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A Cost Benefit Analysis Approach to Identify Improvements in Merchant Navy Deck Officers' HELM (Human Element Leadership and Management) Training

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ABSTRACT: A review of maritime accidents conducted over the last decade confirms that human error is the main contributing factor in these incidents. Well-developed Non-Technical Skills (NTS) can reduce the effects of human error. NTS include 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 a deck officer to recognise the problem quickly, take action to manage the situation, and utilise the available team members safely and effectively.
This paper identifies the importance of NTS training for merchant navy deck officers. It also highlights room for improvement in the existing HELM training. Research has shown that at present the structure of HELM training is not very effective. The other safety critical domains' efforts into NTS developments are investigated and examples of best practice are adapted into the maritime domain's NTS training.
Suggestions are given for improvements to the HELM course based on proven successful methods in other safety critical domains (aviation and anaesthesia). A subsequent Cost Benefit Analysis for improving deck officers' NTS is also carried out through the use of Bayesian Networks and Decision Tree Modelling.

1 INTRODUCTION

A review of maritime accidents' databases from the United Kingdom, the United States of America, Norway and Canada conducted by Barnett et al. in 2006 confirms that human error is the main contributing factor in maritime accidents. Barnett et al. illustrates that major maritime accidents are not caused by technical problems but by failure of the crew to respond to situations appropriately. Based on this assessment, it is now considered that a system for the training and assessment of the main non-technical skills (NTS) of co-operation, leadership and management skills, situation awareness and decision making, needs to be established in the maritime industry.

The shipping industry has become safer over the past two decades. This is evidenced by an improving safety record over the period (Hetherington et al., 2006). However, accidents are still occurring. Analysts and researchers have found many causes for these accidents, including: seafarer training and technical failure (MCA, 2010), fatigue (Akhtar and Utne, 2014), stress (Hetherington et al., 2006) and human error (Gill and Wahner, 2012). Technical failures and seafarer training have been addressed in detail in the STCW 95 (Standard of Training, Certification and Watchkeeping, 1995) and measures have impacted positively on the industry (MCA, 2010). Recently the IMO introduced the STCW Manila amendment 2010, part of which focuses on NTS training, in an attempt to eliminate or minimise the effects of human error.

1.1 *International Maritime Organisation (IMO).*

In the late 1950s and early 1960s, the IMO developed a comprehensive series of conventions to establish a framework of international law addressing maritime safety. In doing so the IMO recognized that one of the most important elements in the safe operation of any ship is the training and competence of its crew. However, it was noted that international regulations lacked a standard of competency for seafarers. As a result, in 1969, the IMO agreed to develop The International Convention on Standards of Training, Certification and Watchkeeping (STCW) (IAMU, 2010). The STCW sets qualification standards for masters, officers and watchkeeping personnel on seagoing merchant ships (Tally, 2012: p326).

1.1.1 *STCW 1978 and 1995*

The STCW was officially adopted by a conference of the IMO in 1978 to standardize the qualifications required for masters, officers and watch personnel on seagoing merchant ships. The 1978 STCW Convention had many limitations such as vague requirements left to the discretion of the parties; unclear standards of competence; no IMO oversight of compliance; limited port state control and inadequacies which did not address modern shipboard functions at that time (Tally, 2012: p326; MCA, 2013b). As a result of the grounding of the Aegean Sea in 1992 on the rocks of the Spanish port of La Coruna, the United States proposed conducting a comprehensive review of the 1978 convention (IAMU, 2010). This proposal suggested the review specifically consider the role of the human element in maritime casualties. The IMO and its members agreed to concentrate on areas relating to people, training and operational practices, rather than issues dealing primarily with improving ship construction and equipment standards (ibid).

The STCW Convention was significantly amended in 1995 to include a code containing mandatory requirements and guidance information for the implementation of the convention. The comprehensive and detailed 1995 amendments established a level playing field among all parties to the convention to help ensure consistent training worldwide. These amendments also established competence based standards that placed emphasis on the requirements for training and assessments of skills in most facets of the mariner's profession (IMO, 2015; IAMU, 2010).

1.1.2 *Manila Amendments*

In January 2006, during the 37th session of the STW (Standards of Training and Watchkeeping) Sub-Committee it was decided to review the STCW Convention to ensure that it met the new challenges facing the shipping industry at the time and in the years to come (Tally, 2012: p326). The new challenges being met included advancement in technology and the emergence of new equipment such as the Electronic Chart Display and Information System (ECDIS).

