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Application Status of CREAM Method in Maritime

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Abstract

Eric Hollnagel proposed the CREAM Method in 1998, namely the Cognitive Reliability and Error Analysis Method, which is a representative Method in the second generation of human factor Reliability Analysis methods.After more than 20 years of development, more and more scholars have introduced other algorithms on the basis of CREAM to optimize the model and make it suitable for human factor reliability assessment in various industries.This paper summarizes the application of CREAM method in the maritime field in the past decade, summarizes and summarizes the status quo of the application field, and puts forward personal opinions.

Keywords

Background; Basic method; Current Situation of industry application; Summary analysis; Cognitive Reliability and Error Analysis Method (CREAM).

1. Introduction

According to the statistical data of many industries [1], about 50%-70% of system failures are caused by human error in nuclear power plants, 70% are caused by human error in offshore oil drilling, at least 50% are caused by commercial plane crashes due to pilot misjudgment, and 80% of maritime accidents are caused by human error [2]. Therefore, it is very important to conduct human factor reliability analysis (HRA) correctly in systematic probabilistic risk assessment (PSA).Human factor reliability analysis (HRA) originated in the 1950s and has developed two generations of HRA methods.The first-generation HRA method focuses on the study of human behavior theory and error classification, and develops statistical analysis and prediction methods of human error probability based on operator experience and expert judgment. However, situational environment is not considered enough, data is lacking, and accuracy is difficult to verify. Meanwhile, the first-generation HRA method lacks psychological basis [3]. Therefore, the second-generation HRA method further studies the internal process of human behavior, focusing on the mechanism and probability of human error occurring in the entire behavioral process from human observation, diagnosis, decision-making and other cognitive activities to the execution of actions in a specific situational environment.In recent years, CREAM has developed rapidly in the maritime field. I have compiled a literature review by referring to the literatures in the past ten years to analyze the application status of CREAM method and my personal views on the future development.

2. Background of CREAM Method

Eric Hollnagel proposed the CREAM Method in 1998, namely Cognitive Reliability and Error Analysis Method. It is a representative method of second-generation human factor reliability analysis [4]. CREAM, based on the situational dependent cognitive model (COCOM), has two main characteristics:

(1) emphasizing the important influence of situational environment on human behavior, it summarizes environmental factors as co-performance condition (CPC), and gives the influence effect of CPC level on human reliability.

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(2) Propose a unique cognitive model and framework with two-way analysis functions of traceability and prediction and provide a set of scientific and practical analysis process, which can not only trace back the root cause of human error events, but also predict and analyze the probability of human error. After more than 20 years of development, this method has been applied to some practical accident analysis, such as reliability prediction analysis of some nuclear power plants in European countries (RELCON 95101/001), which has been widely praised. For example, it was used in the retrospective analysis of the New York subway collision on June 5, 1995, and the Ginna nuclear power plant accident on January 25, 1982 (NUREG -- 0909,1982).

3. The Basic Method of CREAM

The Cognitive Reliability and Failure Analysis Method (CREAM) was developed on the basis of systematic criticism of traditional HRA principles and methods. Its core ideas include common performance condition, observable failure and unobservable failure, cyclic behavior model, human cognition, control model and bidirectional function. The core idea is to emphasize that people's performance output is not an isolated random behavior, but depends on the Context in which people complete the task. It ultimately determines people's response behavior by influencing people's cognitive control mode and its effect in different cognitive activities. This method establishes four cognitive and behavioral control modes, namely strategic, tactical, opportunistic, chaotic [5].

