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ORIGINAL ARTICLE

Determining Human Error Global Causes in a Petrochemical Control Room with a Cognitive Analytical Approach-CREAM

ADEL MAZLOUMI [1*], MOSTAFA HAMZEIYAN ZIARANI [2]

[1]*Associate Professor, Department of Occupational Health Engineering, School of Public Health, Tehran University of Medical Sciences;*

[2] *Department of Industrial Engineering, Institute for Higher Education of Kar, Qhazvin, Iran.*

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ABSTRACT

Control room is the heart of each system in which even a minor error can result in irrecoverable consequences. The purpose of this study was to determine the Probable Control Modes (PCMs) and Cognitive Failure Probability (CFP), and also build a Cognitive Demands Profile (CDP) in a petrochemical control room, using Cognitive Reliability and Error Analysis technique (CREAM). First, tasks of Boardman (B.M), Shift Control (S.C), and Head Control (H.C) in control room were analyzed, applying hierarchical task analysis. Following, PCM, CFP and CDP were determined for the analyzed tasks. According the results, control modes for the tasks of B.M and S.C were determined as opportunistic; while for H.C tasks it was obtained as tactical. Of the all error types, execution failure (48.57%), interpretation failure (18.57%), planning failure (15.71%), and observation failure (17.15%) were identified. The most important CDPs were communicated, monitor, execute, plan, diagnose, evaluate, co-ordinate, verity, record, and scan. Based on the findings, number of simultaneous goals, time of day and adequacy of training and experience in the study field were the Common Performance Conditions that led to reduction of performance reliability. These factors contributed to the opportunistic control mode. In order to prevent or reduce cognitive errors in the control room, we need to know the exact type of cognitive activities, and develop a comprehensive program to increase the knowledge and skills for performing the cognitive activities.

KEYWORDS: *Human error; cognitive reliability; control room; CREAM; petrochemical industry*

INTRODUCTION

Statistical data have shown that the majority of accidents (over 80%) in chemical and petrochemical industries have been occurred due to human failure, as a primary cause of accident. Analysis of 2000 cases of accidents from the first Australian Incident monitoring study revealed that human error was attributed in 83% of these cases. According to a study by Technische Universität Berlin (TUB), a majority of incidents, about 64%, are reported to be caused by human failure.

There are many cases that human error were either main or underlying cause of disaster in serious accidents, such as Texas city disaster in 1947, Bhopal in 1994, Piper Alpha disaster in 1988 and Texaco refinery fire (1994) [1-2].

In parallel, there is ample evidence which directly or indirectly attributes the major causes of many notorious large-scale accidents to human error, especially "operator error", Three Mile Island (1979), Chernobyl (1986) and Bhopal (1994), just to name a few. Accordingly, relevant studies has revealed that the dominant underlying key factors leading to these large-scale accidents has explored to be “lack of human factors consideration” from the micro- and macro-ergonomics points of view[3].

One of the main characteristic of major technological systems is that a massive amount of potentially hazardous materials is amassed in one unit and controlled by operators. Accidents in these units are accounted serious risk not only for workers and belongings, but also for the proximate

Corresponding author: Adel Maloumi
Email: amazlomi@tums.ac.ir

areas and even neighbor countries [4]. Human Reliability Assessment (HRA) techniques for risk assessment targets has been actually started and developted in the early 1970s. HRA methods that mostly represent the reviews of Dougherty are called first generation HRAs. Human Reliability Assessment (HRA) techniques that appeared afterward are called second-generation HRAs. The second-generation HRA methods included different techniques such as Technique for Human Event Analysis (ATHEANA), Misdiagnosis Tree Analysis method (MDTA) and Commission Errors Search and Assessment (CESA) method. The main focus of the second-generation HRAs has been on the indentification of human in errors emergency operations or so called “post-initiator” [5-8].

The well-known technique of Cognitive Reliability and Error Analysis Method (CREAM), was deve;opted by Hollnagel [5]. This method is one of the second-generation HRA's techniques with a theoretical background focus on cognitive fields of human behavior. Some of the most important advantages of CREAM are the organized framwork of this technique for describing and quantifying human errors both prospectively and retrospectively, taxonomy structure, Contextual Control Model (COCOM) of cognition, and description of human errors cause based on associated factors to Man-Technology-Organization (MTO) [5, 9-12].

