Original Article

The comparative study of evaluating human error assessment and reduction technique and cognitive reliability and error analysis method techniques in the control room of the cement industry

Amin Babaei Pouya, Ehsanollah Habibi

Department of Occupational Health Engineering, School of Health, Isfahan University of Medical Sciences, Isfahan, Iran

ABSTRACT

Aims: The present study aimed to evaluate the assessment methods of human errors and compare the results of these techniques in order to introduce the precise method of human error assessment, and recognize the factors affecting the occurrence of these errors.
Materials and Methods: This case study was done at three workstation control room of a cement industry in 2014. After determining the responsibilities and critical jobs by hierarchical task analysis, cognitive reliability and error analysis method (CREAM) and human error assessment and reduction technique (HEART) were used in order to analyze the human errors.
Results: The results showed that in the CREAM method, the highest probability of error occurrence is related to monitoring and control (operator) with a probability of 0.207, and that of in the HEART method, is related to control signs (operator) with a probability of 0.416. The number of errors detected by CREAM and HEART method were 85 and 80, respectively. Time and cost of applying the CREAM methods were 235 h and 1175($), while those in the HEART techniques were 215 h and 1075($).
Conclusion: We concluded that the highest probability of calculated errors relates to "monitoring and control (operator)," "controlling warning signs (operators)," and "cooperation in solving the problem (supervisor)" for both techniques. By considering the time and cost factors, HEART has superiority, while CREAM is better due to its extensive evaluation and the number of detected errors.

Key words: Cement industry, cognitive reliability and error analysis method, human error assessment and reduction technique

Address for correspondence:
Prof. Ehsanollah Habibi,
Department of Occupational Health, Faculty of Health, Isfahan University of Medical Sciences, Hezar Jerib Ave., Isfahan, Iran.
E-mail: habibi@hlth.mui.ac.ir

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INTRODUCTION

For industrial growth and economic development, infrastructure expansion including construction activities and housing programs is the most important factor. Cement is the most important input of the construction

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industry and can be considered as a strategic commodity in a country infrastructure.[1] Iran is among the few countries that diligently seeks to develop this industry.[2] In the cement industry, like other industries, the control room's operator has an important role in arranging and controlling the process. Due to the sensitivity and criticality of the process of the control room, any operator's error in this unit may lead to severe economic damage and possible casualties.[3] Studies on industrial accidents have shown that human factor plays a main role in accident occurrence since about 80% of accidents are as a result of human errors.[4] Human errors refer to the set of human actions which are violated from accepted norms and defined standards.[5] Many researchers have applied and developed several measurement techniques of human reliability such as technique for human error rate prediction (THERP), human error assessment and reduction technique (HEART) human error rate assessment and optimizing system, maintenance error decision aid and justification of human error data information (JHEDI) with the aim to facilitate the accurate and comprehensive assessment of the risk contribution of human factors, through trial and error analysis, measuring and reducing practical errors. Due to the more complexity of the systems, industrial risky process and technology growth in one hand and perception and unpredictability of human error, on the other hand, are the main cause of the decrease in system reliability. Thus, identifying, predicting, and analyzing the human error seem to be necessary.[6] The process of analyzing errors on the base of cognitive reliability and error analysis method (CREAM) was developed by Hollnagel in 1998. This is among the second generation of human reliability assessment (HRA) technique focused on human performance. The approach is very concise, well-structured and follows a well laid out system of procedure as well as quantification of human errors either prospective (anticipating human error) or retrospective (event analysis) in comparison with other approaches. CREAM was used in the analysis of train crash between two Swedish cities, Eksjö and Nässjö, happened in 1996.[7] HEART was developed by Williams in 1985. This is one of the evaluating the probability of a human error technique which reduces the likelihood of errors occurring within a system and, therefore, lead to an improvement in the overall levels of safety applied in nuclear power plants, refineries, chemical and petrochemical industries. HEART is developed for rapid human error assessment based on a special table that includes questions designed to identify the errors. The method essentially takes into consideration that human reliability is considered to be dependent to the task which is done. The Study of Kirwan showed that HEART, by applying THERP and JHEDI, has the highest validity.[8-10] Compare the different ways, the human errors for the development of various methods used to assess human error, the results of this experiment can be effective in identifying errors and provide appropriate strategies to reduce the occurrence of human errors and the guidance of subsequent studies in this field.

MATERIALS AND METHODS

This case study was done at three workstation control room of a cement industry in 2014. The evolution of cement production technology goes toward the greater use of automation and assessment tools.[11] In this unit, a chief-engineer, a supervisor, and operators do their works. While the data were collected via face-to-face interviews with experts, direct-observation, daily reports, and documents. Jobs and critical tasks were determined on the bases of complexity, stress, and fatigues. Then, the identified tasks were analyzed by hierarchical task analysis (HTA). CREAM was applied in two steps.