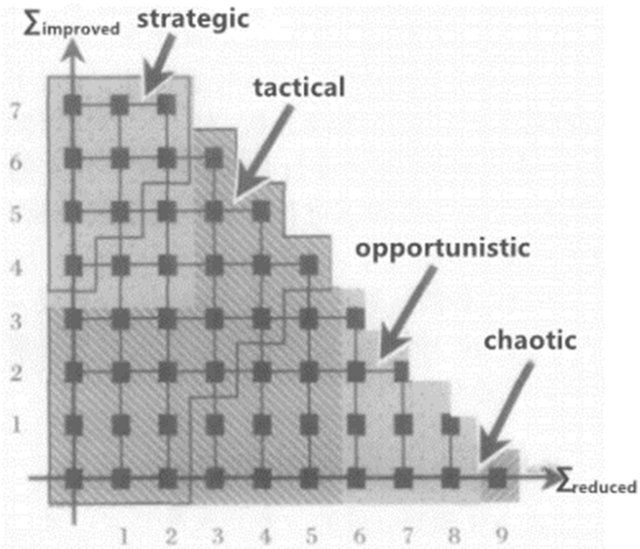

Figure 1. The relationship between CPCs and control patterns

3.1. Common Performance Conditions of CREAM

CREAM method summarized these influencing factors into nine factors, collectively known as Common Performance Conditions CPC (CPCs). Each factor was called a CPC factor, and each CPC factor had several different levels. There are three different levels of impact on human performance: improved, reduced and insignificant. When CREAM performs bidirectional analysis, the levels of various CPC factors should be described according to the situational environment of the accident site, and their expected effect on performance reliability should be determined.

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Table 1. CPCs and performance reliability

CPC	CPC level/description	Effects
Adequacy of organisation	Very efficient	Improved
	Efficient	Not significant
	Inefficient	Reduced
	Deficient	Reduced
Working conditions	Advantageous	Improved
	Compatible	Not significant
	Incompatible	Reduced
Adequacy of MMI and operational support	Supportive	Improved
	Adequate	Not significant
	Tolerable	Not significant
	Inappropriate	Reduced
Availability of procedures/plans	Appropriate	Improved
	Appropriate	Not significant
	Inappropriate	Reduced
Number of simultaneous Goals	Fewer than capacity	Not significan
	Matching current capacity	Not significant
	More than capacity	Reduced
Available time	Adequate	Improved
	Temporarily inadequate	Not significant
	Continuously inadequate	Reduced
Time of day	Day-time (adjusted)	Not significant
	Night-time (unadjusted)	Reduced
Adequacy of training and Experience	Adequate, high experience	Improved
	Adequate, limited experience	Not significant
	Inadequate	Reduced
Crew collaboration quality	Very efficient	Improved
	Efficient	Not significant
	Inefficient	Not significant
	Deficient	Reduced

3.2. CREAM Retrospective Analysis

Hollnagel believes that the definition of failure in traditional HRA is unscientific, because it can be regarded as an abnormal Event, Cause and Consequence in different analysis occasions.

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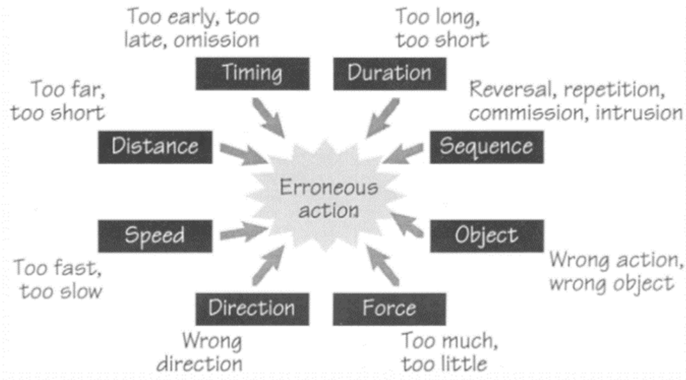

Figure 2. The classification of the error pattern

CREAM divides errors into observable errors and unobservable errors. Observable Error refers to the Error with external manifestation, also known as Error mode. Unobtrusive error refers to the failure in the process of thinking, such as diagnosis, evaluation, decision-making, planning and other cognitive activities. CREAM failure mode can be divided into 8 categories, including time, early, late, miss), process (too long, too short), power (too big, too small), speed (fast, slow) (wrong direction), distance and direction (too far, too close), sequence (upside down, repeat, error, insert), target (the wrong target). CREAM back analysis based on the basic idea of error model as a starting point, in listing 8 patterns such mistakes may be general and specific before because of the failure mode before the table "in the analysis of a selected before because as a consequence, for the classification of the group before containing the corresponding" consequences - the former for list "before analysis and find the possible cause, It can also be used as a consequence to continue analysis to find possible antecedents, and so on, and finally find the root cause [6].

