important is 'Awareness of bridge systems' compared to	Less important								Equally Important	More important						
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Awareness of external environment									x								
Awareness of time									x								
Situation assessment								x									

Awareness of external environment

How important is 'Awareness of external environment' compared to	Less important								Equally Important	More important						
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Awareness of time									x								
Situation assessment										x							

Awareness of time

How important is 'Awareness of time' compared to	Less important								Equally Important	More important							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Situation assessment									x								

E. Goal: Evaluating weights of the following criteria for decision making by the AHP method

Problem definition and diagnosis

How important is 'Problem definition and diagnosis' compared to	Less important								Equally Important	More important							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Option generation										x							
Risk assessment and option selection										x							
Outcome review									x								

Option Generation

How important is 'Option generation' compared to	Less important								Equally Important	More important							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Risk assessment and option selection										x							
Outcome review									x								

Risk assessment and option review

How important is 'Risk assessment and option review' compared to	Less important								Equally Important	More important							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Outcome review									x								

Table A6.5: Expert 05

A. Goal: non-technical skills

Situation Awareness

How important is 'Situation Awareness' compared to	Unimportant								Equally Important	Important						
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Decision Making											x						
Leadership										x							
Teamwork										X							

Decision Making

How important is 'Decision Making' compared to	Unimportant								Equally Important	Important						
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Leadership									x								
Teamwork									x								

Leadership

How important is 'Leadership' compared to	Unimportant								Equally Important	Important						
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Teamwork									x								

B. Goal: teamwork

Teambuilding and maintaining

How important is 'Team Building and maintaining' compared to	Unimportant								Equally Important	Important						
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Considering others										x							
Supporting others										x							
Communication								x									
Information sharing									x								

Considering others

How important is 'Considering Others' compared to	Unimportant								Equally Important	Important						
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Supporting others									x								
Communication								x									
Information sharing									x								

Supporting others

How important is 'Supporting Others' compared to	Unimportant								Equally Important	Important						
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Communication								x									
Information sharing									x								

Communication

How important is 'Communication' compared to	Unimportant								Equally Important	Important						
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Information sharing										x							

C. Goal: Leadership and Managerial Skills

Use of authority and assertiveness

How important is 'Use of authority and assertiveness' compared to	Unimportant								Equally Important	Important						
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Providing and maintaining standards									x								
Planning and co-ordination							x										
Work load management							x										
Prioritisation							x										
Task delegation							x										
Initial Crisis Management						x											

Providing and maintaining standards

How important is 'Providing and maintaining standards' compared to	Unimportant								Equally Important	Important						
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Planning and co-ordination									x								
Work load management									x								
Prioritisation									x								
Task Delegation								x									
Initial Crisis Management							x										

Planning and co-ordination

How important is 'Planning and Co-ordination' compared to	Unimportant								Equally Important	Important						
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Work load management									x								
Prioritisation									x								
Task Delegation										x							
Initial Crisis Management							x										

Work load management

How important is 'Workload management' compared to	Unimportant								Equally Important	Important							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Prioritisation							x										
Task Delegation									x								
Initial Crisis Management						x											

Prioritisation

How important is 'Prioritisation' compared to	Unimportant								Equally Important	Important							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Task Delegation										x							
Initial Crisis Management						x											

Task Delegation

How important is 'Task delegation' compared to	Unimportant								Equally Important	Important							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Initial Crisis Management							x										

D. Goal: Situation awareness

Awareness of bridge systems

How important is 'Awareness of bridge systems' compared to	Unimportant								Equally Important	Important						
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Awareness of external environment									x								
Awareness of time									x								
Situation assessment							x										

Awareness of external environment

How important is 'Awareness of external environment' compared to	Unimportant								Equally Important	Important						
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Awareness of time									x								
Situation assessment							x										

Awareness of time

How important is 'Awareness of time' compared to	Unimportant								Equally Important	Important						
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Situation assessment							x										

E. **Goal:** Decision Making

Problem definition and diagnosis

How important is 'Problem definition and diagnosis' compared to	Unimportant								Equally Important	Important						
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Option generation											x						
Risk assessment and option selection									x								
Outcome review							x										

Option Generation

How important is 'Option generation' compared to	Unimportant								Equally Important	Important						
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Risk assessment and option selection									x								
Outcome review							x										

Risk assessment and option review

How important is 'Risk assessment and option review' compared to	Unimportant								Equally Important	Important						
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Outcome review						x											

Table A6.6: Expert 06

A. Goal: non-technical skills

Situation Awareness

How important is 'Situation Awareness' compared to	Less important								Equally Important	More important							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Decision Making										x							
Leadership								x									
Teamwork									x								

Decision Making

How important is 'Decision Making' compared to	Less important								Equally Important	More important							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Leadership										x							
Teamwork									x								

Leadership

How important is 'Leadership' compared to	Less important								Equally Important	More important							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Teamwork									x								

B. Goal: teamwork

Teambuilding and maintaining

How important is 'Team Building and maintaining' compared to	Less important								Equally Important	More important							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Considering others									x								
Supporting others									x								
Communication									x								
Information sharing									x								

Considering others

How important is 'Considering Others' compared to	Less important								Equally Important	More important							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Supporting others								x									
Communication										x							
Information sharing								x									

Supporting others

How important is 'Supporting Others' compared to	Less important								Equally Important	More important							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Communication										x							
Information sharing									x								

Communication

How important is 'Communication' compared to	Less important								Equally Important	More important							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Information sharing										x							

C. **Goal:** Leadership and Managerial Skills

Use of authority and assertiveness

How important is 'Use of authority and assertiveness' compared to	Less important								Equally Important	More important							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Providing and maintaining standards											x						
Planning and co-ordination									x								
Work load management									x								
Prioritisation								x									
Task delegation									x								
Initial Crisis Management									x								

Providing and maintaining standards

How important is 'Providing and maintaining standards' compared to	Less important								Equally Important	More important							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Planning and co-ordination								x									
Work load management								x									
Prioritisation							x										
Task Delegation							x										
Initial Crisis Management							x										

Planning and co-ordination

How important is 'Planning and Co-ordination' compared to	Less important								Equally Important	More important							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Work load management									x								
Prioritisation								x									
Task Delegation								x									
Initial Crisis Management								x									

Work load management

How important is 'Workload management' compared to	Less important								Equally Important	More important							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Prioritisation								x									
Task Delegation										x							
Initial Crisis Management								x									

Prioritisation

How important is 'Prioritisation' compared to	Less important								Equally Important	More important							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Task Delegation									x								
Initial Crisis Management								x									

Task Delegation

How important is 'Task delegation' compared to	Less important								Equally Important	More important							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Initial Crisis Management								x									

D. Goal: Situation awareness

Awareness of bridge systems

How important is 'Awareness of bridge systems' compared to	Less important								Equally Important	More important							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Awareness of external environment									x								
Awareness of time								x									
Situation assessment									x								

Awareness of external environment

How important is 'Awareness of external environment' compared to	Less important								Equally Important	More important							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Awareness of time								x									
Situation assessment									x								

