Prediction of the Potential Human Errors Probability of Critical Safety Tasks

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Abstract

Safety operations onboard ships and onshore terminals in hazardous processes required the human element to be aware of the operational risks. Since the concept of human error has exposed ample arguments. An overview of the human element's failure is essential because the major provenance of accidents is human errors even there are many conventions and codes to reduce the petition errors. Human Reliability Assessment (HRA) techniques is a theoretical framework to assess human actions for predicting the potential human error probability (probability of failure) of a certain given task or operations' scenario. Accordingly, surveillance of the human performance through an operation "task steps and sub-steps" is vital. The Cognitive Reliability and Error Analysis Method (CREAM) tool is the second generation of HRA which offers a practical approach to both performance analysis and error prediction. CREAM essentially deals with the difficulties of human attention during an action control in the context of human organizational and technological issues under the impact of cognition (competence).

This paper reveals the importance of predicting human errors for keeping lives, by applying the HRA CREAM tool to critical safety tasks onboard ships (lifeboat drilling process). In addition to introducing a newly developed software based on CREAM tool "prospective phase" for monitoring the human performance during the task steps and sub-steps to enhance and expect the human failure points during the process by collecting the expert's opinions and utilizing the software then acquires the process quantitative and qualitative results.

Keywords: HRA – CREAM – CPCs – HEP.

1- Introduction

Seas play a crucial role in dominating history, registering both the destiny of nations as well as the societies in the world’s most populated and economically vibrant regions. Thus the significance of the seas in the development of societies and economies of regions is immense. Seas also acted as a duct for several events that dramatically altered the socio-economic development in several regions throughout history.

The shipping industry system is four times riskier than air transport causing. Over the last four decades, the shipping industry has focused on developing ship structure and the dependability of ship systems in order to decrease the rate of accidents and increase proficiency and productivity. Human elements are contributing in all life times of most technical systems, from design, construction, operation, management, conservation, and system upgrade. Humans have a tendency to make mistakes and it is repeatedly said: “to err is human" (French et al, 2009).

It is obvious that accidents and shipping causalities have been strongly influenced by human errors, as either unintentional or intentional breaking of the rules that have the potential to lead to catastrophic failures. The International Maritime Organization (IMO) has a glorious role in reducing human errors. This occurs by implementing the International Safety Management (ISM) code, and its required procedures, Standard Training, Certification and Watchkeeping (STCW) convention, and other related conventions. Conversely, the annual Overview of Marine Casualties, incidents by European Maritime Safety agency (EMSA), and the statistics of the International Union of Marine Insurance (IUMI) revealed that there are sever maritime casualties, still occurring, that causes loss of lives and properties.

Since the human factor is one of the main concerns of total safety standards, the HRA could be applied to improve an inclusive understanding of human action in context as required in the shipping industry domain. Moreover, it is the way to recognize how reliable the operator to achieve a given action without failure and estimate the probability of human errors for a certain task or operation. Applying the HRA is considered a sophisticated tool to minimize human errors particularly for a maritime high-risk, critical, operation that evolves causalities, pollution, and loss of lives (Rashed, 2019).

As it is necessary to account for reliability in relation to cognition rather than manual action. Some extent may be reasonable to describe the likelihood that a manual operation will succeed or fail in the same way that a first-generation HRA does.

CREAM is what so-called second-generation human reliability tool that offers a practical approach to both act analysis and error prediction. In this tool, human error is not considered to be arbitrary but formed by different issues such as the context of the task, "physical/psychological situation of the human operation and time of day".

This paper reveals the fundamental of the CREAM tool, propose a model based on CREAM, created software, and apply the model on an example of critical safety operation task utilizing qualitative method (Delphi Method) in collecting the expert opinion for both versions of the CREAM tool.

2- Background

CREAM is initially established from the Cognitive Control Model (CoCoM), and offers an applied approach to both performance assessment and error likelihood. Moreover, it is used as retrospective and prospective assessment method and it distinguishes between actions (Phenotype) and possible causes (Genotype) (Hollnagel, 2005).

HRA tool CREAM has been developed by Hollnagel (1998). It represents a second-generation HRA tools with developed applicability and accuracy compared to most of the first generation tools. HRA was comprehensively studied in recent years by many researchers. Hollnagel et al. (2004) have defined the development of the basic screening version in CREAM, whereby a rating of the performance circumstances can be used to calculate a Mean Failure Rate directly without appealing the concept of human error. The method is to derive the failure probability directly from a description of the context in the form of Common Performance Conditions (CPC).