Considering the critical tasks in control rooms and the importance of cognitive failures which lead to human errors in petro-chemical industries in Iran and other countries, having an appropriate human error identification technique has crucial importance. Therefore, the aim of this study is to determine the Probable Control Modes (PCM), Cognitive Failure Probability (CFP) and creating a Cognitive Demands Profile (CDP), using Cognitive Reliability and Error Analysis Method (CREAM) in the control room of aromatic unit in one of the petrochemical companies in Iran and also to propose possible solutions to prevent and reduce errors in this company.

MATERIALS AND METHODS

The present cross sectional study was conducted in control room of Aromatic unit in one of the petrochemical companies, in Iran. Aromatic unit had 39 operators including Unit Chief (U.C), Head Control (H.C), Shift Control (S.C), Board Man (B.M) and Site Man (S.M). After observing control room operators while performing their tasks and interviewing with B.M, S.C, H.C and U.C, tasks related to H.C, S.C and B.M were selected in order to implement CREAM technique. The selection was done based on the factors including: complexity of the tasks, level of stress, strain, and fatigue (this factor particularly affects the operators in night shift with disturbance of the circadian rhythm along with tedious condition) [13]. CREAM technique is consisted of two main methods: the basic method and the extended method. A brief description of CREAM technique, which was used in this study, is provided as below:

Error analysis using basic Method-CREAM: This stage is presented as following:

Conducting Hierarchical Task Analysis [14]: This method analyzes executive activities and concentrates on the operators' perception of the tasks defined by operating programs and instructors to achieve the system goals. The HTA structure is to break up a specific task into detailed related subtasks [15, 18].

Assessment of Common Performance Conditions (CPCs): in this step, the common characteristics of each individual task and the working condition that affects operator's performance has been assessed by CPCs table (Table 1). Therefore, those conditions that improve or reduce operator's performance or make no significant changes on it can be determined and the total number of these conditions can be calculated. Effective working conditions are those factors which influence human error rates as considered in a CPCs human reliability analysis. Parameters to allocate CPCs factors for tasks are based on observing the process, reading and checking the work instructions and interviewing the operators of control room and Unit Chief [5, 9].

Determining the Probable Control Mode (PCM) and the Total of Cognitive Failure Probability (CFPt): In this step the total, number of Improved CPCs (I) is subtracted from the total number of Reduced CPCs (R) (Equation. 1) and the acquired number is used, according to Fig. 2, for determining the probable control mode. Moreover, Equation 2 is used to calculate the CFPt. Table 2 demonstrates the relation between CFPt and control modes. As can be seen in Table 2, by increasing CFPt, the control mode moves from Strategic Control Mode to Scramble Control Mode [8, 14].

Equation 1:

$$\beta = \sum R - \sum I$$

β = Control Mode Index

Equation 2:

$$CFPt=0.0056\times 10^{0.25\beta}$$

Table 1. Common Performance Conditions, CPCs [5,9]

CPC Name	Qualitative level	Expected effect on performance reliability
Adequacy of organization	Very efficient	Improved
	Efficient	Not Significant
	Inefficient	Reduced
	Deficient	Reduced
Working conditions	Advantageous	Improved
	Compatible	Not Significant
	Incompatible	Reduced
Adequacy of human-machine interaction and operational support	Supportive	Improved
	Adequate	Not Significant
	Tolerable	Not Significant
	Inappropriate	Reduced
Availability of procedures/plans	Appropriate	Improved
	Acceptable	Not Significant
	Inappropriate	Reduced
Number of simultaneous goals	Fewer than capacity	Not Significant
	Matching current capacity	Not Significant
	More than capacity	Reduced
Available time	Adequate	Improved
	Temporarily inadequate	Not Significant
	Continuously inadequate	Reduced
Time of day (Circadian rhythm)c	Day-time (adjusted)	Not Significant
	Night-time (unadjusted)	Reduced
Adequacy of training and preparation	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

Table 2. The relations between control mode, Total Cognitive Failure Probability (CFP_t), and Control Mode Index (β) [5]

Control mode	CFP_t	Control Mode Index (β)
Strategic	$0.00005 < P < 0.01$	- 7 to - 4
Tactic	$0.001 < P < 0.1$	- 3 to 1
Opportunistic	$0.01 < P < 0.5$	2 to 5
Scrambled	$0.1 < P < 1.0$	6 to 9

Table 3. List of critical cognitive activities [5]