At its 38th session of the Sub-Committee, and following detailed discussions, it was agreed that the present structure of the convention more than adequately served its purpose and that there was no need to review it all in great detail. It was then agreed that the review should mainly cover the principles of human element training (IAMU, 2010):

Table 1 shows an abridged version of the STCW changes (IMO, 2011: p122). These were approved in relation to NTS training of management level officers of ships of 500 gross tonnage or more. Based on the outcomes outlined in Section A-II/2 of the STCW Manila amendments, the HELM training course became compulsory for all deck and engineering officers effective from 2012 (Davitt and Holford, 2015).

Table 1. Section A-II/2 – Masters and chief mates on ships of 500 gross tonnage or more (bridged version)

Competence	Use of leadership and managerial skills
1	Knowledge of shipboard personnel management and training
2	A knowledge of related international maritime conventions and recommendations, and national legislation
3	Ability to apply task and workload management
4	Knowledge and ability to apply effective resource management
5	Knowledge and ability to apply decision-making techniques
6	Development, implementation, and oversight of standard operating procedures

1.1.3 *HELM Training*

The IMO has now set minimum standards of NTS training by making HELM training compulsory for both operational and management level officers in the deck and engineering departments. This training can either be integrated into the main programme or delivered as a standalone course (MNTB, 2012). HELM (O) is the operational level course for which the required training time is 21 hours. HELM (M) is the management level course requiring a training time of 35 hours (MNTB, 2012).

In the UK, the Maritime and Coastguard Agency (MCA) and the Merchant Navy Training Board (MNTB) have implemented HELM training (MCA; 2013a). This takes the form of a stand-alone short course for experienced seafarers wishing to transfer to officer grade. Presently the same course is delivered to both deck and engineering officers. It has been suggested that this makes the task of delivering the training more difficult (Wall, 2015). The main reason for this is that the college phase (Higher National Diploma - HND) is compulsory for chief mate students. In this they will have studied some leadership and management issues. However, for second engineer students (not following the approved training programme) the college phase is not compulsory and they only have to attend for the written exams. These exams are mainly technical in nature and thus they do not have any prior knowledge of the subjects of leadership and management (Wall, 2015). Separate learning outcomes for both deck and engineering officers that are focused on their specific areas of operation may have been useful.

HELM training is currently in its infancy and it will take time for it to improve. The aviation industry took fifteen years to develop from the first generation of the Crew Resource Management (CRM) course to the sixth generation. In the process it helped to reduce the number of aviation accidents caused by human error (Diehl, 1991).

1.2 *NTS training and assessment developments in other safety critical domains.*

Some domains, such as aviation and anaesthesia, have conducted extensive research aimed at identifying domain specific NTS training methods and behavioural marker systems for use in their assessment. The Aviation industry is considered to be the pioneer in discovering the importance of NTS and researching and developing courses. These efforts have resulted in the evolution of a Crew Resource Management course to supplement the main training. It is important to consider the work performed in aviation and anaesthesia to develop NTS training and assessment. This will provide an insight in to whether the maritime industry could benefit from their efforts and adapt some of their best practices.

1.2.1 *Aviation*

The concept of NTS was generated by the aviation industry when the National Transportation Safety Board (NTSB) in the USA investigated a number of airline accidents in the 1960s and 1970s.

A workshop, entitled "Resource Management on the Flight Deck", sponsored by the National Aeronautics and Space Administration (NASA) was held in 1979. During this workshop elements of human error were identified in the majority of air crash accidents being considered. The main causes were found to be interpersonal communication, decision making and leadership failures. It was suggested that the training of NTS of pilots was required to reduce "pilot error" by making better use of the human resources on the flight deck. Since that time six generations of CRM training programmes have evolved in the United States (Helmreich et al., 1999).

The first CRM programme was proposed and developed by United Airlines in 1981. The course was called 'Command, Leadership and Resource Management' (Helmreich et al., 1999; Kanki et al., 2010: p27). In the second generation of the CRM training programme the name was changed to Crew Resource Management (CRM) and the course began to include team oriented factors. The new programmes focused on specific aviation concepts related to flight operations and were more team oriented in nature. The training conducted focused on team building, situation awareness and stress management (Helmreich et al., 1999; Kanki et al., 2010: p29).