Yoshimura et al. (2014) introduced research that used CREAM, a retrospective phase to clarify how ample the influence conditions have on the human acts and the dependencies between CPCs, even these conditions change across domains, the CPCs will apply differently to domains other than the nuclear industry.

The authors compared the nuclear industry and the maritime industry, there are significant differences in the influence the work environment has on behaviour and human performance. Therefore, the dependencies between CPCs and priority are now evaluated according to the expert judgment of each domain and questionnaire survey for the Officers of the Watch (OOWs), including OOWs on training ships in cooperation with the National Institute for Sea Training, Japan.

De Felice et al. (2013) presented modeling application for the CREAM tool which is a very promising tools in order to manage the "human factors" in production process; considering that most of the production processes are made by the combination of man and machine.

On the other hand, Jianxing et al, 2014 presented in their paper CREAM tool taken into account the characteristics of shipping operations and introduced weight analysis of modified CPCs that suitable for shipping operation then developed quantitative model based on CREAM tool and apply it to case study of analyzing the human reliability of the crew on board of an ocean going dry bulk carrier.

Akyuz et al. (2015) introduced in two studies application of the mentioned HRA tool for a type of maritime operations. The basic and extended versions of HRA CREAM tool, furthermore, Akyuz et al, (2015) answered the question "why used CREAM?" The results of the study showed the real performance reliability.

However, the used CREAM was in a narrow sector in addition to applied the tool to only single operation, and the authors did not created modifications for the use of the tool to reduce the time of applying it. While, Shuen- Tai Ung (2015) illustrated a new CREAM tool utilizing Fuzzy logic and introduced a modified framework capable to resolve difficulties based on under the classification of rule-based approaches of traditional way.

Shuen (2015) presented new adaptive model for using CREAM by fuzzy logic for dealing with human failures on board vessels where technological, environmental and social factors are emerged. The usage of CREAM in maritime domain is still disclosed and weaken the applicability of such an approach. The results acquired are consistent with the principles evolved from the axioms since the outcomes are sensitive to the minor alterations of input data and weights.

In addition to the proving that CREAM tool is capable to produce reliable risk outcomes once applied in different fields in which the probability intervals may vary due to its flexibility, it seems promising that the CREAM tool can be applied to other industries with confidence.

Akyuz and Celik (2015) used the results of De Felice et al, (2013) and Jianxing et al, (2014) then introduced a research of a very critical, potential hazards operation “loading Liquefied Petroleum Gases (LPG) tanker” during these process stages, human reliability (operation without failure) plays a crucial role in maintainable transportation of such type of cargo.

Sana et al. (2017) introduced CREAM as one of the second-generation HRA tools used to evaluate human reliability; they illustrated how it has a strong, detailed theoretical background that focuses on the important cognitive features of human behavior. The study revealed the significance of CPCs, woke environment, and the time available for work were among the most important factors that reduced occupational performance.

Zhou et al (2017) presented risk assessment study of spill accidents of LNG carriers handling operation based on fault tree assessment and CREAM HRA tool taking into account various uncertainties caused by lack of data in human reliability quantification.

Hogenboom (2018) presented a comparison research of human reliability analysis methods.

Zhou et al (2018) proposed a quantitative HRA model based on fuzzy logic theory, Bayesian network, and CREAM for the tanker shipping industry. The CPCs in conventional CREAM approach are custom-modified to better capture the salient aspects of the situations and conditions for on-board tanker work. Human Error Probability (HEP) is obtained from memberships of the control modes and the results of Bayesian network reasoning.

Rashed (2019) proposed a model based on CREAM used for predicting HEP in shipboard a safety critical operation utilizing a created software.

3- The Concept of CREAM Tool

CREAM inspects the environmental context in which humans operate and evaluate actions utilizing a difference between competence and control (competence discusses what a person can do, while control refers to how competence is applied). There are two versions of CREAM to calculate human error probability basic version and extended version. Basic version offers a primary screening of human error, to realize the probability of error. While extended version uses the outcomes of basic version to obtain the detailed value of the probability of error. CREAM introduced nine CPCs.

CPCs constructed the basis of identifying the condition of likely performance. The features of the different conditions were revealed by four control modes (Scrambled, Opportunistic, Tactical, and Strategic).