Basic method-cognitive reliability and error analysis method

Assessing the conditions affecting user performance common performance conditions (CPCs), the description of the conditions affecting the operator's performance and potential relationships between factors of CPCs and reliability performance levels "Improved," "Reduced," and "Not significant" have shown. These three levels represent the expected effect on the performance reliability.

Determines the control styles: By counting the number of positive and negative of CPC, 4 control levels are determined. Then, total cognitive failure probability (CFPt) is calculated by the following formula: $\text{CFPt} = (0.0056 \times 10^{0.25\beta})$ where:

β = (number of reduced performance − number of performance improvements).

Extended method-cognitive reliability and error analysis method

Specific cognitive demands associated with any of the duties or different parts of each job were determined. Then, the possible cognitive errors were identified for each job.

Cognitive failure probability can be calculated by the following formula.[11]

$$\text{CFPi} = (\text{CFP total} \times 10^{0.25\text{PII[Performance Influence Index]}})$$

Then, HEART was used in order to obtain the human errors assessment. The reliability was also evaluated according to the following four stages:

Selecting generic task

It was determined in accordance with the studies task and Generic Error Probability (GEP). By using activity type, amount task uncertainty is determined Selecting error producing conditions

It is a condition in which the error occurs and may have an influence on individual performance.

Assessing the relative effect

The relative effect must be determined for European Patent Convention. It varies between 0 and 1 to represent the strength of each condition.

Obtaining the probability of human error for each selected European Patent Convention, which is measured by the following equation (proportion of effect).

Calculated Effect = ([Max Effect − 1] × Proportion of Effect) + 1

Then:

Human Error Probability = [GEP × Calculated Effect]

Finally, two techniques based on the "number of detected errors," "their probabilities" and "time and cost spent" were compared.

Cognitive modeling approach. Applies cognitive systems engineering to provide a more thoroughly argued and theory supported approach to reliability studies. The approach can be applied retrospectively or prospectively, although further development is required for the latter. The "meat" of CREAM is the distinction between phenotypes (failure modes) and genotypes (possible causes or explanations).

Extended HEART approach, which adds several new generic error probabilities specific to nuclear power plant tasks and systems.

RESULTS

After analyzing the task and identifying the errors related to the tasks, the number and the probability of errors of different tasks were calculated and the data of HEART and CREAM were compared on the base of time and cost. The data of HTA technique including the analysis of the duties of Chief-engineer, supervisor, and the operator of central control room with 8, 6, and 6 main tasks and 29, 25, 23 sub-tasks, respectively, were analyzed. The result of CREAM and HEART is presented in Table 1 according to the likelihood of the calculated error. In CREAM, the highest likelihood of errors occurred in monitoring and control (operator) with 0.207 probabilities, while in HEART, the highest likelihood of errors occurred in controlling warning signs (operator) with 0.416 probabilities. The number of errors detected by CREAM and HEART were 85 and 80, respectively [Table 2]. The time and cost of applying CREAM were 235 h with 1175($), while it was 215 h with 1075($) in HEART techniques [Table 3].

DISCUSSION

In recent decades, adverse and disastrously events such as Felix Bureau (UK, 1976), Three Mile Island accident (US, 1979), Bhopal chemical accident (India, 1984), and Chernobyl disaster (Russia, 1986) showed that despite of technology development and using automation in industry and industrial processes, the human role is so sensitive.[12] In the early of AD, the 30's, Henrich claims that the reason of adverse is unsafe acts.[13] The process of analyzing errors on the base of CREAM was developed by Eric Hollnagel in 1998.This is among the