In the early 1990s a new shape of CRM was introduced which integrated CRM with standard technical training. The idea was to focus on specific skills and behaviours that pilots could use to operate aircraft more effectively and in a safer manner. Many airlines introduced modules covering flight automation issues. At this stage CRM was also offered to other groups such as flight attendants and maintenance personnel. A special CRM was designed for captains to target leadership skills. (Helmreich et al., 1999).

The fifth generation of CRM focused on the fact that human errors are inevitable but the effects of those errors can be minimised by applying the three lines of defence. These three lines are: avoidance of error, the trapping of incipient errors before they are committed, and mitigating the consequences of those errors that occur and are not trapped (Helmreich et al., 1999).

Based on the fifth generation's error management theme, the focus of CRM training was widened from error management to include threat management. In previous generations CRM skills and methods were applied to eliminate, trap or mitigate errors but the sixth generation also focuses on the threats and errors which must be managed by flight crews to ensure a safe flight (Wagener and Ison, 2014).

The Federal Aviation Administration in the USA introduced the Advanced Qualification Program (AQP) in the 1990s and in the UK at the same time, the Civil Aviation Authority required the formal incorporation of non-technical skills evaluation into all levels of flight crew training (CAA, 2006).

A research project, JARTEL (Joint Aviation Regulation – Translation and Elaboration of Legislation), was initiated by the Joint Aviation Authorities (JAA) Human Factors group in 1996. Its goal was to develop a suitable method to identify and assess an individual pilot's non-technical (CRM) skills. The project was sponsored by four European CAAs (Civil Aviation Authority). A research consortium consisting of pilots and psychologists from Germany, France, Holland and the UK was established to work on the NOTECHS (Non-Technical Skills). The system was to be used to assess an individual pilot's skills. It was to be suitable for use across Europe on all flight routes and also had to accommodate all European cultures (Flin et al, 2003).

A review was conducted of the existing behaviour rating system for pilots already in use by larger airlines in Europe and the USA. It appeared that none of the systems could be adopted in their original form because the available systems were either unclear for a Pan-European basis, or specific to a particular airline. Therefore, it was decided by the project team that to assess pilots' NTS a new taxonomy and rating method would be designed (Flin et al, 2003).

The method that was developed included a detailed examination of available behavioural marker systems to assess a pilot's NTS. Airline captains with substantial experience worked as experts to advise on the final design of the NOTECHS system (Flin et al, 2003). The resulting NOTECHS system has four categories with the elements of behaviour shown in Table 2.

Table 2. NOTECHS Taxonomy (Flin et al., 2003)

Category	Element
Co-operation	Team-building and maintaining Considering others Supporting others Conflict solving
Leadership and Managerial Skills	Use of Authority and assertiveness Providing and maintaining standards Planning and co-ordination Work load management
Situation awareness	Awareness of aircraft systems Awareness of external environment Awareness of time
Decision Making	Problem definition and diagnosis Option generation Risk assessment and option selection Outcome review

The main JARTEL study was an experimental rating task study. Eight video recorded scenarios, filmed in a Boeing 757 simulator, were used. The scenarios simulated realistic flight situations highlighting behaviour relevant to NOTECHS. The pilots behaviour was rated ("poor practice" to "good practice"), using the NOTECHS system, by more than 100 assessors. A briefing and practice session was given before the start of each session. The assessors were asked to rate captains' and first officers' behaviours in each of the eight cockpit scenarios using the NOTECHS rating (O'Connor et al., 2002). In the subsequent evaluation questionnaire, the assessors were very satisfied with the NOTECHS rating system and the results of the experimental phase of this project were deemed satisfactory for the further development of the NOTECHS method (Flin et al., 2003).

1.2.2 *Anaesthesia*

It has been determined through critical incident reporting that NTS are the major cause of accidents in anaesthesia crisis management. To focus on this area the Anaesthetists' Non-Technical Skills (ANTS) tool was developed in 2005 for the training and assessment of anaesthetists NTS (Yee et al., 2005). The ANTS is a behavioural marker framework and was developed in a project between the University of Aberdeen Industrial Psychology Research Centre and the Scottish Clinical Simulation Centre (Matveeskii et al., 2008). The programme followed the concepts of CRM, which was developed to improve NTS of aviation personnel (Flin & Maran, 2004).

The Scottish Council for Postgraduate Medical and Dental Education partnered in a project to investigate the NTS in anaesthetists. The project was called 'The Identification and Measurement of Anaesthetists' Non-Technical Skills'. The main purpose of the project was to determine the importance of NTS required by anaesthetists during operations (ANTS, 2014).