Awareness of time

How important is 'Awareness of time' compared to	Less important								Equally Important	More important							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Situation assessment								x									

E. Goal: Decision Making

Problem definition and diagnosis

How important is 'Problem definition and diagnosis' compared to	Less important								Equally Important	More important							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Option generation								x									
Risk assessment and option selection										x							
Outcome review								x									

Option Generation

How important is 'Option generation' compared to	Less important								Equally Important	More important							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Risk assessment and option selection									x								
Outcome review									x								

Risk assessment and option review

How important is 'Risk assessment and option review' compared to	Less important								Equally Important	More important							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Outcome review									x								

Table A6.7: Expert 07

A. Goal: non-technical skills

Situation Awareness

How important is 'Situation Awareness' compared to	Less important								Equally Important	More important						
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Decision Making											x						
Leadership									x								
Teamwork									x								

Decision Making

How important is 'Decision Making' compared to	Less important								Equally Important	More important						
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Leadership									x								
Teamwork							x										

Leadership

How important is 'Leadership' compared to	Less important								Equally Important	More important						
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Teamwork						x											

B. Goal: teamwork

Teambuilding and maintaining

How important is 'Team Building and maintaining' compared to	Less important								Equally Important	More important						
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Considering others									x								
Supporting others											x						
Communication											x						
Information sharing									x								

Considering others

How important is 'Considering Others' compared to	Less important								Equally Important	More important						
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Supporting others									x								
Communication											x						
Information sharing											x						

Supporting others

How important is 'Supporting Others' compared to	Less important								Equally Important	More important						
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Communication									x								
Information sharing									x								

Communication

How important is 'Communication' compared to	Less important								Equally Important	More important						
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Information sharing									x								

C. Goal: Managerial Skills

Use of authority and assertiveness

How important is 'Use of authority and assertiveness' compared to	Less important								Equally Important	More important						
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Providing and maintaining standards											x						
Planning and co-ordination														x			
Work load management											x						
Prioritisation											x						
Task delegation									x								
Initial Crisis Management									x								

Providing and maintaining standards

How important is 'Providing and maintaining standards' compared to	Less important								Equally Important	More important							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Planning and co-ordination					x												
Work load management									x								
Prioritisation									x								
Task Delegation									x								
Initial Crisis Management						x											

Planning and co-ordination

How important is 'Planning and Co-ordination' compared to	Less important								Equally Important	More important							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Work load management							x										
Prioritisation							x										
Task Delegation							x										
Initial Crisis Management								x									

Work load management

How important is 'Workload management' compared to	Less important								Equally Important	More important							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Prioritisation							x										
Task Delegation							x										
Initial Crisis Management					x												

Prioritisation

How important is 'Prioritisation' compared to	Less important								Equally Important	More important							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Task Delegation							x										
Initial Crisis Management					x												

Task Delegation

How important is 'Task delegation' compared to	Less important								Equally Important	More important							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Initial Crisis Management					x												

D. Goal: Situation awareness

Awareness of bridge systems

How important is 'Awareness of bridge systems' compared to	Less important								Equally Important	More important						
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Awareness of external environment							x										
Awareness of time									x								
Situation assessment									x								

Awareness of external environment

How important is 'Awareness of external environment' compared to	Less important								Equally Important	More important						
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Awareness of time									x								
Situation assessment								x									

Awareness of time

How important is 'Awareness of time' compared to	Less important								Equally Important	More important						
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Situation assessment									x								

E. **Goal:** Decision Making

Problem definition and diagnosis

How important is 'Problem definition and diagnosis' compared to	Less important								Equally Important	More important							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Option generation							x										
Risk assessment and option selection							x										
Outcome review									x								

Option Generation

How important is 'Option generation' compared to	Less important								Equally Important	More important							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Risk assessment and option selection									x								
Outcome review										x							

Risk assessment and option review

How important is 'Risk assessment and option review' compared to	Less important								Equally Important	More important							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Outcome review									x								

Table A6.8: Expert 08

A. Goal: non-technical skills

Situation Awareness

How important is 'Situation Awareness' compared to	Unimportant								Equally Important	Important						
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Decision Making									x								
Leadership							x										
Teamwork										x							

Decision Making

How important is 'Decision Making' compared to	Unimportant								Equally Important	Important						
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Leadership									x								
Teamwork											x						

Leadership

How important is 'Leadership' compared to	Unimportant								Equally Important	Important						
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Teamwork											x						

B. Goal: teamwork

Teambuilding and maintaining

How important is 'Team Building and maintaining' compared to	Unimportant								Equally Important	Important							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Considering others										x							
Supporting others												x					
Communication								x									
Information sharing											x						

Considering others

How important is 'Considering Others' compared to	Unimportant								Equally Important	Important							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Supporting others								x									
Communication					x												
Information sharing							x										

Supporting others

How important is 'Supporting Others' compared to	Unimportant								Equally Important	Important							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Communication						x											
Information sharing								x									

Communication

How important is 'Communication' compared to	Unimportant								Equally Important	Important						
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Information sharing								x									

C. **Goal:** Managerial Skills

Use of authority and assertiveness

How important is 'Use of authority and assertiveness' compared to	Unimportant								Equally Important	Important						
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Providing and maintaining standards															x		
Planning and co-ordination									x								
Work load management												x					
Prioritisation											x						
Task delegation										x							
Initial Crisis Management								x									

Providing and maintaining standards

How important is 'Providing and maintaining standards' compared to	Unimportant								Equally Important	Important							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Planning and co-ordination					x												
Work load management						x											
Prioritisation							x										
Task Delegation					x												
Initial Crisis Management			x														

Planning and co-ordination

How important is 'Planning and Co-ordination' compared to	Unimportant								Equally Important	Important							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Work load management										x							
Prioritisation											x						
Task Delegation								x									
Initial Crisis Management					x												

Work load management

How important is 'Workload management' compared to	Unimportant								Equally Important	Important							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Prioritisation										x							
Task Delegation									x								
Initial Crisis Management					x												

Prioritisation

How important is 'Prioritisation' compared to	Unimportant								Equally Important	Important							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Task Delegation										x							
Initial Crisis Management					x												

Task Delegation

How important is 'Task delegation' compared to	Unimportant								Equally Important	Important							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Initial Crisis Management				x													

D. Goal: Situation awareness

Awareness of bridge systems

How important is 'Awareness of bridge systems' compared to	Unimportant								Equally Important	Important						
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Awareness of external environment									x								
Awareness of time											x						
Situation assessment							x										

Awareness of external environment

How important is 'Awareness of external environment' compared to	Unimportant								Equally Important	Important						
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Awareness of time											x						
Situation assessment								x									

Awareness of time

How important is 'Awareness of time' compared to	Unimportant								Equally Important	Important						
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Situation assessment					x												

E. **Goal:** Decision Making

Problem definition and diagnosis

How important is 'Problem definition and diagnosis' compared to	Unimportant								Equally Important	Important						
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Option generation									x								
Risk assessment and option selection									x								
Outcome review									x								