Cognitive Activity	General definition
Co-ordinate	Bring system states and/or control configurations into the specific relation required to carry out a task or task step. Allocate or select resources in preparation for a task/job, calibrate equipment, etc.
Communicate	Pass on or receive person-to-person information needed for system operation by verbal, electronic or mechanical means. Communication is an essential part of management.
Compare	Examine the qualities of two or more entities (measurements) with the aim of discovering similarities or differences. The comparison may require calculation.
Diagnose	Recognize or determine the nature or cause of a condition by means of reasoning about signs or symptoms or by the performance of appropriate tests. "Diagnose" is more thorough than "identify".
Evaluate	Appraise or assess an actual or hypothetical situation, based on available information without requiring special operations. Related terms are "inspect" and "check".
Execute	Perform a previously specified action or plan. Execution comprises actions such as open/close, start/stop, fill/drain, etc.
Identify	Establish the identity of a plant state or sub-system (component) state. This may involve specific operations to retrieve information and investigate details. "Identify" is more thorough than "evaluate".
Maintain	Sustain a specific operational state. (This is different from maintenance that is generally an off-line activity.)
Monitor	Keep track of system states over time, or follow the development of a set of parameters.
Observe	Look for or read specific measurement values or system indications.
Plan	Formulate or organize a set of actions by which a goal will be successfully achieved. Plans may be short-term or long-term.
Record	Write down or log system events, measurements, etc...
Regulate	Alter speed or direction of a control (system) in order to attain a goal. Adjust or position components or subsystems to reach a target state.
Scan	Quick or speedy review of displays or other information source(s) to obtain a general impression of the state of a system / sub-system.
Verify	Confirm the correctness of a system condition or measurement, either by inspection or test. This also includes checking the feedback from prior operations.

Error analysis using extended method-CREAM: *Presenting a Cognitive Demands Profile (CDP) for the tasks:* In this step, the cognitive demands of each sub tasks were assessed by the table of critical cognitive activities (Table 3) in order to build a cognitive demands profile (CDP) and determine the cognitive characteristics required for each task. The purpose of the cognitive profile is to represent the demand characteristics of tasks and sub-tasks, and also to indicate the kind of failures that are expected. The list of characteristics of cognitive activities is shown in Table 3. In this regard, following parameters should be considered while determining cognitive demand of tasks and subtasks: information related to task analysis, observing the process, reading and surveying the work instructions and interviewing the operators of control room and the unit chief [5,9]

Identifying the likely cognitive failures: CREAM uses a model of cognition named the Contextual Control Model (COCOM) which assumes four basic cognitive functions including: observation, interpretation, planning, and execution. Each typical cognitive activity can be described in terms of a combination of these four cognitive functions (Table 4). As an example, co-ordination involves planning as well as execution: the planning is used to specify what is to be done, and the execution is used to perform it. Conversely, a task step that requires monitoring of the system will primarily impose a demand on observation and interpretation parts of cognitive functions. Knowing different cognitive functions, cognitive function failures can be predicted (Table 5). Parameters to allocate predict cognitive function failures for analyzed subtasks included information related to tasks and interviewing the operators of control room and the Unit Chief [5,9].

Determining the Cognitive Failure Probability (CFP): In this step, Equation 3 is used to determine the Cognitive Failure Probability (CFP) for each subtasks with regard to scores obtained from before steps [8, 14].

Equation 3:

$$CFP = CFP_0 \times 10^{0.25PII}$$

Equation 4:

$$PII = \sum_{i=1}^{9} PIIi$$

- CFP_0 = Is the nominal values (basic value) provided for cognitive function failures, listed in the Table 5
- PII = Performance Iinfluence Index
- PIIi = The values for each factor CPCs (*i*=1-9) from Table 1

Table 4. A generic cognitive-activity-by-cognitive- demand matrix [9]

Activity type	COCOM function			
	Observation	**Interpretation**	**Planning**	**Execution**
Co-ordinate			*	*
Communicate				*
Compare		*		
Diagnose		*	*	
Evaluate		*	*	
Execute				*
Identify		*		
Maintain			*	*
Monitor	*	*		
Observe	*			
Plan			*	
Record		*		*
Regulate	*			*
Scan	*			
Verify	*	*		

Table 5. Generic cognitive failure types [5,9]

Cognitive function	Generic failure type	Basic value (CFP_0)
Observation	O1. Wrong object observed	0.0010
	O2. Wrong identification	0.0070
	O3. Observation not made	0.0070
Interpretation	I1. Faulty diagnosis	0.0200
	I2. Decision error	0.0100
	I3. Delayed interpretation	0.0100
Planning	P1. Priority error	0.0100
	P2. Inadequate plan	0.0100
Execution	E1. Action of wrong type	0.0030
	E2. Action at wrong time	0.0030
	E3. Action on wrong object	0.0005
	E4. Action out of sequence	0.0030
	E5. Missed action	0.0030

RESULTS

The basic method-CREAM: In this section, one of the HTA diagrams (Figure 1) and analysis of CPCs factors for B.M tasks are given (Table 6). The results of basic CREAM-Method is presented in Table 7.