The assessors use to find out the score of CPCs for a certain task by counting the number of reduce, not significant, and improve performance reliability which is stated by

$$\sum_{\text{reduce}},\ \sum_{\text{not significant}},\ \text{and}\ \sum_{\text{improve}}.$$

The Context Influence Index (CII) which is equal to $\sum_{\text{reduce minus}} \sum_{\text{improv}}$e of CPCs scores

$$\text{CII} = \sum_{\textbf{reduce}} - \sum_{\textbf{improve}} \quad \text{(Akyuz, 2015).}$$

The values of CII indicate the control modes through using table (1),and graphically Fig(1), if the score of CPCs is not significant, i.e. there is no effect upon human performance reliability, so it can be discounted and ignored.

Table (1) CREAM Control Modes and its values

Control modes	HEP Interval	CII values	Control modes descriptions
Strategic	0.00005< HEP<0.01	-7 to -4	The strategic mode provides a more efficient and robust act and may consequently seem the ideal to strive for.
Tactical	0.001 < HEP < 0.1	-3 to 1	Performance typically follows planned procedures while some definite deviations are probable.
Opportunistic	0.01 < HEP< 0.5	2 to 5	The person does very little planning or anticipation, perhaps because the context is not clearly understood or because time is too constrained.
Scrambled	0.1 < HEP < 1.0	6 to 9	In scrambled control the choice of next action is in practice irregular or arbitrary. Scrambled control illustrates a situation where there is slight or no thinking involved in selecting what to do.

Source: NASA, 2006 & Akyuz, 2015

3.1- CREAM Basic Version

The CREAM tool basic version is utilized to evaluate the overall human acts reliability. Its outcome is a generic appraisal of CPCs probability for the whole task, this result is used in the extended version estimation, if the probability of error is not accepted, to take a closer look at the parts of the task that should be inspected more specifically, in order to provide a probabilistic estimation. The basic version of CREAM divided to three main steps:

- Identify the task
- CPCs Evaluation
- Find the control mode error interval determination

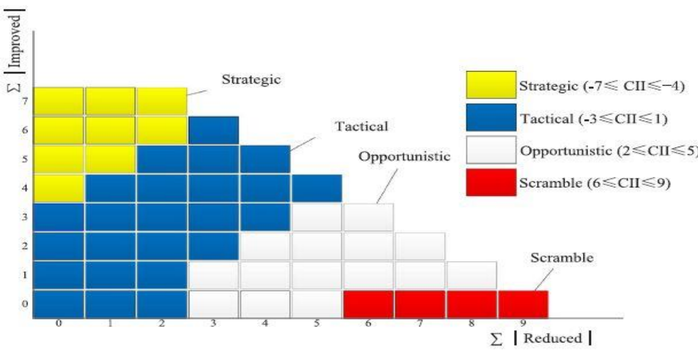

Fig (1) The relationship of each CPC and COCOM.
Source: (Xuhong et al, 2008) (Rashed, 2016)

3.2- CREAM Extended Version

The extended version of CREAM recognizes Error Modes of the four cognitive functions (observation, interpretation, planning, and execution). Extended version of CREAM is essential in cases where the general action probability of the basic method is unacceptably or when the uncertainty is large and intolerable (Hollnagel, 1998).

In the extended version, the task requires to divided the Task into sub-tasks or sub-steps each sub-step can be matched to one of fifteen pre-specified cognitive activities and identify Cognitive Failure Probability (CFP) type for each sub-task, then use the following equation to quantify it.

$$\mathbf{CII} = \sum_{i=1}^{9} \mathbf{PII} \text{---------------------------(1)}$$

PII of CPCs, which must have adjusted by expert judgement,

$$\mathbf{CFP} = \mathbf{CFP_0} \times \mathbf{10}^{\mathbf{0.26.CII}} \text{--------------(2) (Akyuz, 2015)}$$

The extended version contains the following steps:

- **Cognitive Profile Construction**: Finding the values of Performance Influence Index PII, then construct a table include the CPCs and the values of PII for each main step of the task count on the results of Basic Version before utilizing equation (1)
- **Finding Human Error Probability:** Identify the cognitive activities, generic failures type related to the cognitive functions, which selected from a list of failures, CII for each main step of the task has been found, so using equation (2) using nominal CFP_0 to find the adjusted CFP. The main purpose of this step is to state the Cognitive Profile considering the dependences between cognitive activities and Contextual Control Model (COCOM) (De Felice et al, 2013).
- **Finding HEP:** It will be beneficial to construct a table collect the assessment task's sub-steps elements (sub-step – cognitive activity – cognitive function – generic failure type – nominal CFP or CFP_0 – $CFP_{adjusted}$) of the extended version. To use the tool, it is essential to follow the proposed diagram illustrated in Fig. (2) box diagram

4- CREAM MHEP Assessor Software.