Option Generation

How important is 'Option generation' compared to	Unimportant								Equally Important	Important						
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Risk assessment and option selection									x								
Outcome review									x								

Risk assessment and option review

How important is 'Risk assessment and option review' compared to	Unimportant								Equally Important	Important							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Outcome review									x								

Appendix 7: Behavioural Markers for Group 1 - (Without HELM Training)

Table A7.1: Team working (Group 1)

Element	Very Good Practice	5	4	3	2	1	Very Poor Practice
Team building and maintaining	Fully encourages input and feedback from others			x			Keeps barriers between team members
Considering others	Take notice of the suggestions of other team members		x				Ignores suggestions of other team members
	Considers condition of other team members into account				x		Does not take account of the condition of other team members
	Provide detailed personal feedback				x		Show no reaction to other team members
Supporting others	Provide ample help to other team members in demanding situation			x			Do not help other team members in demanding situation
	Offers very good assistance			x			Does not offer assistance
Communication	Establish total atmosphere for open communication				x		Blocks open communication
	Communicates very effectively				x		Ineffective communication
Information sharing	Shares information among all team members			x			Does not share information properly among all team members

Table A7.2: Leadership and Managerial Skills (Group 1)

Element	Very Good Practice	5	4	3	2	1	Very Poor Practice
Use of authority and assertiveness	Takes full initiative to ensure crew involvement and task completion				x		Hinders or withholds crew involvement.
	Takes full control if situation requires					x	Does not show initiative for decision
	Totally reflects on suggestions of others			x			Ignores suggestions of others
Providing and maintaining standards	Demonstrates complete will to achieve top performance			x			Does not care for performance effectiveness.
Planning and co-ordination	Completely encourages crew participation in planning and task completion			x			Does not encourage crew participation in planning and task completion
	Plan is well clearly stated and confirmed				x		Plan is not clearly stated and confirmed
	Well clearly states goals and boundaries for task completion				x		Goals and boundaries remain unclear
Workload management	Completely notifies signs of stress and fatigue				x		Ignores signs of fatigue
	Allots good time to complete tasks					x	Allots very little time to complete tasks
Prioritisation	Demonstrate very good prioritisation of tasks				x		Demonstrate no prioritisation of tasks
Task delegation	Delegates all tasks properly					x	Does not delegate tasks
Initial crisis management	Identifies initial crisis situation very quickly and respond accordingly					x	Does not identify initial crisis situation

Table A7.3: Situation Awareness (Group 1)

Element	Very Good Practice	5	4	3	2	1	Very Poor Practice
Awareness of bridge systems	Fully monitors and report changes in systems' states			x			Do not monitors changes in systems' states
Awareness of external environment	Collects full information about environment (own ship's position, traffic and weather)				x		Does not collect information about environment (own ship's position, traffic and weather)
	Shares complete key information about environment with team members			x			Does not share key information about environment with crew
Awareness of time	Fully discuss time constraints with other team members				x		Does not discuss time constraints with other CM
Situation assessment	Makes full assessment of changing situation					x	Does not make an assessment of changing situation

Table A7.4: Decision making (Group 1)

Element	Very Good Practice	5	4	3	2	1	Very Poor Practice
Problem definition and diagnosis	Gather all information to identify problem		x				Failure to diagnose the problem
	Review all casual factors with other crew members				x		No discussion of probable cause
Option generation	States all alternative option					x	Does not search for information
	Asks crew members for all options				x		Does not ask crew for alternatives
Risk assessment and option selection	Considers and shares all estimated risk of alternative options				x		No discussion of limiting factors with crew
	Confirms and states all selected options/agreed action			x			Does not inform crew of decision path being taken
Outcome review	Complete checking of outcome against plan					x	Fails to check selected outcome against plan

Appendix 8: Behavioural Markers for Group 2 - (Without HELM Training)

Table A8.1: Team working (Group 2)

Element	Very Good Practice	5	4	3	2	1	Very Poor Practice
Team building and maintaining	Fully encourages input and feedback from others			x			Keeps barriers between team members
Considering others	Take notice of the suggestions of other team members				x		Ignores suggestions of other team members
	Considers condition of other team members into account			x			Does not take account of the condition of other team members
	Provide detailed personal feedback					x	Show no reaction to other team members
Supporting others	Provide ample help to other team members in demanding situation				x		Do not help other team members in demanding situation
	Offers very good assistance				x		Does not offer assistance
Communication	Establish total atmosphere for open communication			x			Blocks open communication
	Communicates very effectively			x			Ineffective communication
Information sharing	Shares information among all team members			x			Does not share information properly among all team members

Table A8.2: Leadership and Managerial Skills (Group 2)

Element	Very Good Practice	5	4	3	2	1	Very Poor Practice
Use of authority and assertiveness	Takes full initiative to ensure crew involvement and task completion			x			Hinders or withholds crew involvement.
	Takes full control if situation requires			x			Does not show initiative for decision
	Totally reflects on suggestions of others				x		Ignores suggestions of others
Providing and maintaining standards	Demonstrates complete will to achieve top performance				x		Does not care for performance effectiveness.
Planning and co-ordination	Completely encourages crew participation in planning and task completion			x			Does not encourage crew participation in planning and task completion
	Plan is well clearly stated and confirmed			x			Plan is not clearly stated and confirmed
	Well clearly states goals and boundaries for task completion			x			Goals and boundaries remain unclear
Workload management	Completely notifies signs of stress and fatigue					x	Ignores signs of fatigue
	Allots good time to complete tasks				x		Allots very little time to complete tasks
Prioritisation	Demonstrate very good prioritisation of tasks				x		Demonstrate no prioritisation of tasks
Task delegation	Delegates all tasks properly				x		Does not delegate tasks
Initial crisis management	Identifies initial crisis situation very quickly and respond accordingly				x		Does not identify initial crisis situation

Table A8.3: Situation Awareness (Group 2)

Element	Very Good Practice	5	4	3	2	1	Very Poor Practice
Awareness of bridge systems	Fully monitors and report changes in systems' states				x		Do not monitors changes in systems' states
Awareness of external environment	Collects full information about environment (own ship's position, traffic and weather)				x		Does not collect information about environment (own ship's position, traffic and weather)
	Shares complete key information about environment with team members			x			Does not share key information about environment with crew
Awareness of time	Fully discuss time constraints with other team members					x	Does not discuss time constraints with other CM
Situation assessment	Makes full assessment of changing situation				x		Does not make an assessment of changing situation

Table A8.4: Decision making (Group 2)

Element	Very Good Practice	5	4	3	2	1	Very Poor Practice
Problem definition and diagnosis	Gather all information to identify problem				x		Failure to diagnose the problem
	Review all casual factors with other crew members				x		No discussion of probable cause
Option generation	States all alternative option				x		Does not search for information
	Asks crew members for all options				x		Does not ask crew for alternatives
Risk assessment and option selection	Considers and shares all estimated risk of alternative options				x		No discussion of limiting factors with crew
	Confirms and states all selected options/agreed action				x		Does not inform crew of decision path being taken
Outcome review	Complete checking of outcome against plan					x	Fails to check selected outcome against plan

