

Enhancement of Non-Technical Skills Training for Deck Officers

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IAMU sponsored study in 2013-14 “Development of taxonomy for deck officers’ non-technical skills (NTS) and analysing training needs for human element, leadership and management (HELM) course” concluded that present HELM course is ineffective for many reasons. One being there was no domain specific research conducted by the organisation before the implementation of HELM training course to develop the taxonomy of the deck officers’ non-technical skills and behavioural markers to train and assess such skills. Although such research is now available through the above mentioned study but there is lot of room of improvement. The comparison with other safety critical industries shows that more is needed to make non-technical skills training effective such as a change to training structure and shifting training responsibilities from nautical colleges to shipping companies and implementing an aviation style training cycle. To improve the HELM training it would require further research, more resources and more time to train the deck officers. This additional research, resources and time will put further cost to the maritime industry. In this paper author intends to conduct a cost analysis, by using ‘Decision Tree’ method, of developing a domain specific research to develop the taxonomy of the deck officers’ non-technical skills and behavioural markers used to train and assess the non-technical skills and also cost analysis of extended training to explore if there are any benefits of improving safety at sea.

Keywords: Deck officers, non-technical skills, HELM, NTS training, Decision Tree Model, Cost benefit analysis.

1. Introduction

One of the reasons that Human Element Leadership and Management (HELM) course is found to be not effective was due to the fact that IMO did not conduct enough or any research into domain specific non-technical skills, and the manner HELM training courses needs to be delivered and assessed. A thorough research needs to be carried into maritime domain specific human factors to identify deck officers’ non-technical skills and behaviour markers system to be developed for the training and assessments of the non-technical skills of the deck officers in a ship bridge simulator.

A workshop was conducted with students who have completed the HELM course as part of the Chief Mate course of study to give feedback on the course. Following are some of the remarks received from students;

- Simulation training is not sufficient; 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.

The question now arises is that how the HELM course or non-technical skills training be improved? First part of the question is which non-technical skills are required to be taught to the deck officers and to answer that taxonomy of the deck officers’ non-technical skills are developed (Table 1) as part of International Association of Maritime Universities (IAMU) research project 2013-2. The industries which have researched into non-technical skills have developed the skills taxonomy first then developed the training and assessment models. Anaesthetics non-technical skills research project

(Fletcher *et al.*, 2003) is quite impressive, which developed the taxonomy and the behavioural markers system for the anaesthetics first before implementing the NTS training.

1.1 Methodology

The methodology for this paper is divided into following three steps;

1. A comparison with other safety critical industries' efforts into non-technical skills research and training needs be conducted. Two main industries are looked into are aviation and anaesthetics. The possibility of the adoption of successful methods of aviation and anaesthesia will be explored.
2. A cost benefit analysis will be conducted of all the options explored in step 1. The analysis will be carried out by Decision Tree Model.
3. Based on the cost benefit analysis decision will be made for which option to select.

2.0 Comparison with other Safety Critical Industries' Efforts into Non-Technical Skills Research and Training (Step 1)

Many safety critical industries have conducted a thorough research into domain specific human elements before implementing training course. Anaesthetics, for example, conducted a study which took five years for six full time researchers before implementing a comprehensive and reliable nontechnical skills assessment tool called the Anaesthetists' Non-Technical Skills (ANTS) (Yee *et al.*, 2005). The project was divided into following seven work packages (Fletcher *et al.*, 2003);

1. Review of Human Factors Research in Anaesthesia. Report written by G. Fletcher, R. Flin and P. McGeorge (1999 – 2003).
2. Review of Behavioural Marker Systems in Anaesthesia. Report written by G. Fletcher, R. Flin and P. McGeorge (2000 – 2003).
3. Interview study to Identify Anaesthetists' Non-Technical Skills. Report written by G. Fletcher, R. Flin and P. McGeorge (2001 – 2003).
4. Review of Incident Data - Confidential
5. Development of a Prototype Behavioural Marker System for Anaesthetista' Non-Technical Skills (ANTS). Report written by G. Fletcher, R. Flin, P. McGeorge, R. Glavin, N. Maran and R. Patey (2001 – 2003).
6. Preliminary Evaluation of the Prototype Behavioural Marker System for Anaesthetists' Non-Technical Skills (ANTS). Report written by G. Fletcher, R. Flin and P. McGeorge (2000 – 2003).
7. Experimental Report. Report written by G. Fletcher, R. Flin, P. McGeorge, R. Glavin, N. Maran and R. Patey (2002 – 2003).