At the start of the project researchers reviewed the human factors involved in anaesthesia. It was determined that 80% of anaesthetic incidents at the time were due to human error and most of them could have been avoided with the use of appropriate skills (Fletcher et al., 2003a).

Table 3. ANTS Taxonomy (Yee et al., 2005)

Category	Element
Task Management	Planning and preparing Prioritizing Providing and maintaining standards Identifying and utilizing resources
Team working	Coordinating activities with team member Exchanging information Using authority and assertiveness Assessing capabilities Supporting others
Situation awareness	Gathering information Recognizing and understanding Anticipating
Decision Making	Identifying options Balancing risks and selection options Re-evaluation

Incident reporting data was collected from around the world to analyse the extent of the problem. While collecting this data, limiting factors were considered. Chief among these was that, for a variety of reasons, not all incidents were reported. Also the reported factors did not always provide an accurate picture of the incident. As long as limitations in reporting exist are considered then there is great benefit to be found in analysing incident reports in the domain (Fletcher et al., 2003).

Through a series of interviews a taxonomy (Table 3) of anaesthetists' NTS (a prototype behavioural markers system) was developed for rating observed behaviours (Table 4) (Yee et al., 2005). In 2004, after the preliminary evaluation of the prototype behavioural markers system, the ANTS system was released to anaesthetists free of charge by the University of Aberdeen (Flin, 2013) and is now being used successfully across the world (Livingston, 2014). This system has now been translated into many languages and is being used in anaesthesia simulation training and assessment in countries around the world including the United Kingdom, United States of America, India and Canada (Bhagwant, 2012; Flin, 2013).

Table 4. ANTS Rating System (Yee et al., 2005)

Rating Level	Description
4 – Good	Performance was of a consistently high standard, enhancing patient safety. Could be used as positive example for others.
3 – Acceptable	Performance was of a satisfactory standard but could be improved.
2 – Marginal	Performance indicated cause for concern. Considerable improvement needed.
1 – Poor	Performance endangered or potentially endangered patient safety. Serious remediation is required.
Not observed	Skill could not be observed in this scenario.

1.2.3 *Maritime*

To better evaluate the role of NTS in shipboard operational safety, a thorough review of existing research is required to underpin the selection of criteria for use in identifying behavioural markers for the assessment of maritime NTS. Such research is limited in the maritime domain (Davitt and Holford, 2015) and mostly not initiated by any regulatory body but rather conducted by universities as part of PhD theses or published papers. The only notable research conducted by a regulatory body is the MCA's 'simulator training for handling escalating emergencies' in which it has recommended further definition of the main NTS to handle escalating emergencies (Habberley et al., 2001). The MCA also produced a guide in 2006 outlining best practices in leadership and management (Davitt and Holford, 2015) which was based on a piece of leadership research conducted by Arthur D Little (2004). Other notable research has been undertaken by Warsash Maritime Academy and the US Navy.

At Warsash Maritime Academy, after the success of the various efforts in other safety critical industries to develop behavioural markers for the assessment of NTS in simulators, Gatfield (2008) conducted extensive research and was first to develop a system of behavioural markers for the assessment of competence of marine engineering officers in maritime engine room simulators (Long, 2010). In this research a video recorded crisis scenario was developed which was run twelve times with three engineers in each run. The behavioural markers observed during the exercises were then rated against four filtration criteria: ease of observation, ease of evaluation, frequency of occurrence, and relevance to competence. Filtration was deemed necessary to keep the number of behaviour markers to a minimum so that the assessment process would be more manageable (Gatfield, 2008).

Two groups of assessors, one group of six marine engineers and another group of six non-domain crisis management assessment experts were selected to assess each marker on a four point rating scale (good, towards good, towards poor and poor). There was another group of seven expert crisis management assessors who were asked to use their 'gut' feeling to rank Chief Engineers in the scenario from best to worst crisis manager. It was concluded that the assessment framework was valid as there was a high degree of correlation between the findings of assessors in all groups (Gatfield, 2008).

The US Navy used a three stage methodology to develop domain specific behavioural markers for their Officer of the Deck (OOD) training course. The three stages were comprised of: literature review, focus group interview, and critical incident review. The literature review aimed to identify a list of NTS found in other safety critical domains that were assumed to be relevant to effective performance in a maritime environment (O'Connor and Long, 2011). This was necessary as it was found that very little research had been conducted in to NTS in the maritime domain (Heterington et al., 2006).