Appendix 9: Behavioural Markers for Group 3 - (Without HELM Training)

Table A9.1: Team working (Group 3)

Element	Very Good Practice	5	4	3	2	1	Very Poor Practice
Team building and maintaining	Fully encourages input and feedback from others				x		Keeps barriers between team members
Considering others	Take notice of the suggestions of other team members			x			Ignores suggestions of other team members
	Considers condition of other team members into account				x		Does not take account of the condition of other team members
	Provide detailed personal feedback				x		Show no reaction to other team members
Supporting others	Provide ample help to other team members in demanding situation			x			Do not help other team members in demanding situation
	Offers very good assistance			x			Does not offer assistance
Communication	Establish total atmosphere for open communication			x			Blocks open communication
	Communicates very effectively			x			Ineffective communication
Information sharing	Shares information among all team members				x		Does not share information properly among all team members

Table A9.2: Leadership and Managerial Skills (Group 3)

Element	Very Good Practice	5	4	3	2	1	Very Poor Practice
Use of authority and assertiveness	Takes full initiative to ensure crew involvement and task completion			x			Hinders or withholds crew involvement.
	Takes full control if situation requires				x		Does not show initiative for decision
	Totally reflects on suggestions of others			x			Ignores suggestions of others
Providing and maintaining standards	Demonstrates complete will to achieve top performance				x		Does not care for performance effectiveness.
Planning and co-ordination	Completely encourages crew participation in planning and task completion			x			Does not encourage crew participation in planning and task completion
	Plan is well clearly stated and confirmed				x		Plan is not clearly stated and confirmed
	Well clearly states goals and boundaries for task completion			x			Goals and boundaries remain unclear
Workload management	Completely notifies signs of stress and fatigue				x		Ignores signs of fatigue
	Allots good time to complete tasks					x	Allots very little time to complete tasks
Prioritisation	Demonstrate very good prioritisation of tasks			x			Demonstrate no prioritisation of tasks
Task delegation	Delegates all tasks properly					x	Does not delegate tasks
Initial crisis management	Identifies initial crisis situation very quickly and respond accordingly				x		Does not identify initial crisis situation

Table A9.3: Situation Awareness (Group 3)

Element	Very Good Practice	5	4	3	2	1	Very Poor Practice
Awareness of bridge systems	Fully monitors and report changes in systems' states			x			Do not monitors changes in systems' states
Awareness of external environment	Collects full information about environment (own ship's position, traffic and weather)				x		Does not collect information about environment (own ship's position, traffic and weather)
	Shares complete key information about environment with team members				x		Does not share key information about environment with crew
Awareness of time	Fully discuss time constraints with other team members			x			Does not discuss time constraints with other CM
Situation assessment	Makes full assessment of changing situation			x			Does not make an assessment of changing situation

Table A9.4: Decision making (Group 3)

Element	Very Good Practice	5	4	3	2	1	Very Poor Practice
Problem definition and diagnosis	Gather all information to identify problem				x		Failure to diagnose the problem
	Review all casual factors with other crew members				x		No discussion of probable cause
Option generation	States all alternative option			x			Does not search for information
	Asks crew members for all options			x			Does not ask crew for alternatives
Risk assessment and option selection	Considers and shares all estimated risk of alternative options				x		No discussion of limiting factors with crew
	Confirms and states all selected options/agreed action			x			Does not inform crew of decision path being taken
Outcome review	Complete checking of outcome against plan			x			Fails to check selected outcome against plan

Appendix 10: Behavioural Markers for Group 4 - (Without HELM Training)

Table A10.1: Team working (Group 4)

	Very Good Practice	5	4	3	2	1	Very Poor Practice
Team building and maintaining	Fully encourages input and feedback from others			x			Keeps barriers between team members
Considering others	Take notice of the suggestions of other team members			x			Ignores suggestions of other team members
	Considers condition of other team members into account				x		Does not take account of the condition of other team members
	Provide detailed personal feedback					x	Show no reaction to other team members
Supporting others	Provide ample help to other team members in demanding situation				x		Do not help other team members in demanding situation
	Offers very good assistance				x		Does not offer assistance
Communication	Establish total atmosphere for open communication				x		Blocks open communication
	Communicates very effectively					x	Ineffective communication
Information sharing	Shares information among all team members					x	Does not share information properly among all team members

Table A10.2: Leadership and Managerial Skills (Group 4)

Element	Very Good Practice	5	4	3	2	1	Very Poor Practice
Use of authority and assertiveness	Takes full initiative to ensure crew involvement and task completion					x	Hinders or withholds crew involvement.
	Takes full control if situation requires				x		Does not show initiative for decision
	Totally reflects on suggestions of others				x		Ignores suggestions of others
Providing and maintaining standards	Demonstrates complete will to achieve top performance				x		Does not care for performance effectiveness.
Planning and co-ordination	Completely encourages crew participation in planning and task completion			x			Does not encourage crew participation in planning and task completion
	Plan is well clearly stated and confirmed			x			Plan is not clearly stated and confirmed
	Well clearly states goals and boundaries for task completion				x		Goals and boundaries remain unclear
Workload management	Completely notifies signs of stress and fatigue					x	Ignores signs of fatigue
	Allots good time to complete tasks				x		Allots very little time to complete tasks
Prioritisation	Demonstrate very good prioritisation of tasks				x		Demonstrate no prioritisation of tasks
Task delegation	Delegates all tasks properly				x		Does not delegate tasks
Initial crisis management	Identifies initial crisis situation very quickly and respond accordingly					x	Does not identify initial crisis situation

Table A10.3: Situation Awareness (Group 4)

Element	Very Good Practice	5	4	3	2	1	Very Poor Practice
Awareness of bridge systems	Fully monitors and report changes in systems' states				x		Do not monitors changes in systems' states
Awareness of external environment	Collects full information about environment (own ship's position, traffic and weather)					x	Does not collect information about environment (own ship's position, traffic and weather)
	Shares complete key information about environment with team members				x		Does not share key information about environment with crew
Awareness of time	Fully discuss time constraints with other team members				x		Does not discuss time constraints with other CM
Situation assessment	Makes full assessment of changing situation					x	Does not make an assessment of changing situation

Table A10.4: Decision making (Group 4)

Element	Very Good Practice	5	4	3	2	1	Very Poor Practice
Problem definition and diagnosis	Gather all information to identify problem					x	Failure to diagnose the problem
	Review all casual factors with other crew members				x		No discussion of probable cause
Option generation	States all alternative option				x		Does not search for information
	Asks crew members for all options			x			Does not ask crew for alternatives
Risk assessment and option selection	Considers and shares all estimated risk of alternative options					x	No discussion of limiting factors with crew
	Confirms and states all selected options/agreed action					x	Does not inform crew of decision path being taken
Outcome review	Complete checking of outcome against plan					x	Fails to check selected outcome against plan