3.3. CREAM Prediction Analysis

The main function of CREAM predictive analysis is to predict the probability of failure of a task in a person's cognitive activity, which includes two methods: basic law and extension method. In the basic law, the basic idea of predictive analysis determines the CPC factor level according to the situational environment of the task, and the cognitive control mode of completing the task is determined by the synthesis of the CPC factor level, which basically determines the probability of failure. Extension method can be applied to more precise HEP data task, further analysis of the people in the process of completing the task of cognitive activities and possible cognitive function failure, first get the cognitive function failure probability of the basic values, followed by the CPC scene environment factor levels to modify the basic values, when the person is to complete the task to predict the probability of failure may occur, HEP can be quantified according to the basic error probability data of control mode and cognitive function obtained [7].

3.4. Basic Steps

(1) Establish a sequence of events for the analyzed task. Task analysis is generally used and accident scenarios can be obtained from PRA.

(2) Evaluate common performance conditions (CPCs). The nine factors listed in Table 1 are evaluated and scored, which requires the participation of professionals from a variety of technical fields. After considering the correlation effect, the final evaluation results were recorded.

(3) Identify possible cognitive control models. After obtaining the reliability evaluation value of CPCs of a task/subtask, the control mode in which personnel complete the task/subtask can be determined according to. Table 2 shows the quantitative relationship between the control

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mode and the error probability interval, based on which the general probability range of task completion can be preliminarily obtained. In order to reduce the uncertainty and obtain more accurate probability value for specific tasks, extended analysis method can be used.

Table 2. Control modes and HEP intervals

Control mode	HEP interval
Strategic	0.5 E-5 < P < 1.0 E-2
Tactical	1.0 E-3 < P < 1.0 E-1
Opportunistic	1.0 E-2 < P < 0.5 E-0
Scrambled	1.0 E-1 < P < 1.0 E-0

3.5. Steps of Expansion Method

(1) Establish a cognitive demand map of the task and identify the cognitive activities required by each step of the task sequence, including coordination, communication, comparison, diagnosis, evaluation, implementation, identification, maintenance, monitoring, observation, planning, recording, adjustment, scanning, confirmation, etc.

(2) Identify possible cognitive function failure modes. Based on specific analysis and evaluation, the possible cognitive function failure modes in each step of the task/sub-task and their quantitative probability point values and upper and lower ranges can be obtained through the cognitive function failure mode manual provided by CREAM.

(3) Determine the specific action error probability. According to the results obtained in the previous step, consider the influence of different factors in CPCs on the weight value of the completed task on the result probability and adjust obtain the quantitative results of each step. The population probability can be obtained by the following criteria:

$$MAX(CFP_i), i = 1,2 \dots n \tag{1}$$

CFP_i——— Adjusted probability of cognitive function failure; n———Count the number of values

4. Application Status and Effect of Cream

Since Cream was proposed in 1998, after more than 20 years of development, Cream has been widely used in accident analysis, safety analysis and risk assessment in navigation and maritime fields. On this basis, scholars introduced various algorithms, such as BN, FS and ER, quantified HEP and reformed CREAM to make CPC values more suitable for current industry applications. The following table is the literature I searched and sorted out.

Table 3. Classification and summary of references

Reference	scenario	Method
Emre Akyuz 2015	LPG carrier	CII with modified CREAM
Tai Shuen Ung 2015	Seamanship	FS+ weighting
Tai Shuen Ung 2019	Tanker collision	BN+FS+ fault tree
YANG Z.L. 2013	Engine staff	BN+FS
Zhiqiang Sun 2012	Submarine	The modified CREAM
ZHOU Qing-ji 2018	Oilanker	BN+FS
XI Yong-tao 2015	Officer on watch	FS+BN+ER
ZHANG Jin-peng 2012	Seaman	BN+ Triangle whiten function
JIANG Fei-fei 2017	Ship pilot	DEMATLE

4.1. Maritime Field

The International Maritime Organization requires member countries to carry out human reliability analysis (HRA) in the formal Safety Analysis (FSA) of ships, which is used to evaluate the probability of human accidents in water operations. Due to the lack of historical or simulation data, it is difficult to directly adopt the first-generation HRA method because the water transportation industry started late in the quantification of human factor reliability compared with other industries. Therefore, the second-generation RHA method emphasizing situational environment has been optimized and modified and widely used in the field of maritime vessels.