To develop an OOD NTS taxonomy, focus group interviews were conducted to filter the list down to only those skills which were applicable to the role of OOD (Table 5). To evaluate the validity of the developed taxonomy the critical scenarios were developed in the third stage. The scenarios were used to generate interview data for analysis (O'Connor and Long, 2011). The interviews conducted had four stages:

1. Interviewee explains a relevant incident
2. Interviewer repeats incident back to interviewee to confirm understanding
3. Interviewer expands the discussion on the incident and looks for the cues and factors affecting NTS
4. Interviewer probes further to extract more knowledge about NTS links.

A total of 149 interview statements were collected and independently classified. The inter-rater reliability of all the analysis was found to be higher than normal hence no further changes were made to the original taxonomy (Table 5) (O'Connor and Long, 2011).

Saeed and Riahi (2014) found that HELM training provided to senior deck officer students is in its early stages and is currently not very effective. In a study conducted at Liverpool John Moores University, they compared the NTS performance of two groups of chief mate students in a ship bridge simulator. One group with HELM training and the other without HELM training. The NTS performances were analysed by Evidential Reasoning and Utility Value to provide a crisp number of each performance. The performance of the group with HELM training was only 0.8% better than the group without HELM training (Saeed et al., 2016; Saeed and Riahi, 2014). Similar results were found through a survey conducted by the MCA in 2015 to evaluate the effectiveness of the HELM course. (MCA, 2015).

To improve NTS of deck officers some of proven methods of other safety critical industries can be adapted to the benefit of the maritime industry and a cost benefit analysis is conducted in this paper to analyse if the adapted methods are cost effective and beneficial to the industry.

Table 5. Initial OOD nontechnical taxonomy (Source: O'Connor and Long, 2011)

Category	Element
Leadership	Establishing authority Managing workload Maintaining the standards of the Watch
Decision Making	Defining problem Generating possible solution Implementing best solution
Situational awareness	Actively gathering information Responding to changes in information Anticipating future events
Communication	Selecting correct medium Sending information clearly and concisely Effectively receiving information
Managing stress	Maintaining concentration Coping with stressors

2 COST BENEFIT ANALYSIS AND OPTIONS

The purpose of this paper is to conduct cost benefit analysis of the improvements in the HELM training based on the best practices of the other safety critical industries. The methodology pursued to achieve this is divided into three steps:

1 The possibility of adapting successful methods found in other safety critical industries, such as aviation and anaesthesia, is explored and options are generated.
2 A cost benefit analysis is conducted of the most suitable options identified in step one. Analysis of these options is carried out by Bayesian Network and Decision Tree Modelling.
3 A decision is made on which option to select.

2.1 *Suggestions to Improve the HELM Course Based on Other Safety Critical Domains' NTS Research and Training Methods*

Based on the deck officers' NTS taxonomy, and behavioural markers for training and assessment an effective training model was developed. This was done by conducting a workshop to which educational and subject experts and psychologists were invited. The first task was to find out what would be the best mode of NTS training. It was ascertained that Aviation, anaesthetics and other safety critical industries use simulator based training of their personnel.

After some debate the workshop agreed that, based on the aviation and anaesthesia methods, the underpinning knowledge of NTS should be integrated into the main course. This should then be followed by extensive simulator training composed of carefully thought out exercises to be developed to cover each skill and element of the NTS. This method is then followed by CRM and research suggests that the course is quite effective (Diehl, 1991). The present approach, in the maritime sector, of delivering underpinning knowledge within five days of the course may not be very effective as it does not give enough time for students to study the NTS material. It is possible that if a module is introduced into the main course by teaching 3-4 hours every week, over 10-12 weeks, this would give an opportunity to students to absorb the underpinning knowledge more effectively. An exam at the end of the course would then test their NTS theoretical knowledge.

Presently, in the maritime industry, training institutes are responsible for conducting such training and the HELM training is offered only as one off course. In the aviation industry flight operators are responsible for conducting NTS training of flight crew and the course is repeated regularly.