Appendix 11: Behavioural Markers for Group 5 - (Without HELM Training)

Table A11.1: Team working (Group 5)

Element	Very Good Practice	5	4	3	2	1	Very Poor Practice
Team building and maintaining	Fully encourages input and feedback from others			x			Keeps barriers between team members
Considering others	Take notice of the suggestions of other team members		x				Ignores suggestions of other team members
	Considers condition of other team members into account				x		Does not take account of the condition of other team members
	Provide detailed personal feedback				x		Show no reaction to other team members
Supporting others	Provide ample help to other team members in demanding situation			x			Do not help other team members in demanding situation
	Offers very good assistance			x			Does not offer assistance
Communication	Establish total atmosphere for open communication			x			Blocks open communication
	Communicates very effectively			x			Ineffective communication
Information sharing	Shares information among all team members			x			Does not share information properly among all team members

Table A11.2: Leadership and Managerial Skills (Group 5)

Element	Very Good Practice	5	4	3	2	1	Very Poor Practice
Use of authority and assertiveness	Takes full initiative to ensure crew involvement and task completion			x			Hinders or withholds crew involvement.
	Takes full control if situation requires			x			Does not show initiative for decision
	Totally reflects on suggestions of others			x			Ignores suggestions of others
Providing and maintaining standards	Demonstrates complete will to achieve top performance				x		Does not care for performance effectiveness.
Planning and co-ordination	Completely encourages crew participation in planning and task completion			x			Does not encourage crew participation in planning and task completion
	Plan is well clearly stated and confirmed				x		Plan is not clearly stated and confirmed
	Well clearly states goals and boundaries for task completion				x		Goals and boundaries remain unclear
Workload management	Completely notifies signs of stress and fatigue				x		Ignores signs of fatigue
	Allots good time to complete tasks				x		Allots very little time to complete tasks
Prioritisation	Demonstrate very good prioritisation of tasks				x		Demonstrate no prioritisation of tasks
Task delegation	Delegates all tasks properly				x		Does not delegate tasks
Initial crisis management	Identifies initial crisis situation very quickly and respond accordingly				x		Does not identify initial crisis situation

Table A11.3: Situation Awareness (Group 5)

Element	Very Good Practice	5	4	3	2	1	Very Poor Practice
Awareness of bridge systems	Fully monitors and report changes in systems' states			x			Do not monitors changes in systems' states
Awareness of external environment	Collects full information about environment (own ship's position, traffic and weather)				x		Does not collect information about environment (own ship's position, traffic and weather)
	Shares complete key information about environment with team members			x			Does not share key information about environment with crew
Awareness of time	Fully discuss time constraints with other team members					x	Does not discuss time constraints with other CM
Situation assessment	Makes full assessment of changing situation			x			Does not make an assessment of changing situation

Table A11.4: Decision making (Group 5)

Element	Very Good Practice	5	4	3	2	1	Very Poor Practice
Problem definition and diagnosis	Gather all information to identify problem			x			Failure to diagnose the problem
	Review all casual factors with other crew members				x		No discussion of probable cause
Option generation	States all alternative option					x	Does not search for information
	Asks crew members for all options				x		Does not ask crew for alternatives
Risk assessment and option selection	Considers and shares all estimated risk of alternative options					x	No discussion of limiting factors with crew
	Confirms and states all selected options/agreed action				x		Does not inform crew of decision path being taken
Outcome review	Complete checking of outcome against plan				x		Fails to check selected outcome against plan

Appendix 12: Behavioural Markers for Group 6 - (Without HELM Training)

Table A12.1: Team working (Group 6)

Element	Very Good Practice	5	4	3	2	1	Very Poor Practice
Team building and maintaining	Fully encourages input and feedback from others			x			Keeps barriers between team members
Considering others	Take notice of the suggestions of other team members			x			Ignores suggestions of other team members
	Considers condition of other team members into account	x					Does not take account of the condition of other team members
	Provide detailed personal feedback				x		Show no reaction to other team members
Supporting others	Provide ample help to other team members in demanding situation		x				Do not help other team members in demanding situation
	Offers very good assistance			x			Does not offer assistance
Communication	Establish total atmosphere for open communication		x				Blocks open communication
	Communicates very effectively		x				Ineffective communication
Information sharing	Shares information among all team members		x				Does not share information properly among all team members

Table A12.2: Leadership and Managerial Skills (Group 6)

Element	Very Good Practice	5	4	3	2	1	Very Poor Practice
Use of authority and assertiveness	Takes full initiative to ensure crew involvement and task completion			x			Hinders or withholds crew involvement.
	Takes full control if situation requires		x				Does not show initiative for decision
	Totally reflects on suggestions of others			x			Ignores suggestions of others
Providing and maintaining standards	Demonstrates complete will to achieve top performance		x				Does not care for performance effectiveness.
Planning and co-ordination	Completely encourages crew participation in planning and task completion			x			Does not encourage crew participation in planning and task completion
	Plan is well clearly stated and confirmed		x				Plan is not clearly stated and confirmed
	Well clearly states goals and boundaries for task completion		x				Goals and boundaries remain unclear
Workload management	Completely notifies signs of stress and fatigue			x			Ignores signs of fatigue
	Allots good time to complete tasks			x			Allots very little time to complete tasks
Prioritisation	Demonstrate very good prioritisation of tasks			x			Demonstrate no prioritisation of tasks
Task delegation	Delegates all tasks properly	x					Does not delegate tasks
Initial crisis management	Identifies initial crisis situation very quickly and respond accordingly			x			Does not identify initial crisis situation

Table A12.3: Situation Awareness (Group 6)

Element	Very Good Practice	5	4	3	2	1	Very Poor Practice
Awareness of bridge systems	Fully monitors and report changes in systems' states				x		Do not monitors changes in systems' states
Awareness of external environment	Collects full information about environment (own ship's position, traffic and weather)		x				Does not collect information about environment (own ship's position, traffic and weather)
	Shares complete key information about environment with team members		x				Does not share key information about environment with crew
Awareness of time	Fully discuss time constraints with other team members				x		Does not discuss time constraints with other CM
Situation assessment	Makes full assessment of changing situation		x				Does not make an assessment of changing situation

Table A12.4: Decision making (Group 6)

Element	Very Good Practice	5	4	3	2	1	Very Poor Practice
Problem definition and diagnosis	Gather all information to identify problem		x				Failure to diagnose the problem
	Review all casual factors with other crew members			x			No discussion of probable cause
Option generation	States all alternative option			x			Does not search for information
	Asks crew members for all options				x		Does not ask crew for alternatives
Risk assessment and option selection	Considers and shares all estimated risk of alternative options				x		No discussion of limiting factors with crew
	Confirms and states all selected options/agreed action				x		Does not inform crew of decision path being taken
Outcome review	Complete checking of outcome against plan				x		Fails to check selected outcome against plan