(1) For the assessment of the operational error probability of the officer on Watch (OOW). OOW operations on board require decisions to be made and are highly dependent on the dynamics of the technology, organization, and environment at sea. When using the CREAM, therefore, the observation data are highly dependent on experts, CPC value technical experience and cognitive preferences is not integrity, to solve the problem of fuzziness of the CPC, professor yong-tao xi proposed fuzzy set and evidence reasoning process of observation values, and the fusion [8], will first CPC assessment values into fuzzy output, After establishing the membership function of language variables at each level, and adjusting the situational environment elements through BN, the adjusted CPC level star can be used as the input of evidence inference as the quantification of HEP, and a modified model based on CREAM can be established to quantify OOW operation reliability under the condition of uncertain information. Through the case analysis of OOW duty duty in Taizhou section of Yangtze River, the current model can further reduce the error probability interval and obtain a more accurate and perfect value with stability and validity, which is suitable for evaluating the current OOW human error probability.

(2) For the same officer on ship duty, Professor Zhang Jinpeng proposed to use the modified trigonometric whitening weight function and BN network [9] to obtain different probability values for the four different control modes of the officer in ship hedging, which can be used to calculate the degree of reliability. And applies the theory of data instances, to evaluate some shipping company sailing and month, after experts for CPC to assess, using the principle of correction, the integrated use of series-parallel reliability principle, calculate the class in the driver's safety reliability degree, the results on the surface of the calculated value more in line with the actual situation, To a large extent, the CPC value is overcome because of the interference of personal cognitive bias.

(3) Crew members on LPG tankers should be fully aware of the operational risks associated with cargo handling, including various critical tasks such as drying, inerting, aeration, cooling and re-liquefaction. During these phases, human reliability (trouble-free operation) plays a vital role in the sustainable transport of goods. Human reliability analysis (HRA) involves various parameters, such as human factors, technology, and ergonomics, as well as operational safety and environmental safety. E. Akyuz studied that CII (Context Influence Index) was introduced to quantify the CREAM model when LPG was loaded ashore [10], which was used to evaluate CPC and was applied to LPG loading safety assessment. The results showed that After CII improvement, the CREAM method is applied to the safety assessment of LIQUEFIED petroleum gas, and the evaluation result shows that the current human factor reliability is at an ideal level. At the same time, using this evaluation method can improve the safety parameters of LNG and LPG loading, which has reference value for the shipping company and safety departments. By referring to the deficiencies in CPCs, the error of personnel/crew can be prevented.

(4) The loading and unloading of oil tankers in ports is also a scenario prone to production accidents. ZHOU Qing-ji used algorithms based on CREAM [11] and FS and BN network to calculate the probability of human error in this process, and took the tanker shipping with 18

crew members as a case study. After experiments, the results showed that the HEP evaluation based on the general model was very promising. Can provide reliable results of human performance failure. The method presented in this study can be used by shipping company management to evaluate the reliability of seafarers in the shipping process.

(5) For port production operations, pilots are responsible for ship navigation in and out of the port. How to effectively predict the human factor reliability of ship pilots, Jiang Feifei uses triangular fuzzy number improved Decision Experiment and Evaluation Experiment method (DEMATEL) based on CREAM [12] to obtain the weight of CPC factor. At the same time will be introduced to the theory of fuzzy comprehensive evaluation to the CPC effect factor of performance evaluation, reduce the effects of the subjectivity of expert judgment, and applied it in the pilot station along the coast of China, the results show that after the improved method can make the result of forecasting model is more accurate, can provide reference to decision makers improve pilot for reliability.

(6) In the working environment of submarines, to achieve more covert navigation effect, electric propulsion is generally adopted as its driving force and generator diesel engine is used as the source of electricity. Before the generator reaches a certain speed, it is necessary to have a certain slow start time, keep the generator running at low speed and warm cylinder, and then raise the speed to standard speed, which can effectively provide combustion conditions and prolong the service life of the machine. But this operation will be ignored or directly skipped because of people at some time, there are production accidents. Therefore, author Sun Zhiqiang proposed to first use five accepted assumptions [13] and derive the HEP point estimation formula on this basis. In addition, the rationality of this approach is discussed and its consistency with THERP and HEART, two other benchmark HRA methods, is verified.