To use the CREAM HRA tool with the explained procedures framework (model) it takes a long time and exerted effort to assess operation task for estimating HEPs for decision making. Therefore, it is essential to create a software as an assistance in prediction of HEPs, and to ease the procedures in practical usage.

CREAM MHEP Assessor Software is built using programing code "Node.js" and modules directly from browser and also use web technologies, rapid prototyping solution for user interface design. Node.js is a framework for building desktop applications with HTML, and JavaScript. The CREAM supporting software tool is based on CREAM HRA tool "prospective phase" with CPCs suitable for shipping industry domains. It contains the basic version and extended version of CREAM tool.

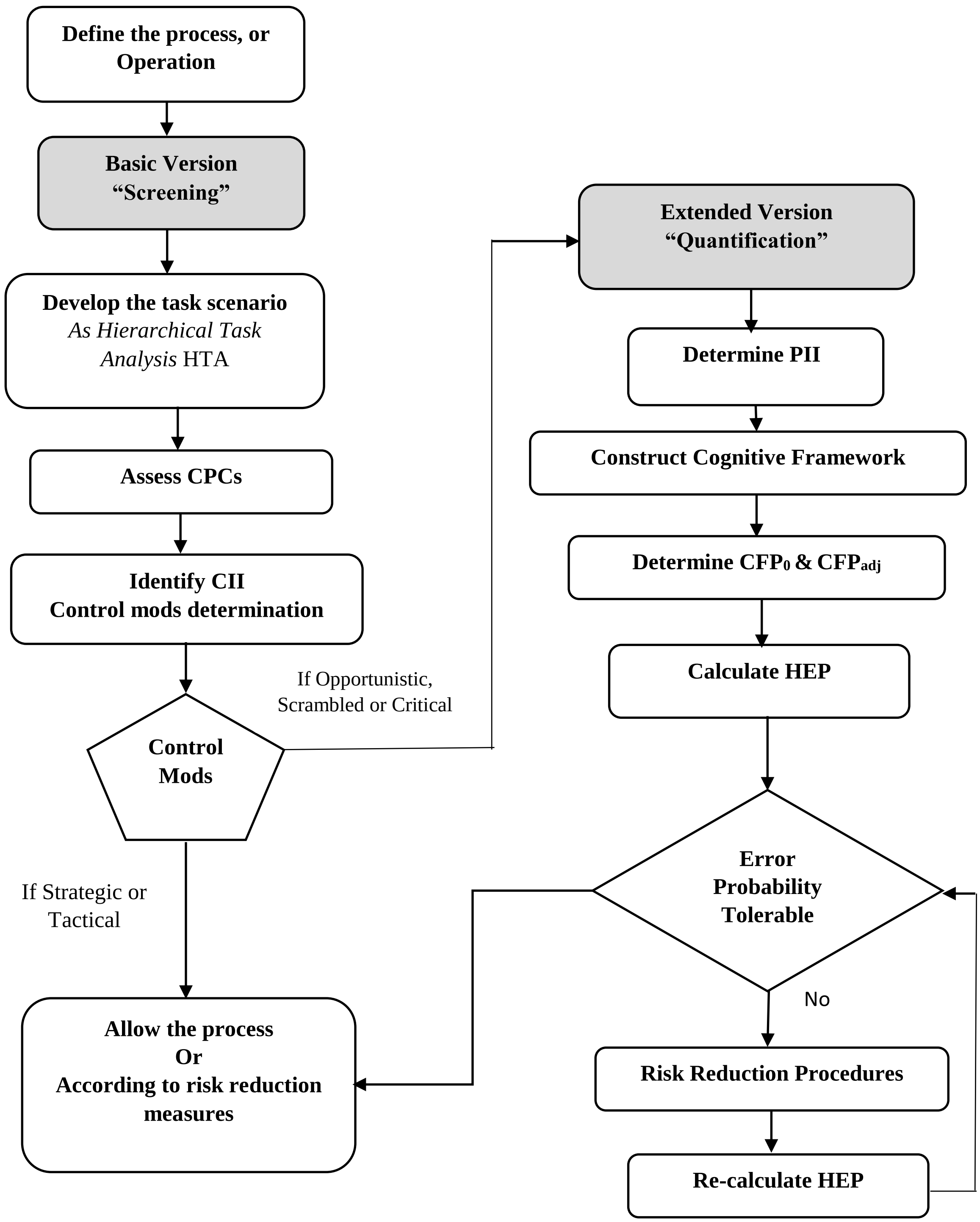

Fig (2) CREAM tool model

Source: Rashed (2019)

4.1- The Limitation of the MHEP Software

The CREAM MHEP Software is designed mainly to utilize with shipping industry domain working environment particularly safety and ship board critical operations, if required to use with another domain it needs a further re-adjustment.

5- Application Based on CREAM Tool Utilizing MHEP Software.

5.1- Lifeboat Drilling Task

Ship crew members training for abandon ship using life boats attached to gravity davits, and lowering the boat for a specific job under normal circumstances and good weather condition which changed to moderate with light swell when recovering the boat on day time drill. Table (2) contains accidents with significant impact of life boat fall during routine drill which have results of severe injury or loss of lives.

Table (2) Life boats drill accidents

Ship Name	Ship Type	Ship Flag	Accident Causes	Accident Date	Result
Harmony of the sea	Passengers	Bahamas,	Recovery of lifeboat During boat drill	Sep 2016	1 died
Norwegian Breakaway	Passengers	Bahamas,	Recovery of lifeboat Routine rescue drill	July 2016	1 died 3 injured
Nagato	Reefer	Panama	Life boat Recovery Abandon ship drill	Apr 2014	1 injured
Thomson Majesty	Passengers	Panama	Recovery of lifeboat During boat drill	Feb 2013	5 died