In a similar way to aviation, shipping companies may need to develop NTS training specific to their own area of operations. The courses may be developed by focusing on different cargo operations such as oil, chemical, cargo, container and dry bulk. It would also need repeating regularly and a deck officer's NTS assessment would be conducted before repeating the course. This would help to identify the weak areas of each individual and the repeat course would then be able to focus on those areas to improve their performance. The whole process of the NTS training model needs evaluating for the purpose of analysing its effectiveness. However, the costs associated with the development of a new course and the evaluation of that course may be prohibitive.

2.2 *Cost Benefit Analysis*

Cost benefits are calculated using a Decision Tree Model which is based on Bayesian Networks.

2.2.1 *Interference Formulism of Bayesian Networks*

The basis of reasoning under uncertainty in Bayesian Networks (BNs) is known as Bayesian interference formulism. It was developed for the task of computing the probability of each value of a node in a BN when the values of other variables are known (Richardson, 1997). The element of uncertainty may be due to: imperfect understanding of the domain, incomplete knowledge of the state of the domain at the time when a given task is to be performed, randomness in the mechanism governing the behaviour of the domain, or a combination of these. One of the main advantages of BNs is that they allow alterations to be made based on observed evidence. An existing model can be updated in accordance with observations made in line with Bayes rule. For random variables "X_1" and "X_2", as shown in Figure 5.1, Bayes rule states:

$$P(X_1|X_2) = \frac{P(X_2|X_1)P(X_1)}{\sum_{all..i} P(X_2|X_1 = x_i)P(X_1 = x_i)} \quad (1)$$

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 observations. By applying Equation 4.1 to each state of "X_1" the probability distribution "$P(X_1 \mid X_2 = x_j)$" is computed:

$$P(X_1|X_2 = x_j) = \frac{P(X_2 = x_j|X_1)P(X_1)}{\sum_{all..i} P(X_2 = x_j|X_1 = x_i)P(X_1 = x_i)} \quad (2)$$

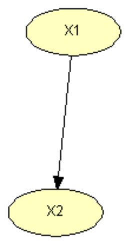

Figure 1. BN consisting of two nodes

2.2.2 *Decision Tree calculation*

BN decision trees are valuable techniques that are used to make a decision from a set of alternative options (Janssens et al., 2005). In a decision tree there are two types of nodes: decision nodes and leaves. Leaves are the terminal nodes of the tree and they specify the decisions to be made. The case is routed down the tree according to the values of attributes tested in successive decision nodes. When a leaf is reached, the options are classified according to the probability distribution over all classification possibilities (ibid).

The company has to take a decision whether to take action to improve their deck officers' performance, or not. The company is uncertain whether the performance of their deck officers (Deck Officers' Performance or DOP) is high, average or low. The cost of an action is C_1. It is believed by taking action and enhancing the performance of deck officers (with average performance) the reliability of the company's vessels will increase and as a result so will the associated profit and net profit. Profit and net profit can be estimated as B_1 and $B_1 - C_1$ respectively. Similarly for 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 (Audit) will help determine the company's performance (CP). The cost of an assessment programme (Audit) is C_2. Based on the performance data collected from deck officers (Saeed and Riahi, 2014), and the following rules:

- 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 experts' opinion the relationship between a company's performance and its employees is shown in Table 6.

Table 6. 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 (Equation 1) 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 2:

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

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

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

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

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

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

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

$$P(DOP=A|CP=L)=\frac{P(CP=L|DOP=A)\times P(DOP=A)}{P(CP=L)}$$
$$P(DOP=A|CP=L)=\frac{0.1x0.5}{0.4}=0.125$$

$$P(DOP=L|CP=L)=\frac{P(CP=L|DOP=L)\times P(DOP=L)}{P(CP=L)}$$
$$P(DOP=L|CP=L)=\frac{0.7\times 0.5}{0.4}=0.875 \quad (3)$$

A decision tree is a diagram that represents, in an organised manner, the decisions and the events that influence uncertainty. In addition, the possible outcomes of each of these decision and events are included. Figure 2 shows a decision tree representation and solution to this problem. In Figure 2, squares represent decisions and the lines coming out of each square show all available distinct options that can be selected at the point of decision. For instance, as shown in Figure 2, to perform an assessment programme (an audit) or not to perform one. Two lines come out of the relevant "audit square" to show both of the available options (Yes or No) that can be selected by the manager.