Table 6. Results of CPCs for B.M tasks

CPC Name	Level/Descriptors	Expected effect on performance reliability	Performance Influence Index (PII)
Adequacy of organization	Efficient	Not Significant	0.0
Working conditions	Compatible	Not Significant	0.0
Adequacy of MMI and operational support	Adequate	Not Significant	-0.4
Availability of procedures/plans	Acceptable	Not Significant	0.0
Number of simultaneous goals	More than capacity	Reduced	1.2
Available time	Temporarily inadequate	Not Significant	0.0
Time of day (Circadian rhythm)	Night-time (unadjusted)	Reduced	0.6
Adequacy of training and preparation	Inadequate	Reduced	1.8
Crew collaboration quality	Efficient	Not Significant	0.0
	$\sum R = 3$, $\sum I = 0$ $\beta = 3 - 0 = 3$		$\sum PII = 3.2$

Table 7. Results of CFP for analyzed tasks (basic method-CREAM)

Tasks	Control Mode Index (β)	CFPt	Control Mode
B.M	3	0.0315	Opportunistic
S.C	2	0.0177	Opportunistic
H.C	1	0.0099	Tactic

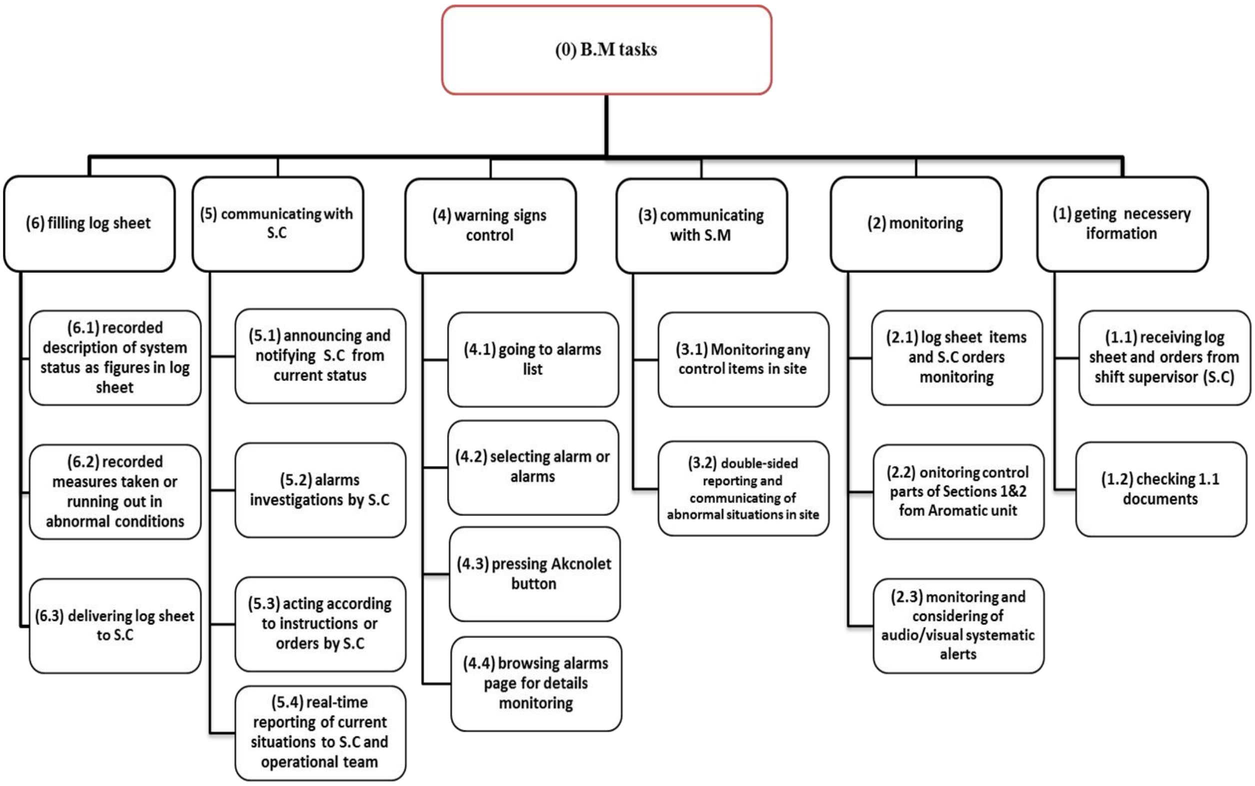
Base on the HTA, the job of B.M in aromatic control room of the study company included 6 main tasks and 18 subtasks. At the beginning of each shift, B.M gets necessary information from log sheet and S.C (first step). Then, he checks log sheet and S.C orders for controlling and monitoring of any items with close comminuting by S.M till end of shift work (second and third step). In case there is any alarm he would investigate the alarm and determine type of the alarm for troubleshooting by S.C supervision till end of solving the problems (step four and five). Recording and filling description of system status as figures in log sheet are other routine tasks of B.M in the end of shift work (step 6).