Saga Sapphire	Passengers	Malta	Recovery of lifeboat During lifeboat drill	March 2012	2 injured
Tombarra	RO-RO Car Carrier,	UK	Rescue Boat Recovery Fall. Stop of electronic proximity switch during monthly regular launching drill	Feb 2011	1 died
Velox	General Cargo	Isle of Man (UK)	Boat Fall During regular launching drill	Sep 2009	2 injured
Stena Britannica	RO-RO Passengers	UK	Life boat Recovery Abandon ship drill	May 2007	1 injured
St. Rognvald	Dry cargo	UK	Recovery of lifeboat.	Oct 2003	5 injured

Source : MAIB (2018)

Table (2) also reveals the significance of the operation task, even with different type of vessels and different flags. The task is prepared according to Hierarchical Tasks Analysis (HTA).

The Task Main Steps and Sub-steps in (HTA)

AS1 Prepare to abandon ship

1.1 Switch on the alarm.
1.2 Start announcement for abandon ship.
1.3 Report the situation to the crew.

AS2 Gathering at muster station.

2.1 Check that all crew gathered at muster station.
2.2 Check that all crew put on lifejackets correctly.
2.3 Announce a short brief all to crew for abandon ship procedures.
2.4 Confirm that crew fully understand the procedures.

AS3 Launch the Lifeboat.

3.1 Start the boat engine, close the drain plug, and put the boat ruder to the seaside.
3.2 Check that the painter is rigged in a correct manner.
3.3 Check that the harbor pins are out.
3.4 The gripes should be slipped and any triggers checked to see that they are clear.
3.5 Winch man lowers the boat down to the embarkation deck.
3.6 Check that the over side is clear, then lower away by lifting the brake handle.
3.7 The bowsing in tackles should be rigged in such a manner that the downhaul is secured in the boat.
3.8 The two men in the boat slip the tricing pendants once both ends of the boat are securely bowsed in.
3.9 Embark the Crew, and seated as low as possible in the boat.
3.10 Ease out on the bowsing in tackles to allow the boat to come away from the ship's side.
3.11 Let go the tackles from inside the boat and throw them clear.
3.12 Winch man lower the boat with a run.
3.13 Release the boat from the lifting hooks and clear the ship.

AS4 Boat Recovery.