Circles show various circumstances that have uncertain outcomes and the lines coming out of each circle denote a possible outcome of that uncertainty. For instance, "circle R" shows the result of an assessment programme. The lines that come out of "circle R" denote possible outcomes of that uncertainty (a company's performance is high, average or low). The probability of each outcome is written on the respective line. Based on Figure 2, the manager can calculate the overall desirability of those choices. For instance, if a manager makes a decision to perform the audit and based on the audit's result the company's performance is found to be high, then the desirability for taking an action can be calculated as follows:

$$0\times(C_1+C_2)+0.5\times[B_1-(C_1+C_2)]+0.5\times[B_2-(C_1+C_2)]= \\ 0.5\times B_1+0.5\times B_2-(C1+C2) \quad (4)$$

If the assessment (evaluated by Equation 4) is lesser than "-C", then no action has to be taken. Thus:

$$0.5\times B_1+0.5\times B_2-(C_1+C_2)<(-C_2) \\ 0.5\times B_1+0.5\times B_2<C_1 \quad (5)$$

If the company makes a decision to perform the audit, 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 $C_1 > 0.5\,x\,B_1 + 0.5\,x\,B_2$, then take no action.
2 If a company's performance is average and $C_1 > 0.8\,x\,B_1 + 0.2\,x\,B_2$, then take no action.
3 If a company's performance is low and $C_1 > 0.125\,x\,B_1 + 0.875\,x\,B_2$, then take no action.

As an illustrative example, in 2011, the Costa Cruise Line owned 27 ships with revenues of 3.1 billion euros and 2.3 million guests (Costa Cruises, 2014). One of the Costa Cruise Line ships, Costa Concordia partially sank when it ran aground at Isola del Giglio on 13th January 2012 with the loss of 32 lives. The accident was mainly caused by human error (Lieto, 2014). After the salvage of Costa Concordia the total cost of the accident was estimated to be $800 million (£480 million) (NBC News, 2014).

For the purpose of the following calculations it is assumed that the £480 million loss was as a direct result of the deck officers' poor performance. For the company to address the loss it has to take action. After taking appropriate action, profit will become B_2 for a company having officers with low performance as explained earlier in this section. Assume B_2 = 2 x B_1. Thus:

$$B_1+B_2=£480m \\ B_2=2\times B_1 \\ B_1=£160m \\ B_2=£320m$$

The company may decide to improve the NTS of the deck officers by introducing further human element training. This decision needs evaluating based on the proposed methodology in this paper. If further training is to be introduced then this will require the development of an NTS training model and its implementation in a CRM style training cycle. The cost of evaluation of NTS taxonomy is estimated as £200,000. For 27 ships a company would have 216 deck officers. As a result the training cost of deck officers would be £216,000 (216 x £1000). Therefore, the total estimated cost of C_1 is £416,000.

The cost of an assessment programme (C_2) is estimated as £200,000. The assessment programme could be implemented by sending experts onboard ships to assess the performance of the deck officers in the real life such as a Line Operations Safety Audit (LOSA) program. During LOSA observation, an observer records and codes 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 (Pedigo et al., 2011).

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

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

$$0.1\times\{-0\times(C_1+C_2)+0.5\times[B_1-(C_1+C_2)]+0.5\times[B_2-(C_1+C_2)]\}+ \\ 0.5\times\{-0\times(C_1+C_2)+0.8\times[B_1-(C_1+C_2)]+0.2\times[B_2-(C_1+C_2)]\}+ \\ 0.4\{-0\times(C_1+C_2)+0.125\times[B_1-(C_1+C_2)]+0.875\times[B_2-(C_1+C_2)]\}= \\ £239,384,000 \quad (6)$$

Based on Figure 2, the expected profits associated with taking an action and not performing the assessment programme is calculated as:

$$0\,x(-C_1)+0.5(B_1-C_1)+0.5(B_2-C_1)= \\ 0.5\,B_1+0.5\,B_2-C_1=£239,584,000 \quad (7)$$

Based on Equations 6 and 7, 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 Figure 3, is illustrated. In Figure 3, squares represent decisions and diamonds (U_1 and U_2) represent utilities. The values for U_1 and U_2 are shown in Tables 7 and 8. In Figure 3, the expected profits associated with taking an action and performing the audit (yes) or not performing the audit (no) are estimated as £239.38m and £239.58m respectively.

Table 7. Values of U_1

Audit	Yes	No
U_1	-£200,000	0

Table 8. Values of U_2

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

2.3 *Options*

After conducting decision tree calculations now there are the following three options available;

1 Do not take any action and continue with existing HELM course / NTS training arrangements.
2 Follow the suggestions in section 3.2 to evaluate deck officers' NTS taxonomy and behavioural markers system, integrate the HELM theory into the main course and run HELM simulator training

at the end of the main course and implement an aviation style training cycle.