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

2.1. Adaption of Anaesthetics' Non-Technical Skills Taxonomy

Based on the proven method used by Anaesthetics, a similar research is performed in the IAMU research project 2013-2 to develop domain specific non-technical skills by developing the following;

1. Review of Human Factors Research in maritime industry.
2. Review of Behavioural Marker Systems in maritime industry.
3. Interview study to Identify Deck Officers' Non-Technical Skills.

4. Review of Incident Data
5. Development of a Prototype Taxonomy and Behavioural Marker System for Deck Officers' Non-Technical Skills.

In the project above areas are covered such as taxonomy of deck officers' non-technical skills (Table 1) and a detailed behavioural markers system for the assessment of deck officers' non-technical skills.

Table 1: Non-technical skills taxonomy of deck officers

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

2.2 Developing non-technical skills training model

The non-technical skills taxonomy (Table 1) has been developed in the research conducted by Liverpool John Moores University (LJMU) as part of International Association of Maritime Universities (IAMU) project (2013-2) and it was found that there is a need to develop the training model of training the deck officers' non-technical skills. A workshop needs to be organised where educational and subject experts and psychologists are to be invited. First task will be to find out what would be the best mode of training such skills. Aviation, anaesthetics and other safety critical industry uses simulator based training to train the non-technical skills.

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. An idea may be underpinning knowledge of non-technical skills is integrated into the main course and then extensive simulator training conducted at the end with 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. If a module is introduced into the main course by teaching 3-4 hours every week over 10-12 weeks will give opportunity to students to absorb the knowledge slowly and then the exam in the end will test their knowledge. Once students have completed the non-technical skills module then they will be introduced to non-technical skills simulator exercises where they will learn the practical aspects of non-technical skills.

2.3 Adapting CRM training Model

To adapt CRM training model it is necessary to draw training objectives based on CRM training (CAA, 2006):

- a. To enhance crew and management awareness of human factors which could cause or exacerbate incidents which affect the safe conduct of ship operations.
- b. 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.
- c. 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, so as to prevent the onset of incidents and potential accidents.
- d. To use these skills to integrate commercially efficient ship operations with safety.
- e. To improve the working environment for crews and all those associated with ship operations.
- f. To enhance the prevention and management of crew error.

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. The theory should concentrate on developing an understanding on the non-technical skills concepts and any reference to the theory of human performance and limitation should be backed up by practical examples in shipping industry.

In maritime industry presently training institutes seem responsible for conducting such training and , in UK, the HELM course is a one off training only. In aviation this responsibility is given to operators. The CRM course is repeated every three years, or when individual changes aircraft or company. When course is repeated it is not religious cycling of the knowledge. It is rather focused on the weak areas within individual or the company (CAA, 2006). 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 HELM course specific to the company.

Measurement of learning can be divided into following two categories:

1. Those assessing knowledge required
2. Those assessing attitude or attitude change.

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 (CAA, 2006);

- *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.*

Acquisition of knowledge has limited effect on a person as one can be knowledgeable about a subject but not agree to adopt its principles in practice. Attitude measures are probably more useful as indicators of whether HELM training likely to be effective in particular there are if they are measures of attitude change prior to and after HELM training.

3. Decision Tree calculation (Step 2)

The improvement in the deck officers' non-technical skills will improve a shipping company's performance and hence will improve the profits. 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 (ie 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 non-technical skills observations (Table 2) conducted in the IAMU project 2013-2, that 0%, 50% and 50% of the company's 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 3.

Table 2: Non-technical skills performance data

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

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.

Table 3: Conditional probability table

CP \ DOP	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;

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

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

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

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

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

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

And;

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

$$P(DOP = L | CP = L) = \frac{0.7 \times 0.5}{0.4} = 0.875 \quad (1)$$

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. Figures 1 shows a decision tree representation and solution to this problem. In Figure 1, 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 Figure 1, 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 Figure 1, 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 figure 1, 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 Equation 1 the probability of each outcome is written on each respective line. Based on Figure 1, 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:

$$0 \times (C_1 + C_2) + 0.5 \times [B_1 - (C_1 + C_2)] + 0.5 \times [B_2 - (C_1 + C_2)]$$

$$= 0.5 \times B_1 + 0.5 \times B_2 - (C_1 + C_2) \quad (2)$$

If the assessment (i.e. evaluated by Equation 5.4) is lesser than “-C”, then no action has to be taken. Thus:

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

$$0.5 \times B_1 + 0.5 \times B_2 < C_1 \quad (3)$$

If the company makes a decision to perform the audit, with similar techniques Equations 2 and 3 are evaluated, 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 and 2.3 million guest in year 2011 (Costa Cruise website, 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 loss of 32 lives. The accident mainly caused by human error (Lieto, 2014). After salvage of Costa Concordia the total cost of accident is estimated to be \$800 million (£480 million) (NBC News, 2014).