Appendix 13: Behavioural Markers for Group 7 – (With HELM Training)

Table A13.1: Team working (Group 7)

Element	Very Good Practice	5	4	3	2	1	Very Poor Practice
Team building and maintaining	Fully encourages input and feedback from others			x			Keeps barriers between team members
Considering others	Take notice of the suggestions of other team members		x				Ignores suggestions of other team members
	Considers condition of other team members into account		x	x			Does not take account of the condition of other team members
	Provide detailed personal feedback				x		Show no reaction to other team members
Supporting others	Provide ample help to other team members in demanding situation		x	x			Do not help other team members in demanding situation
	Offers very good assistance		x	x			Does not offer assistance
Communication	Establish total atmosphere for open communication			x			Blocks open communication
	Communicates very effectively				x		Ineffective communication
Information sharing	Shares information among all team members			x	x		Does not share information properly among all team members

Table A13.2: Leadership and Managerial Skills (Group 7)

Element	Very Good Practice	5	4	3	2	1	Very Poor Practice
Use of authority and assertiveness	Takes full initiative to ensure crew involvement and task completion			x			Hinders or withholds crew involvement.
	Takes full control if situation requires			x			Does not show initiative for decision
	Totally reflects on suggestions of others			x			Ignores suggestions of others
Providing and maintaining standards	Demonstrates complete will to achieve top performance			x	x		Does not care for performance effectiveness.
Planning and co-ordination	Completely encourages crew participation in planning and task completion			x	x		Does not encourage crew participation in planning and task completion
	Plan is well clearly stated and confirmed			x	x		Plan is not clearly stated and confirmed
	Well clearly states goals and boundaries for task completion				x		Goals and boundaries remain unclear
Workload management	Completely notifies signs of stress and fatigue				x		Ignores signs of fatigue
	Allots good time to complete tasks			x			Allots very little time to complete tasks
Prioritisation	Demonstrate very good prioritisation of tasks			x			Demonstrate no prioritisation of tasks
Task delegation	Delegates all tasks properly			x	x		Does not delegate tasks
Initial crisis management	Identifies initial crisis situation very quickly and respond accordingly			x			Does not identify initial crisis situation

Table A13.3: Situation Awareness (Group 7)

Element	Very Good Practice	5	4	3	2	1	Very Poor Practice
Awareness of bridge systems	Fully monitors and report changes in systems' states		x				Do not monitors changes in systems' states
Awareness of external environment	Collects full information about environment (own ship's position, traffic and weather)		x				Does not collect information about environment (own ship's position, traffic and weather)
	Shares complete key information about environment with team members		x	x			Does not share key information about environment with crew
Awareness of time	Fully discuss time constraints with other team members			x			Does not discuss time constraints with other CM
Situation assessment	Makes full assessment of changing situation			x			Does not make an assessment of changing situation

Table A13.4: Decision making (Group 7)

Element	Very Good Practice	5	4	3	2	1	Very Poor Practice
Problem definition and diagnosis	Gather all information to identify problem		x	x			Failure to diagnose the problem
	Review all casual factors with other crew members			x	x		No discussion of probable cause
Option generation	States all alternative option			x			Does not search for information
	Asks crew members for all options					x	Does not ask crew for alternatives
Risk assessment and option selection	Considers and shares all estimated risk of alternative options				x		No discussion of limiting factors with crew
	Confirms and states all selected options/agreed action			x			Does not inform crew of decision path being taken
Outcome review	Complete checking of outcome against plan				x		Fails to check selected outcome against plan

Appendix 14: Behavioural Markers for Group 8 – (With HELM Training)

Table A14.1: Team working (Group 8)

Element	Very Good Practice	5	4	3	2	1	Very Poor Practice
Team building and maintaining	Fully encourages input and feedback from others				x		Keeps barriers between team members
Considering others	Take notice of the suggestions of other team members				x		Ignores suggestions of other team members
	Considers condition of other team members into account				x		Does not take account of the condition of other team members
	Provide detailed personal feedback					x	Show no reaction to other team members
Supporting others	Provide ample help to other team members in demanding situation					x	Do not help other team members in demanding situation
	Offers very good assistance				x	x	Does not offer assistance
Communication	Establish total atmosphere for open communication				x		Blocks open communication
	Communicates very effectively				x		Ineffective communication
Information sharing	Shares information among all team members				x		Does not share information properly among all team members

Table A14.2: Leadership and Managerial Skills (Group 8)

Element	Very Good Practice	5	4	3	2	1	Very Poor Practice
Use of authority and assertiveness	Takes full initiative to ensure crew involvement and task completion				x		Hinders or withholds crew involvement.
	Takes full control if situation requires					x	Does not show initiative for decision
	Totally reflects on suggestions of others			x			Ignores suggestions of others
Providing and maintaining standards	Demonstrates complete will to achieve top performance				x	x	Does not care for performance effectiveness.
Planning and co-ordination	Completely encourages crew participation in planning and task completion				x	x	Does not encourage crew participation in planning and task completion
	Plan is well clearly stated and confirmed				x		Plan is not clearly stated and confirmed
	Well clearly states goals and boundaries for task completion				x	x	Goals and boundaries remain unclear
Workload management	Completely notifies signs of stress and fatigue					x	Ignores signs of fatigue
	Allots good time to complete tasks				x		Allots very little time to complete tasks
Prioritisation	Demonstrate very good prioritisation of tasks				x		Demonstrate no prioritisation of tasks
Task delegation	Delegates all tasks properly			x	x		Does not delegate tasks
Initial crisis management	Identifies initial crisis situation very quickly and respond accordingly					x	Does not identify initial crisis situation

Table A14.3: Situation Awareness (Group 8)

Element	Very Good Practice	5	4	3	2	1	Very Poor Practice
Awareness of bridge systems	Fully monitors and report changes in systems' states			x	x		Do not monitors changes in systems' states
Awareness of external environment	Collects full information about environment (own ship's position, traffic and weather)			x	x		Does not collect information about environment (own ship's position, traffic and weather)
	Shares complete key information about environment with team members				x	x	Does not share key information about environment with crew
Awareness of time	Fully discuss time constraints with other team members				x	x	Does not discuss time constraints with other CM
Situation assessment	Makes full assessment of changing situation					x	Does not make an assessment of changing situation

Table A14.4: Decision making (Group 8)

Element	Very Good Practice	5	4	3	2	1	Very Poor Practice
Problem definition and diagnosis	Gather all information to identify problem				x	x	Failure to diagnose the problem
	Review all casual factors with other crew members				x	x	No discussion of probable cause
Option generation	States all alternative option					x	Does not search for information
	Asks crew members for all options				x	x	Does not ask crew for alternatives
Risk assessment and option selection	Considers and shares all estimated risk of alternative options				x	x	No discussion of limiting factors with crew
	Confirms and states all selected options/agreed action					x	Does not inform crew of decision path being taken
Outcome review	Complete checking of outcome against plan				x	x	Fails to check selected outcome against plan

Appendix 15: Behavioural Markers for Group 9 - (With HELM Training)