Results pertinent to assessment of CPCs for B.M tasks are presented in Table 6. Moreover, Table 7 shows results related to CFP of tasks in basic method-CREAM.

According to results shown in Table 6, the total number of conditions that will reduce performance (ΣR) is equal to 3 and the total conditions that will improve performance (ΣI) is equal to 0. The Control Mode Index (β), according to Euation 1, would be 3. According to Figure 2 the opportunistic control mode is selected for control mode type. β being 3, as shown above, based on Equation 2 the CFPt would be 0.0315. As shown in Table 2 this number is in opportunistic control mode area. A similar calculation has been performed for the S.C & H.C and the CFPt in these cases would be 0.0177, 0.0099, respectively. The control modes fall into opportunistic control and tactical control, based on CFPt values.

The extended method-CREAM: Table 8 presents one of the Cognitive Failure Probability (CFP) tables. Cognitive Demands Profile (CDP) is depicted in Figure 3, as well. According to results, total of identified error types and Cognitive Demands Profile (CDP) for the three analyzed tasks (H.C, S.C and B.M) are presented in Figures 4 and 5, respectively.

As an example, for subtask 2.2 (Table 8) type of cognitive activity was determined as Monitor. This activity refers to the cognitive functions of Interpretation and Observation (Table 4). Accordingly, the type of cognitive failure and CFP$_0$ score (basic value) for subtask 2.2 was obtained O2 and 0.007, respectively (Table 5). Based on Equation 4 the Performance Influence Index (PII) for B.M tasks from is equal to 3.2 (Table 6) and finally the CFP for this subtask (2.2), according to Equation 1, would be 0.04417. A similar calculation can be performed for each sub task.



Plan 0: First 1 then 2 & 3 simultaneous till end of shift. If there is alarm 4 & 5 and in the end of work shift 6.
Plan 1: First 1.1 then 1.2.
Plan 2: 2.1- 2.2- 2.3 simultaneously.
Plan 3: 3.1 in normal situations and 3.2 in abnormal situations.
Plan 4: If alarm was on the page 4.2 otherwise 4.1 then 4.3. If alarm not resolved 4.4 & 4.5 simultaneously.
Plan 5: 5.1 – 5.2. If problems was systematical 5.3 otherwise 5.4 till end of solving the problems.
Plan 6: 6.1- 6.2 - 6.3 respectively.