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:

$$\begin{aligned}
B_1 + B_2 &= \text{£}480\text{m} \\
B_2 &= 2 \times B_1 \\
B_1 &= \text{£}160\text{m} \\
B_2 &= \text{£}320\text{m}
\end{aligned}$$

The company may decide to improve the non-technical skills of the deck officers by introducing further Human Element training. This needs evaluation based on the proposed methodology in the research, developing non-technical skills training model and implementing CRM style training cycle. 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 x £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 onboard ships to assess the performance of the deck officers in the real life 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 (Pedigo *et al.*, 2011).

1. $\text{£}416,000 > 0.5 \times 160\text{m} + 0.5 \times 320\text{m}$
 $\text{£}416,000 > \text{£}240\text{m} = \text{Condition not satisfied}$
2. $\text{£}416,000 > 0.8 \times 160\text{m} + 0.2 \times 320\text{m}$
 $\text{£}416,000 > \text{£}192\text{m} = \text{Condition not satisfied}$
3. $\text{£}416,000 > 0.125 \times 160\text{m} + 0.875 \times 320\text{m}$
 $\text{£}416,000 > \text{£}300\text{m} = \text{Condition not satisfied}$

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

$$\begin{aligned}
&0.1 \times \{-0 \times (C_1 + C_2) + 0.5 \times [B_1 - (C_1 + C_2)] + 0.5 \times [B_2 - (C_1 + C_2)]\} + \\
&0.5 \times \{-0 \times (C_1 + C_2) + 0.8 \times [B_1 - (C_1 + C_2)] + 0.2 \times [B_2 - (C_1 + C_2)]\} + \\
&0.4 \{-0 \times (C_1 + C_2) + 0.125 \times [B_1 - (C_1 + C_2)] + 0.875 \times [B_2 - (C_1 + C_2)]\} = \\
&= \text{£}239,384,000
\end{aligned} \tag{4}$$

Based on Figure 1, the expected profits associated with taking an action and not performing the assessment programme is calculated as:

$$\begin{aligned}
&0 \times (-C_1) + 0.5 (B_1 - C_1) + 0.5 (B_2 - C_1) = \\
&0.5 B_1 + 0.5 B_2 - C_1 = \text{£}239,584,000
\end{aligned} \tag{5}$$

Based on Equations 4 and 5, the optimal strategy is to take an action immediately.