4.1 Secure a wire pendant to an accessible point on the davit arms.
4.2 Take extreme care to ensure that the strop and the wire Pendant with any shackles used, are of sufficient strength.
4.3 Put nylon strop on lifting hook of the boat.
4.4 Retrieve the boat falls at deck level and nylon rope strops shackled to the linkage from the floating blocks.
4.5 Fit both nylon strops over the lifting hooks, fore and aft in the boat.
4.6 Hoist the boat clear of the water until the floating blocks are 'block on block' with the davit head.
4.7 Cut away or work free the nylon strop when the strop becomes slack.
4.8 Walk back on the fall and secure linkage over the wire pendant on to lifting hook.
4.9 Detach pendant at davit head.

4.10 Make a check to the boat, davit wires, total links before secure (Seamanship Techniques).

6- The Results of Basic Version

Contain results summary of estimated weights of CPCs collected by expert's judgment opinionnaire during the interview and processed by CREAM MHEP Software, for the operation task's four main steps. Fig. (3) (graphically fig 4) contains relationship between the four main steps and the calculated results of CII values, control modes, and HEP intervals of the four main steps based on the CPCs levels collected by expert's judgment opinions that were entered into the software after the compilation.

NO	MAIN STEP	Σ IMPROVED	Σ REDUCED	CII	CII VALUES	CONTROL MODES	HEP INTERVAL
AS.1	Prepare to abandon ship	-3	1	-2	-3 to 1	Tactical	0.001<HEP<0.1
AS.2	Gathering at muster station	-3	1	-2	-3 to 1	Tactical	0.001<HEP<0.1
AS.3	Launch the Lifeboat	-3	1	-2	-3 to 1	Tactical	0.001<HEP<0.1
AS.4	Boat Recovery	-3	1	-2	-3 to 1	Tactical	0.001<HEP<0.1

Fig (3) The Results of Basic Version.

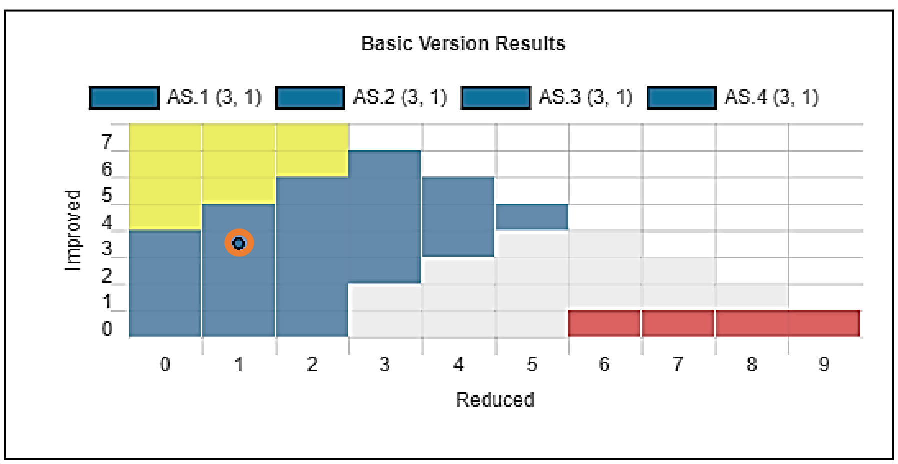

Fig (4) Graphical screening of the basic version results.

The results of basic version of the task four steps are "Tactical" control modes. The control modes HEP intervals is (0.001<HEP< 0.1), as shown in Fig. (3), and according to Table(1) this means "the performance more or less follows planned procedures, but some variation is still possible also the task is of critical grade that means it needs a deep analysis.

7- The Results of Extended Version

The extended version results are shown in Fig. (5) which illustrates the value of four main steps CII according to equations (1&2), the all steps relations and dependences collected by expert's judgment opinion. The table shows HEPs for the four steps, and the potential HEP of the whole operation task.

CODE	MAIN STEP	CII	RELATION	DEPENDENCE	RULE	HEP
AS1	Prepare to abandon ship	-2.6	Serial Relation	Low Dependency	$1 - \prod (1 - value_i)$	1.4E-3
AS2	Gathering at muster station	-2.6	Serial Relation	High Dependency	Maximum Value	4.2E-2
AS3	Launch the Lifeboat	-2.6	Serial Relation	High Dependency	Maximum Value	4.2E-2
AS4	Boat Recovery	-2.6	Serial Relation	High Dependency	Maximum Value	4.2E-2
Potential Human Error Probability			Serial Relation	High Dependency	Maximum Value	4.2E-2

Main Steps HEP

Fig. (5): The Results of Extended Version.