***Fig* 1.** HTA for the shift control (B.M) task

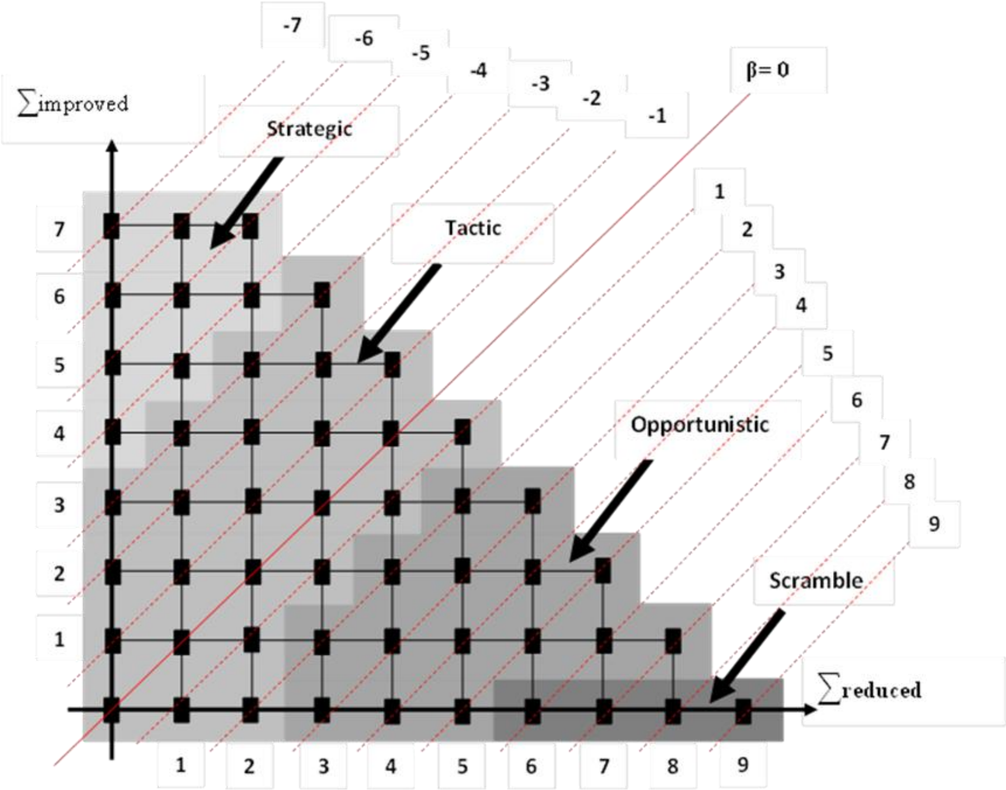


***Fig* 2.** Allocation of probable control modes according to CPCs (x=the number of reduced influenced indexes, y=the number of improved influence indexes) [8, 14]

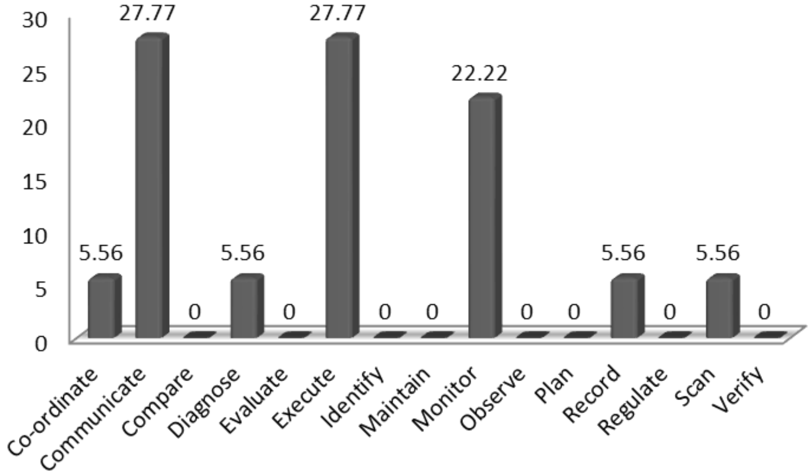


***Fig* 3.** Cognitive Demand Profile (CDP) for B.M task

Figure 4 shows the identified error types for the three analyzed tasks (H.C, S.C and B.M) as: execution failure (48.57%), interpretation failure (18.57%), planning failure (15.71%), and observation failure (17.15%). Cognitive Demands Profiles (CDP) of B.M task (Figure 3) shows that, the majority of its executive cognitive activities related are: co-ordinate (5.56%), communicate (27.77%), diagnose (5.56%), execute (27.77%), monitor (22.22%), record (5.56%) and scan activity (5.56%). Reviewing of CDP for the three analyzed tasks (Figure 5) showed that, the majority of cognitive activities, related to execution of those tasks in control room of petrochemical industries, are as: communicate, monitor, execute, plan, diagnose, evaluate, co-ordinate, verity, record and scan.