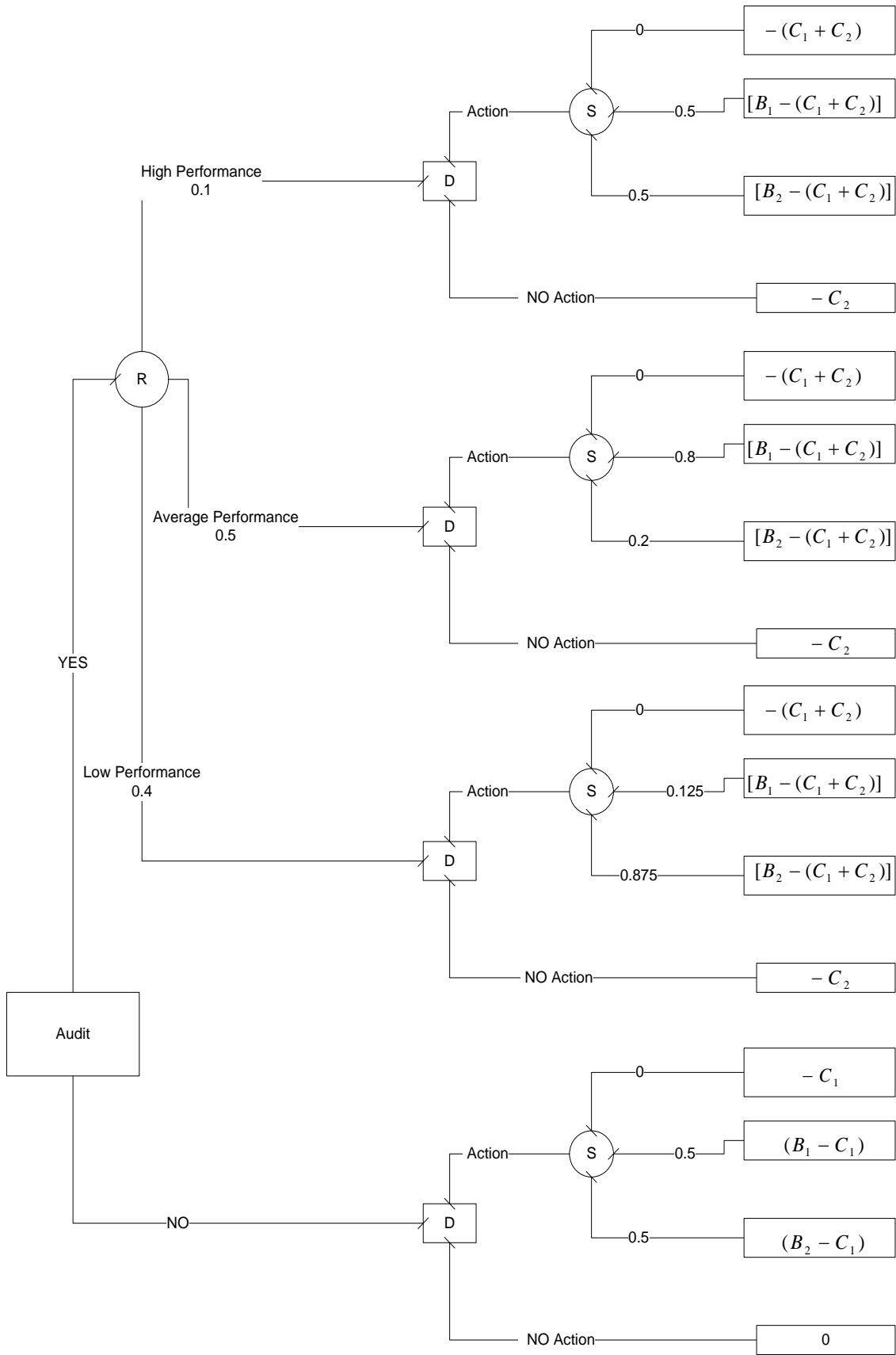


Figure 1: Decision Tree

5.6 Options (step 3)

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

1. Do not take any action and continue with existing HELM course arrangements.
2. Follow the suggestions in section 2 to evaluate deck officers' non-technical skills taxonomy and behavioural markers system, integrate the HELM theory into main course and run HELM simulator training at the end of the main course and implement aviation style training cycle.
3. In addition to following the suggestions in section 2, an assessment programme is implemented.

By choosing option 1 the accidents will continue to happen, innocent seafarers will lose their lives and industry will bear the cost of \$541m per year caused by the human error (P&I, 2014). As it is apparent from the decision tree calculations that there is more profit to the company by just carrying out the evaluation of deck officers' non-technical skills taxonomy and behavioural markers system, integrate the HELM theory into main course and run HELM simulator training at the end of the main course and implement aviation style training cycle and do not run the assessment programme.

It can be concluded from the decision tree calculations that option 2 is the most profitable and feasible option to choose at this stage.

5.7 Conclusion

After the study conducted by LJMU as part of IAMU project (2013-2) it was concluded that HELM course is not very effective. It was discussed here reasons why HELM course is not very effective by comparing other safety critical industries practices. It was explored in this paper that what other safety critical industries have done in this area such as Anaesthetics and Aviation and how their proven methods can be adapted for maritime domain. The anaesthetics proven research method can be adopted to develop the deck officers' non-technical skills taxonomy and behavioural markers systems for the training assessment. It was also suggested that a HELM training model need to be developed. Aviation style training implementation will help improving the HELM training in the maritime domain. To improve the HELM training it would require further research, more resources and more time to train the deck officers. The cost of this additional research, resources and time was calculated by choosing an example shipping company. A cost analysis carried out by decision tree method to work out if there are any benefits of applying such methods to improve HELM training to the industry. The results of cost analysis have shown that there is a benefit to the industry by carrying out further research and implementing further training.

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