The following Figs (6), (7), (8), and (9) show each main steps of the task and its sub-steps HEP values as curves after assessment by the software.

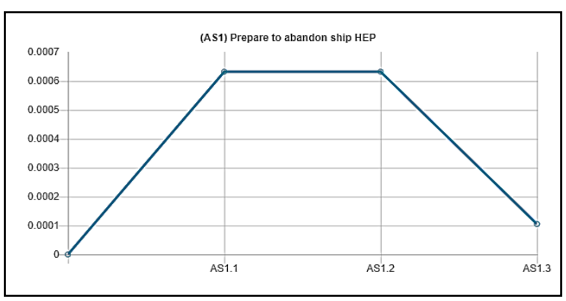

Fig (6) Main step AS1 and its sub-steps

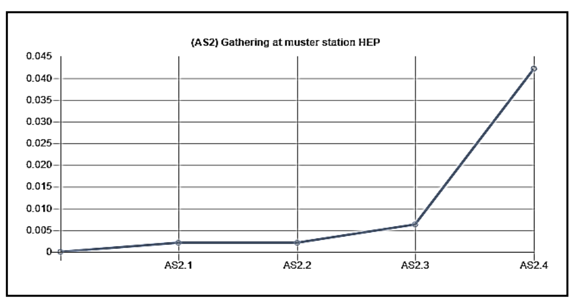

Fig (7) Main step AS2 and its sub-steps

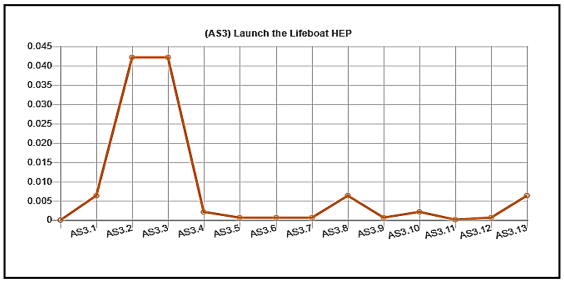

Fig (8) Main step AS3 and its sub-steps

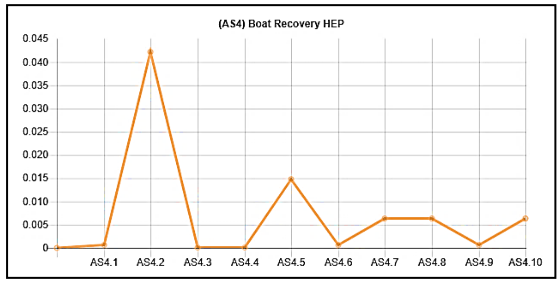

Fig (9) Main step AS4 and its sub-steps

8- The Task Results analysis

In the view of calculated HEP values, Fig. (5) reveals the potential HEP value of the whole operation task (extended version) is 4.2E-2, the software graphic result shows that the first main step (AS1) is comparatively low HEP, in comparison with the others steps, because there is less contribution of human elements in the preparation to boat drill, this makes the human error is less and serial relation between the main step (AS1) and its sub-steps with low dependence.

On the other hand, the other three main steps are equal in the potential HEPs and comparatively high as the number of crew members involved is greater in addition to the crew duties particularly the operation task at day time i.e. the human errors expected is higher than main step (AS1).

Fig. (6) shows the relation between the sub-steps and its HEP values of the main step AS1 that contains sub-steps (AS1.1) Switch on the alarm, and (AS1.2) “Start announcement for abandon ship”. Both steps look comparatively higher HEP values, but th**e** HEP of its Main step is low.

Fig (7) illustrates main step AS2 “Gathering at muster station”; it is important for the operation to ensure that the crew understand the operation procedures to complete the operation with satisfactory level. For this reason, the expected human failure and HEP of sub-step (AS2.4) is drastically increase and skill based errors are expected. On the other hand, the other three sub-steps (AS2.1), (AS2.2), (AS2.3) HEP are law.

Fig (8) shows the main step (AS3) “Launch the Lifeboat” it is important step because the correct and safe procedure to launch the lifeboat is the core of whole operation that is why the expected HEP is nearer to the value of operation task HEP. The sub-step (3.2)

“Check that the painter is rigged in a correct manner.” and sub-step (3.3) “Check that the harbor pins are out” those two steps pertaining to the boat safety lowering process as a result Knowledge-Based Mistakes and Skill-Based Errors expected that’s why the HEP expected to be higher than the rest sub-steps HEPs.