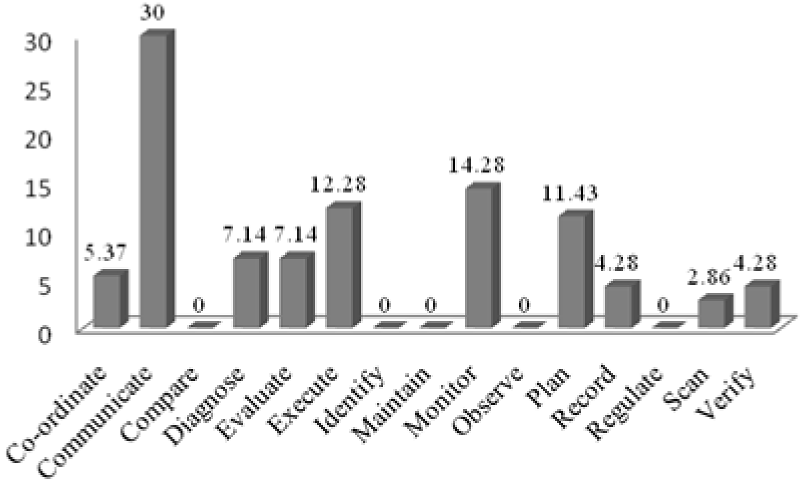


***Fig* 4.** Identified error types for 3 analyzed tasks (H.C, S.C and B.M)

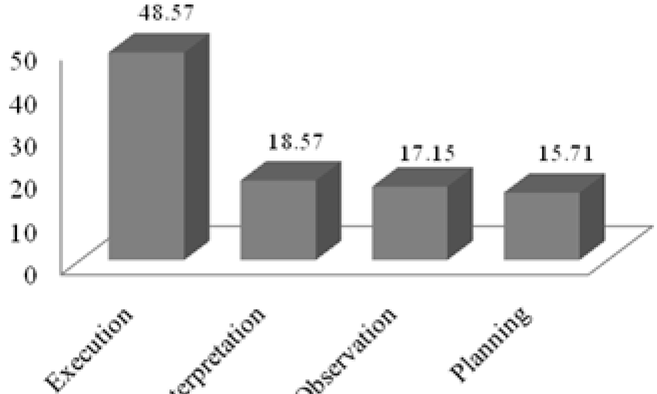


***Fig* 5.** Cognitive Demand Profile (CDP) for 3 tasks

Table 8. Results of CFP for B.M tasks (extended method-CREAM)

Task NO.	Sub-tasks NO.	Cognitive Activity	Cognitive function	Generic failure type	CFP_0	CFP
1.	1.1	Communicate	Execution	E2.	0.003	0.01893
	1.2	Scan	Observation	O2.	0.007	0.04417
2.	1.2	Monitor	Observation & Interpretation	O1.	0.001	0.00631
	2.2	Monitor	Observation & Interpretation	O2.	0.007	0.04417
	3.2	Monitor	Observation & Interpretation	O2.	0.007	0.04417
3.	1.3	Monitor	Observation & Interpretation	O2.	0.007	0.04417
	2.3	Communicate	Execution	E2.	0.003	0.01893
4.	1.4	Execute	Execution	E1.	0.003	0.01893
	2.4	Execute	Execution	E1.	0.003	0.01893
	3.4	Execute	Execution	E1.	0.003	0.01893
	4.4	Execute	Execution	E2.	0.003	0.01893
5.	1.5	Communicate	Execution	E2.	0.003	0.01893
	2.5	Diagnose	Planning & Interpretation	I1.	0.020	0.12620
	3.5	Execute	Execution	E1.	0.003	0.01893
	4.5	Communicate	Execution	E2.	0.003	0.01893
6.	1.6	Record	Execution & Interpretation	E5.	0.003	0.01893
	2.6	Co-ordinate	Execution & Planning	E5.	0.003	0.01893
	3.6	Communicate	Execution	E2.	0.003	0.01893

DISCUSSION

Basic method-CREAM: The Probable Control Modes (PCM), Cognitive Failure Probability (CFP) and Cognitive Demands Profile (CDP) were determined in the control room of aromatic unit in one of the petrochemical companies in Iran, using Cognitive Reliability and Error Analysis Method (CREAM). The final goal of the basic method-CREAM was to increase performance reliability and to decrease CFPt. In order to reach proper results, the control mode type should move from opportunistic mode to strategic mode. The reason is that when the performance reliability increases there would be less failure by the operators [17].

Wikstrand used CREAM technique to analyze a train collision between towns of Eksjö and Nässjö, occurred in 1996. In this study, CPCs factors were analyzed and demonstrated two mistakes including inadequate time to dispose for the task and lack of experience for switchman [17].

In the present study the analysis of CPCs factors for H.C, S.C and B.M demonstrated that "number of simultaneous work", "time of day (circadian rhythm)" and "adequacy of training and experience" are related to reduction of performance reliability. In order to increase performance reliability, the instruction for emergency situation should be used and the shift work schedule should be noted. Another strategy is to improve the quality of training courses.

In normal situations, operators of control room have the ability to do multiple tasks. However, in some cases (i.e. emergencies), the operators have to work simultaneously on various tasks and do their duties as reliable as possible. Therefore, a task instruction and an adequate training for performing it would be necessary. Lack of such instructions will make operators do their tasks by their own understanding and experience of process. Moreover, since each person has its own perception, the probability of error of commission and accordingly the probability of accident occurrence will increase.