3 In addition to following the suggestions in section 3.2, an assessment programme is implemented.

By choosing option 1 the accidents will continue to happen, innocent seafarers will lose their lives. It is apparent from the decision tree calculations (Equations 6 - 7) that there is more benefit to the company by choosing option 2. This will involve implementing an aviation style training cycle, carrying out the evaluation of deck officers' NTS taxonomy and the behavioural marker system, integrating the HELM theory into the main course and running HELM simulator training at the end of the main course.

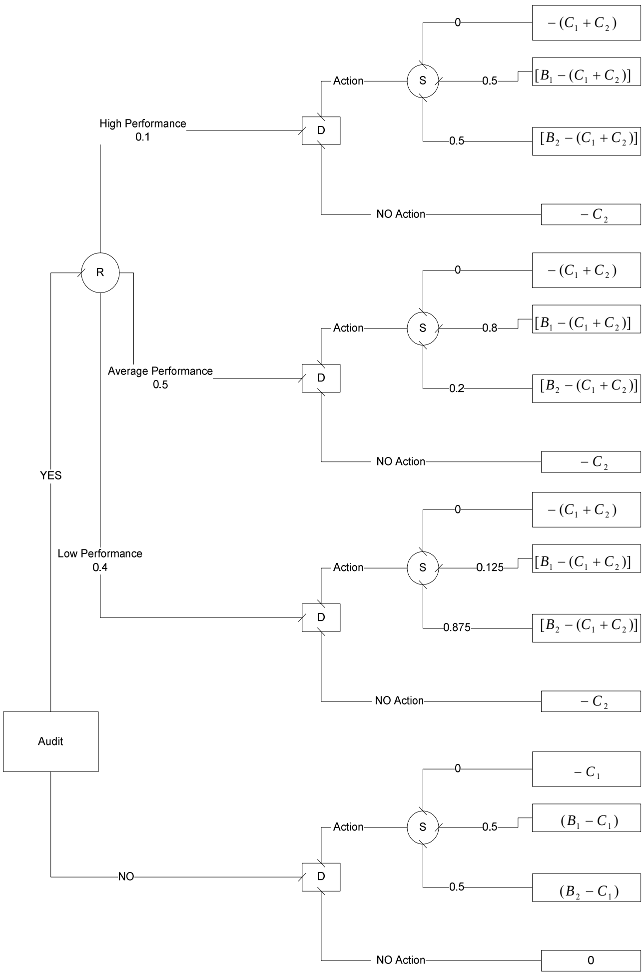

Figure 2: Decision Tree

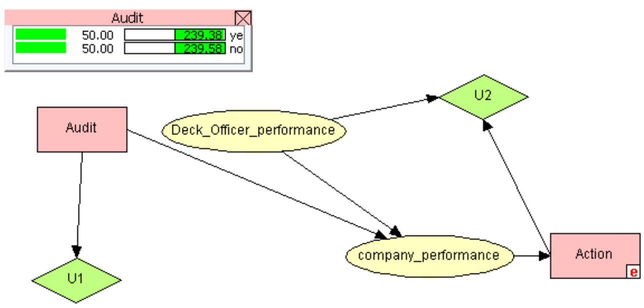

Figure 3. BN Decision Making Model for Measuring the Shipping Company's Profit

3 CONCLUSION

A comparison made between the maritime sector and other safety critical domains (aviation and anaesthesia) found that course development and delivery methods are different. In anaesthesia, the ANTS was developed by conducting extensive research. In aviation, underpinning knowledge of NTS is provided before the NTS course begins. In addition, the CRM course, which is mainly simulator based, is provided by operators and not a training college.

Based on the NTS courses delivered in other safety critical domains, a training model has been suggested for the maritime sector. The cost benefit analysis that was conducted in this paper, shows that there is long term benefit to be gained from applying this model to evaluate deck officers' NTS. The development of a suitable taxonomy and behavioural markers can then lead to the further integration of HELM training into the main course and the introduction of HELM simulator training at the end of the course. This will effectively mean the implementation of an aviation style training cycle. In this way the work done in other safety critical industries can be used to the advantage of the maritime industry. Successful methods adopted elsewhere can be adapted for inclusion in NTS training, such as the HELM course.

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