Finally, a simple example of submarine engine slow start is given to calculate the probability of forgetting thermal operation due to human error. The calculated results of this simplified method are basically consistent with the actual recorded personnel performance data and experimental results, and it is suitable for the evaluation of human factor reliability in this environment.

(7) When loading and unloading ships, especially special ships, need to use their own deck machinery, so the test of engine room power equipment is relatively large, and the production safety of engine room has been paid more attention. YANG Z.L. proposed to transform CREAM [14] and introduce fuzzy evidence inference and Bayesian network, which is convenient for quantifying the human factor reliability of crew members. Meanwhile, an IF-then rule base is established and the bayesian inference mechanism is used to aggregate the responsibility distribution of relevant crew members and estimate the failure probability. He introduced this model to an actual case and analyzed the unloading accident of Jalalpur oil tanker in 2004, demonstrating the superiority of this method, which can reduce the interval of probability estimation as much as possible. This method is suitable for ship safety risk assessment.

(8) Human error is an important cause of tanker collision. Shuen-tai Ung studied the risk assessment of tanker collision caused by human error [15] and adopted fault tree analysis method to assess tanker collision probability. On this basis, he proposed an improved cognitive reliability error analysis method based on fuzzy Bayesian network to evaluate human error. Invite 39 experts with extensive maritime experience to provide expert judgment on tanker navigation, especially in the vicinity of Taiwan waters. Unlike traditional studies, this method provides a higher degree of result differentiability while taking into account the weight and quantitative impact of environmental factors without losing expert information. It is considered that the lack of communication in bridge resource management, lack of communication between ships, fatigue and violation of collision rules are the factors contributing to the high accident rate. Once the accident rate deteriorates, tanker collision may also occur. In addition,

the number of simultaneous targets on the bridge is the common performance condition (CPC) that causes all basic human error events to occur.

(9) At the same time, the author proposes in another article that there is a lack of sufficient data in the shipping industry to evaluate HRA. Therefore, the method of fuzzy CREAM is proposed in the rule base [16] to solve the above problems. Meanwhile, two axioms are used to verify the framework, and an example of a tanker is analyzed and verified. The results were found to be significant for small changes in the input data and weights, so that the weighted CREAM model could produce reliable estimates.

5. Summary and development of CREAM

I classified the literatures found in the above table. Since the CREAM method was proposed in 1998, on this basis, scholars introduced various algorithms, such as BN, FS and ER, to quantify HEP and transform CREAM, as shown in the above table, to make CPC value more suitable for current industry applications. Many scholars have proposed that the lack of data in some industries leads to the imprecise calculation and processing of HRA. At the same time, as CPC is an evaluation item, there are evaluation differences, so it is necessary to conduct a comprehensive evaluation of its confidence level and weight. Meanwhile, a single CPC factor may be affected by other factors and change. How to establish a reasonable and scientific judgment and dependence relationship between various factors is a problem that needs to be carefully solved in the future.

As the second generation of HRA methods, optimization of the first generation of HRA discriminant boundary is too big, due to various defects exist at the same time the CPC optimization space, such as cognitive psychology can be further refined, such as the evaluation of the CPC (on duty time zone, circadian rhythm) is only a rough evaluation, I think it can add detailed inner psychology, such as the stand or fall of mood, external interference to human psychology, there may also be judgment and evaluation error. Application scenario and work environment can also do further optimization analysis, such as sailing voyage, weather, wind is also a is very important for the work environment of the interference factors, the current assessment data is a data collection for a whole day's weather, one point is not specific to something, people work in this environment the concrete is feeling in times indicating the change, I think in CREAM, on the basis of analysis of the CPC to further refine, human's perceptions of the work environment at a certain moment, can be combined with the human physiological indexes, such as heart rate, blood sugar, oxygen concentration, etc. combining with the physiology and medicine, that can get a simulation model, a more scientific and accurate for the CPC factor evaluation, So that the final evaluation has more reference value.

Through literature search and literature review, I have a further understanding of the second generation OF HRA. CREAM, as a widely used evaluation method at present, can be modified and optimized to be introduced into the corresponding industry. Maybe the time is too short, and the research on this method has not been thorough. In the future, I will conduct further research and study on this method and combine it with my major to evaluate the human factor reliability analysis in ship safety and management.

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