In the study in petrochemical company, operators work in a regular 8 hour schedule for four shifts except for situations such as those with overtime working hours, working instead of other colleagues, working in times beyond normal daily working hours (except H.C who works only in day shifts). Therefore, it is important to manage shift schedules in a way that irregular shift work be restrained. In addition, according to B.Ms and supervisors assertions, training courses, provided by the company, are not up to dated, sufficient or informative enough to provide an adequate knowledge. Therefore, it is very important to consider training as an essential element and to schedule a codified program for teaching and reminding task details in order to prevent likely errors by control room operators.

Extended method-CREAM: Kubota et al. [17] analyzed organization-committed human errors, related to six departments, by extended CREAM [16].

These human errors were not caused by the tasks spotlighted by CREAM, but were concentrated on managerial or administrative tasks, so that the authors have corrected and analyzed the definitions and links of cause–effect relations related to the large organization by means of an extended method of CREAM.

According to these analyses, findings effective relations between organization-related casual factors and person-related ones were observed. This has demonstrated that organization-caused human errors can be analyzed by means of the extended method of CREAM. Moreover, of the seven human errors, a total of 21 final causal factors were extracted and of these causal factors, eight ones were related to person and 13 ones related to organization. Of the causes related to the organization, nine factors were pertinent to management, for instance inadequate role allocation, standard and rule problem, and inadequate task allocation. Two factors were related to tasks to meet excessive demand due to tasks in parallel, one factor related to communication, and one factor related to training. Regarding person-related factors, three were related to insistence and other cognitive bias, two were related to getting pressed for time, boredom and other psychological stressors, two were related to competing tasks, and one factor related to misjudgment about priority. This has demonstrated that organization-caused human errors are sufficiently analyzable by means of the extended method of CREAM [17].

In another study, [10] used a fuzzy classification system for human reliability analysis in order to calculate the probability of erroneous actions according to CREAM in specific contexts e.g. maintenance tasks, in-field actions or control room operations in the running of a chemical plant [10]. Analysis of the system's complexities was done and considerations for proper action procedures was suggested to developers. This study was a pilot application that showed the successful 'translation' of CREAM technique into a fuzzy logic model [10].

Reviewing the percentages of errors associated with each job task, in the present investigation, (Figure 5) it was indicated that among the total number of identified errors for B.M tasks, the execution error, has the maximum level, whereas the plan error has the minimum. Additionally, this mode For H.C task is the inverse of B.M task. This result can be illustrated by this fact that by moving toward high level of management not only execution error is reduced, but also plan error is increased. Considering the nature of tasks as well as the Cognitive Demands Profile (CDP) to perform each of job tasks, these results are reasonable because the most important task in relation to H.C is planning, whereas for B.M it is executing and communicating.

Cognitive Demands Profile (CDP) relating to performing each of job tasks, in control room, must be reviewed to find the root causes of cognitive failures. For instance, communicate is the pass on or receive person-to-person information needed for system operation by verbal, electronic or mechanical means [5]. The most commonly used system of the communication in the understudy control room is wireless system. It is worthwhile to note two important points related to those wireless system: First, the sound quality of wireless system was not desirable. Second, the noises in the control room impacted the quality of the received messages and thus increased probability of cognitive failures.

The aim of the first step of the CREAM-extended method is to create a cognitive demands profile (CDP) for each tasks. The purpose of the CDP is to represent the cognitive activities in relation to each task or sub-task. Therefore, to prevent or reduce cognitive errors in the control room, we need to know the exact type of cognitive activity, and develop a comprehensive program to increase the knowledge and skills.

CONCLUSION

This research was conducted to determine the Probable Control Modes (PCM), Cognitive Failure Probability (CFP) and create a Cognitive Demands Profile (CDP) in control room of Aromatic unit in one of the petrochemical companies in Iran, using basic and extended CREAM methods. Based on the results, control modes for the tasks of both B.M and S.C were determined as opportunistic, while it was in tactical mode for H.C tasks. The number of simultaneous goals, time of day (circadian rhythm) and adequacy of training and experience in the study field were the Common Performance Conditions (CPCs) that led to reduction of performance reliability. These CPCs factors contributed to the opportunistic control mode among employees. Considering the underlying causes of the low level control mode in this company, applying an appropriate instruction for emergency situation, accentuating on shift works and contents of training programs will improve CPC factors and will increase performance reliability (moving from opportunistic control mode to tactical and strategic control modes). In addition, in order to prevent or reduce cognitive errors in the control rooms, we need to know the exact types of cognitive activities, and develop a comprehensive program to increase the knowledge and skills. For workplaces such as control rooms, CREAM method is helpful and sensitive enough to determine types of control mode and Cognitive Failure Probability in control rooms.

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