Table 1: Probability calculated error

Probability of the calculated error with CREAM technique		Probability calculated error with HEART technique	
Duty and job	*P* (%)	Duty and job	*P* (%)
Monitoring and control (operator)	0.207	Controlling warning signs (operator)	0.416
Controlling warning signs (operator)	0.201	Monitoring and control (operator)	0.347
Coordinating in problem solving (supervisor)	0.089	Coordinating in problem solving (supervisor)	0.319
Production cohesion in (chief engineer)	0.065	Decision about abnormal conditions (chief engineer)	0.220
Association with the local operator (the operator)	0.063	Production cohesion in (chief engineer)	0.192
Association with supervisor (operator)	0.063	Business licensing (supervisor)	0.189
Business licensing (supervisor)	0.056	Monitoring unit and studying reports (chief engineer)	0.041
Decision about abnormal conditions (chief engineer)	0.039	Supervision and shift working in charge (supervisor)	0.039
Organizing educational affairs (chief engineer)	0.019	Association with local operator (operator)	0.033
Receiving data and instructions (operator)	0.018	Association with supervisor (operator)	0.033
Filling out the report sheet (operator)	0.018	Receiving data and instructions (operator)	0.033
Study of unit circumstance (chief engineer)	0.013	Take over the shift (supervisor)	0.033
Staff affairs (chief engineer)	0.013	Handover the shift (supervisor)	0.033
Take over the shift (supervisor)	0.008	Staff affairs (chief engineer)	0.031
handover the shift (supervisor)	0.008	Association with control room operator (supervisor)	0.029
Supervision and shift working in charge (supervisor)	0.008	Filling out the report sheets (operator)	0.023
Association with control room operator (supervisor)	0.008	Study of unit circumstance (chief engineer)	0.022
Monitoring unit and studying reports (chief engineer)	0.005	Organizing the educational affairs organizing (chief engineer)	0.022
Shift reports (chief engineer)	0.005	Shift reports (chief engineer)	0.022
Attend meetings (chief engineer)	0.005	Attend meetings (chief engineer)	0.022

second generation of HRA technique focused on human performance. In the CREAM technique, detected human errors by primary method were: "Doing two or more jobs at the same time," "work time-Circadian rhytm" and "the quality of education and work experiences." While, these Cognitive errors were "performance errors" (43%), "interpretation errors" (26%), "planning errors" (20%), and "observation errors" (11%) by extensive methods cream. These results are consistent with the results Murto et al. in 2006, that study was carried out in the control room of the chemical industry, the most cause of human error was "cognitive errors." Among all errors identified in hamzeiyan study in the control room was related to the "Task shift control room." Error performed the most and had the least amount of errors in "planning."[14] HEART was developed by Williams in 1985. This is one of the evaluating the probability of a human error technique which reduces the likelihood of errors occurring within a system and, therefore, lead to an improvement in the overall levels of safety applied in nuclear power plants, refineries, chemical and petrochemical industries. In the HEART technique, the most important factors in the occurrence of human error happened in the control room when the "abnormal sleep cycle (fatigue)," "disease during the work such as fever," "low morale among the workforce," and "meaningless of the task," which were consistent with the results of Galenoii study in 2009, the most influential factor on the performance of "fatigue" and "experience" was expressed.[15] Also in the research, evaluation of human error in the control room of Mr. Jahangiri, most errors were related to "monitor equipment performance." In the present study, monitoring and control (operator), coordinating in problem solving (supervisor), and controlling warning signs (Operator) were identified as the main and the most prone tasks contributed in the incidence of human error.

Table 2: Number of detected errors by the two techniques

Duty	Number of detected errors by CREAM	Number of detected errors by HEART
Chief engineer	31	21
Supervisor	28	27
Operator	26	32
Total	85	80

CONCLUSION

We can concluded that the tasks had the highest probability of error in both techniques, including "Monitoring and Control (operator)," " controlling warning signs (operator)," and "Coordinating in problem solving (supervisor)" was similar. The lowest probability of error in both techniques, including "Shift Reports (Chief-engineer)" and "Attend meetings (Chief-engineer)." By considering the time and cost, HEART has superiority, while CREAM is better due to its extensive task evaluation and the number of detected errors. Finally, in detecting errors in tasks which require cognitive operations such as perception, memory, reasoning, and motor response, CREAM has high sensitivity.

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Table 3: Time and cost of HEART and CEARM

CEARM			HEART		
The type of performed activity	Time	Estimated cost ($)	The type of performed activity	Time	Estimated cost ($)
Understanding the process	40	200	Understanding the process	40	200
Guidelines evaluation	10	50	Guidelines evaluation	10	50
Determining the critical tasks of the unit	5	25	Determining the critical tasks of the unit	5	25
Task analysis of HTA	20	100	Task analysis of HTA	20	100
Primary method					
Analysis of the conditions affecting the performance of individual	15	75	Determining GTT of task and choosing GEP	5	25
Estimating the overall probability of error and control styles	10	50	Study on the effect of human error	25	125
Broad method					
Providing cognitive demands and identifying cognitive errors	35	175	Assess the relative effect	25	125
Quantitative assessment of cognitive errors	25	125	Calculating the probability of human error	10	50
Initial report preparation	25	125	Initial report preparation	25	125
Expert comments	20	100	Expert comments	20	100
Final report preparation	30	150	Final report preparation	30	150
Total	235	1175	total	215	1075

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