Table A15.1: Team working (Group 9)

Element	Very Good Practice	5	4	3	2	1	Very Poor Practice
Team building and maintaining	Fully encourages input and feedback from others			x			Keeps barriers between team members
Considering others	Take notice of the suggestions of other team members			x	x		Ignores suggestions of other team members
	Considers condition of other team members into account			x			Does not take account of the condition of other team members
	Provide detailed personal feedback					x	Show no reaction to other team members
Supporting others	Provide ample help to other team members in demanding situation				x		Do not help other team members in demanding situation
	Offers very good assistance				x	x	Does not offer assistance
Communication	Establish total atmosphere for open communication			x	x		Blocks open communication
	Communicates very effectively				x		Ineffective communication
Information sharing	Shares information among all team members				x	x	Does not share information properly among all team members

Table A15.2: Leadership and Managerial Skills (Group 9)

Element	Very Good Practice	5	4	3	2	1	Very Poor Practice
Use of authority and assertiveness	Takes full initiative to ensure crew involvement and task completion				x		Hinders or withholds crew involvement.
	Takes full control if situation requires				x	x	Does not show initiative for decision
	Totally reflects on suggestions of others			x	x		Ignores suggestions of others
Providing and maintaining standards	Demonstrates complete will to achieve top performance				x		Does not care for performance effectiveness.
Planning and co-ordination	Completely encourages crew participation in planning and task completion			x	x		Does not encourage crew participation in planning and task completion
	Plan is well clearly stated and confirmed				x	x	Plan is not clearly stated and confirmed
	Well clearly states goals and boundaries for task completion			x	x		Goals and boundaries remain unclear
Workload management	Completely notifies signs of stress and fatigue				x		Ignores signs of fatigue
	Allots good time to complete tasks			x			Allots very little time to complete tasks
Prioritisation	Demonstrate very good prioritisation of tasks				x		Demonstrate no prioritisation of tasks
Task delegation	Delegates all tasks properly			x		x	Does not delegate tasks
Initial crisis management	Identifies initial crisis situation very quickly and respond accordingly				x		Does not identify initial crisis situation

Table A15.3: Situation Awareness (Group 9)

Element	Very Good Practice	5	4	3	2	1	Very Poor Practice
Awareness of bridge systems	Fully monitors and report changes in systems' states			x			Do not monitors changes in systems' states
Awareness of external environment	Collects full information about environment (own ship's position, traffic and weather)				x		Does not collect information about environment (own ship's position, traffic and weather)
	Shares complete key information about environment with team members				x		Does not share key information about environment with crew
Awareness of time	Fully discuss time constraints with other team members				x		Does not discuss time constraints with other CM
Situation assessment	Makes full assessment of changing situation				x		Does not make an assessment of changing situation

Table A15.4: Decision making (Group 9)

Element	Very Good Practice	5	4	3	2	1	Very Poor Practice
Problem definition and diagnosis	Gather all information to identify problem				x	x	Failure to diagnose the problem
	Review all casual factors with other crew members			x	x		No discussion of probable cause
Option generation	States all alternative option				x		Does not search for information
	Asks crew members for all options			x			Does not ask crew for alternatives
Risk assessment and option selection	Considers and shares all estimated risk of alternative options				x		No discussion of limiting factors with crew
	Confirms and states all selected options/agreed action			x	x		Does not inform crew of decision path being taken
Outcome review	Complete checking of outcome against plan				x		Fails to check selected outcome against plan

Appendix 16: Behavioural Markers for Group 10 – (With HELM Training)

Table A16.1: Team working (Group 10)

Element	Very Good Practice	5	4	3	2	1	Very Poor Practice
Team building and maintaining	Fully encourages input and feedback from others			x			Keeps barriers between team members
Considering others	Take notice of the suggestions of other team members			x			Ignores suggestions of other team members
	Considers condition of other team members into account	Not Observed					Does not take account of the condition of other team members
	Provide detailed personal feedback				x		Show no reaction to other team members
Supporting others	Provide ample help to other team members in demanding situation		x	x			Do not help other team members in demanding situation
	Offers very good assistance			x			Does not offer assistance
Communication	Establish total atmosphere for open communication		x	x			Blocks open communication
	Communicates very effectively			x			Ineffective communication
Information sharing	Shares information among all team members			x			Does not share information properly among all team members

Table A16.2: Leadership and Managerial Skills (Group 10)

Element	Very Good Practice	5	4	3	2	1	Very Poor Practice
Use of authority and assertiveness	Takes full initiative to ensure crew involvement and task completion			x			Hinders or withholds crew involvement.
	Takes full control if situation requires				x		Does not show initiative for decision
	Totally reflects on suggestions of others			x	x		Ignores suggestions of others
Providing and maintaining standards	Demonstrates complete will to achieve top performance			x	x		Does not care for performance effectiveness.
Planning and co-ordination	Completely encourages crew participation in planning and task completion			x			Does not encourage crew participation in planning and task completion
	Plan is well clearly stated and confirmed			x			Plan is not clearly stated and confirmed
	Well clearly states goals and boundaries for task completion		x	x			Goals and boundaries remain unclear
Workload management	Completely notifies signs of stress and fatigue	Not Observed					Ignores signs of fatigue
	Allots good time to complete tasks			x			Allots very little time to complete tasks
Prioritisation	Demonstrate very good prioritisation of tasks			x			Demonstrate no prioritisation of tasks
Task delegation	Delegates all tasks properly				x	x	Does not delegate tasks
Initial crisis management	Identifies initial crisis situation very quickly and respond accordingly				x		Does not identify initial crisis situation

Table A16.3: Situation Awareness (Group 10)

Element	Very Good Practice	5	4	3	2	1	Very Poor Practice
Awareness of bridge systems	Fully monitors and report changes in systems' states			x	x		Do not monitors changes in systems' states
Awareness of external environment	Collects full information about environment (own ship's position, traffic and weather)		x	x	x		Does not collect information about environment (own ship's position, traffic and weather)
	Shares complete key information about environment with team members		x	x			Does not share key information about environment with crew
Awareness of time	Fully discuss time constraints with other team members				x		Does not discuss time constraints with other CM
Situation assessment	Makes full assessment of changing situation			x	x		Does not make an assessment of changing situation

Table A16.4: Decision making (Group 10)

Element	Very Good Practice	5	4	3	2	1	Very Poor Practice
Problem definition and diagnosis	Gather all information to identify problem			x	x		Failure to diagnose the problem
	Review all casual factors with other crew members			x	x		No discussion of probable cause
Option generation	States all alternative option			x	x		Does not search for information
	Asks crew members for all options			x	x		Does not ask crew for alternatives
Risk assessment and option selection	Considers and shares all estimated risk of alternative options				x		No discussion of limiting factors with crew
	Confirms and states all selected options/agreed action			x			Does not inform crew of decision path being taken
Outcome review	Complete checking of outcome against plan				x		Fails to check selected outcome against plan