Table (3) and Fig (10) conclude the sub-steps which have higher HEPs, and the sub-steps (AS2.4, AS3.2, AS3.3, AS4.2, and AS4.5) are more critical because the values of HEP of each is approximately equal to whole HEP of the whole task, that mean the probability of the task failure are confined in these five steps.

Also Fig (9) which illustrates main step (AS4) during the boat recovery, there is very important sub-step (AS 4.2) “taking extreme care to ensure that the strop and the wire pendant with any shackles used, are of sufficient strength”; there are many accidents of boat fall caused by unsuitable shackles, and the expected HEP of this sub-step is equal (4.2E-2) the same value of the excepted operation task HEP.

The table (2) reveals that the majority of lifeboat drilling fall accidents during boat recovery, specifically sub-step (4.2) “Take extreme care to ensure that the strop and the wire Pendant with any shackles used, are of sufficient strength”, and sub-step (4.5) “Fit nylon strops over both lifting hooks, fore and aft in the boat”. (even its HEP is comparatively low in and sub-step 4.5). The boat falls accidents of M/V Thomson Majesty, and M/V Harmony of sea occurred as a result of the mentioned two sub-steps (MAIB, 2018).

Table (3) Sub-steps with comparatively high HEPs

Sub-steps codes	**Sub-steps**	**HEPs**
AS2.4	Confirm that crew fully understand the procedures.	4.2E-2
AS3.2	Check that the painter is rigged in a correct manner.	4.2E-2
AS3.3	Check that the harbor pins are out.	4.2E-2
AS4.2	Take extreme care to ensure that the strop and the wire Pendant with any shackles used, are of sufficient strength.	4.2E-2
AS4.5	Fit nylon strops over both lifting hooks, fore and aft in the boat.	1.5E-2

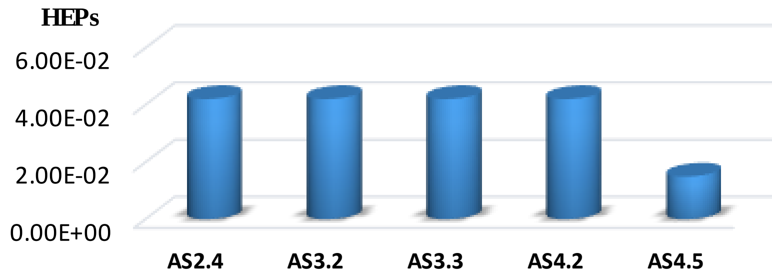

Fig (10) Sub-steps with comparatively high HEPs

By studying the causes and final flag state reports of the ships in table it was found that the majority of accidents occurred through sub-step (4.5) and sub-step (4.2) illustrates in the table (3) as comparatively high HEP results from the assessment of the task through the expert's judgement opinionnaire.

The whole results of the task revealed that the assessment can improve the level of safety training courses as well since studying the most critical steps or sub-steps of safety or shipboard operations tasks that require mitigation is very essential to modify such courses. Moreover, The CREAM HRA tool presents additional standards for safety procedures, awareness, and skills to build the safety culture and shipping organization safety strategies. The CREAM HRA tool is a prospective way for predicting the potential errors before commencing a critical safety task or scenario.

Conclusion

Human errors still the major causation of the ships accidents with the fast rate of development of the shipping industry and the technology of operations, and there is no database even national or regional counting the human errors in a suitable taxonomy. HRA has been used to update safety and risk-based decision-making in many industries for years, and a variety of tools have been accepted it remains a divisive area, it would deliver a practical power, and resource-efficient tool to the assessment and improvement of human reliability.

The CREAM HRA tool presents additional standards for safety procedures, awareness, and skills to build the safety culture and shipping organization safety strategies. The model Based on CREAM provides benefits to ship operators as an indicator for crew performance reliability and human error reduction tool onboard ships. Furthermore, the model is developed in a sequence that provides an integrated approach to increase the safety and effectiveness of safety and shipboard operations. The paper illustrated the utilization of the introduced model through CREAM MHEP Assessor software by applying it to the lifeboat drill process as a safety-critical shipboard operation task.

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