Appendix 17: Behavioural Markers for Group 11 – (With HELM Training)

Table A17.1: Team working (Group 11)

Element	Very Good Practice	5	4	3	2	1	Very Poor Practice
Team building and maintaining	Fully encourages input and feedback from others		x				Keeps barriers between team members
Considering others	Take notice of the suggestions of other team members		x				Ignores suggestions of other team members
	Considers condition of other team members into account	Not Observed					Does not take account of the condition of other team members
	Provide detailed personal feedback	Not Observed					Show no reaction to other team members
Supporting others	Provide ample help to other team members in demanding situation			x			Do not help other team members in demanding situation
	Offers very good assistance			x			Does not offer assistance
Communication	Establish total atmosphere for open communication			x			Blocks open communication
	Communicates very effectively			x			Ineffective communication
Information sharing	Shares information among all team members		x	x			Does not share information properly among all team members

Table A17.2: Leadership and Managerial Skills (Group 11)

Element	Very Good Practice	5	4	3	2	1	Very Poor Practice
Use of authority and assertiveness	Takes full initiative to ensure crew involvement and task completion			x			Hinders or withholds crew involvement.
	Takes full control if situation requires			x	x		Does not show initiative for decision
	Totally reflects on suggestions of others		x	x			Ignores suggestions of others
Providing and maintaining standards	Demonstrates complete will to achieve top performance			x			Does not care for performance effectiveness.
Planning and co-ordination	Completely encourages crew participation in planning and task completion	Not Observed					Does not encourage crew participation in planning and task completion
	Plan is well clearly stated and confirmed						Plan is not clearly stated and confirmed
	Well clearly states goals and boundaries for task completion			x			Goals and boundaries remain unclear
Workload management	Completely notifies signs of stress and fatigue	Not Observed					Ignores signs of fatigue
	Allots good time to complete tasks			x			Allots very little time to complete tasks
Prioritisation	Demonstrate very good prioritisation of tasks			x			Demonstrate no prioritisation of tasks
Task delegation	Delegates all tasks properly				x		Does not delegate tasks
Initial crisis management	Identifies initial crisis situation very quickly and respond accordingly				x		Does not identify initial crisis situation

Table A17.3: Situation Awareness (Group 11)

Element	Very Good Practice	5	4	3	2	1	Very Poor Practice
Awareness of bridge systems	Fully monitors and report changes in systems' states		x		x		Do not monitors changes in systems' states
Awareness of external environment	Collects full information about environment (own ship's position, traffic and weather)			x	x		Does not collect information about environment (own ship's position, traffic and weather)
	Shares complete key information about environment with team members		x		x		Does not share key information about environment with crew
Awareness of time	Fully discuss time constraints with other team members			x	x		Does not discuss time constraints with other CM
Situation assessment	Makes full assessment of changing situation			x	x		Does not make an assessment of changing situation

Table A17.4: Decision making (Group 11)

Element	Very Good Practice	5	4	3	2	1	Very Poor Practice
Problem definition and diagnosis	Gather all information to identify problem		x				Failure to diagnose the problem
	Review all casual factors with other crew members			x			No discussion of probable cause
Option generation	States all alternative option				x		Does not search for information
	Asks crew members for all options				x		Does not ask crew for alternatives
Risk assessment and option selection	Considers and shares all estimated risk of alternative options				x		No discussion of limiting factors with crew
	Confirms and states all selected options/agreed action			x			Does not inform crew of decision path being taken
Outcome review	Complete checking of outcome against plan			x			Fails to check selected outcome against plan

Appendix 18: Behavioural Markers for Group 12 – (With HELM Training)

Table A18.1: Team working (Group 12)

Element	Very Good Practice	5	4	3	2	1	Very Poor Practice
Team building and maintaining	Fully encourages input and feedback from others			x	x		Keeps barriers between team members
Considering others	Take notice of the suggestions of other team members			x	x		Ignores suggestions of other team members
	Considers condition of other team members into account						Does not take account of the condition of other team members
	Provide detailed personal feedback						Show no reaction to other team members
Supporting others	Provide ample help to other team members in demanding situation			x			Do not help other team members in demanding situation
	Offers very good assistance			x			Does not offer assistance
Communication	Establish total atmosphere for open communication		x	x			Blocks open communication
	Communicates very effectively		x	x			Ineffective communication
Information sharing	Shares information among all team members			x	x		Does not share information properly among all team members

Table A18.2: Leadership and Managerial Skills (Group 12)

Element	Very Good Practice	5	4	3	2	1	Very Poor Practice
Use of authority and assertiveness	Takes full initiative to ensure crew involvement and task completion			x			Hinders or withholds crew involvement.
	Takes full control if situation requires				x		Does not show initiative for decision
	Totally reflects on suggestions of others			x	x		Ignores suggestions of others
Providing and maintaining standards	Demonstrates complete will to achieve top performance			x	x		Does not care for performance effectiveness.
Planning and co-ordination	Completely encourages crew participation in planning and task completion			x			Does not encourage crew participation in planning and task completion
	Plan is well clearly stated and confirmed						Plan is not clearly stated and confirmed
	Well clearly states goals and boundaries for task completion			x	x		Goals and boundaries remain unclear
Workload management	Completely notifies signs of stress and fatigue						Ignores signs of fatigue
	Allots good time to complete tasks			x			Allots very little time to complete tasks
Prioritisation	Demonstrate very good prioritisation of tasks			x			Demonstrate no prioritisation of tasks
Task delegation	Delegates all tasks properly				x		Does not delegate tasks
Initial crisis management	Identifies initial crisis situation very quickly and respond accordingly				x	x	Does not identify initial crisis situation

Table A18.3: Situation Awareness (Group 12)

Element	Very Good Practice	5	4	3	2	1	Very Poor Practice
Awareness of bridge systems	Fully monitors and report changes in systems' states				x	x	Do not monitors changes in systems' states
Awareness of external environment	Collects full information about environment (own ship's position, traffic and weather)			x	x		Does not collect information about environment (own ship's position, traffic and weather)
	Shares complete key information about environment with team members			x	x		Does not share key information about environment with crew
Awareness of time	Fully discuss time constraints with other team members				x		Does not discuss time constraints with other CM
Situation assessment	Makes full assessment of changing situation					x	Does not make an assessment of changing situation

Table A18.4: Decision making (Group 12)

Element	Very Good Practice	5	4	3	2	1	Very Poor Practice
Problem definition and diagnosis	Gather all information to identify problem				x	x	Failure to diagnose the problem
	Review all casual factors with other crew members				x		No discussion of probable cause
Option generation	States all alternative option				x		Does not search for information
	Asks crew members for all options				x	x	Does not ask crew for alternatives
Risk assessment and option selection	Considers and shares all estimated risk of alternative options					x	No discussion of limiting factors with crew
	Confirms and states all selected options/agreed action					x	Does not inform crew of decision path being taken
Outcome review	Complete checking of outcome against plan				x	x	Fails to check selected outcome against plan

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ISBN No. 978-4-907408-06-0