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Human Reliability Analysis by Cognitive Approach for Unloading Process in an ALDS (Auto LPG Dispensing Station)

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Abstract

Background/Objectives: Accident dynamics always considers the role of humans in order to ensure effective prevention of dangerous events in engineering industries where the execution of highly repetitive and standardized tasks occurs. The centrality and responsibility of the role entrusted to the human operators are exalted because it requires problem solving and decision making ability. **Methods/Statistical Analysis:** Human operator is the core of a cognitive process that leads to decisions, influencing the safety of the whole system in function of their reliability. The main focus of the research is to systematically predict human error potentials (Failure probability) during unloading process of LPG from truck tank to the storage tank and to determine the required safety control levels. The paper adopted CREAM (Cognitive Reliability and Error Analysis Method) basic and extended versions in order to assess human reliability and is demonstrated with the above stated operator activity. **Findings:** The probability value for most of the failures are included in the 'tactical'control mode range 1.2E-3<P<8E-2 (1.0E-3 < p < 1E-1), as shown by the basic version of methodology. The overall human error probability value is assigned as the maximum value of the sub-tasks which is 8E-2. **Application/Improvements:** Quantification of failure probability is HRA is a highly difficult task. Availability of failure data helps to take various maintenance and management decisions. Consequently, the research contributes to safety at work and prevention of human injury and loss of life.

Keywords: Cognition, CREAM, Failure Probability, Human Reliability Analysis, LPG Dispensing Station

1. Introduction

In the context of reliability concept one of the most "critical" component is "human", whose rate of error changes the rate of breakdowns of components. In accident dynamics the "human factor" has contributed significantly, statistically and also in severity of consequences. It has been observed that human intervention are not negligible in system failures (Kirwan B,1994), some literatures has stated that human error is the cause of failure in systems having disastrous consequences which, in many cases are due to man - machine - environment interaction. In fact, estimates agree that 60% of accidents are due to errors committed by man and for the remaining part the causes are due to technical deficiencies.

Generally, in reliability systems studies, assessment disregarding aspects that depend on human factors, focuses on industry processes and technologies constituting it, and its contribution to the same reliability system. Over 90% of nuclear industries accidents[1], over 80% of petro-chemical and chemical industries[2], over 75% of casualties in marine sector[3], and over 70% of accidents in aeronautical sector[4,5]. Thus, the role of humans in accident dynamics should be considered in order to ensure effective prevention of dangerous events, during risk assessment processes[6]. The researchers propose models

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of human behavior[7] favoring prediction of error probability[8,9]. The analysis of human factors are not yet well defined, constitute a highly interdisciplinary field of study and a complete taxonomy of different types of human errors and its causes is not present. The objective difficulties of governing the human factor and human error have made many experts to relate it with a person's inherent characteristics, such as personality traits[10,11].

Fortunately, in recent years, techniques of risk analysis with human factor evaluation methodologies are collected under the name Human Reliability Analysis (HRA). Human Reliability Analysis identifies weaknesses and errors in a system by examining methods of work and the workers. HRA falls within the field of human factors and has been defined as the application of relevant information on human characteristics and behaviors to the design of facilities, objects and environments that people use[12]. HRA techniques are used retrospectively, in accident analysis, or to examine a system. Most approaches are firmly beached in a general approach which sees the human contribution in wider organizational and technical contexts[13,14]. The purpose is not to find fault or apportion blame but to examine task, process, system or organizational structure for where limitation may recline or create a vulnerability to errors. HRA can be applied to almost any process, in which humans are involved[15,16]. These human reliability analysis methodologies are first applied in the nuclear industries and then spread over to other industries. Shah Gholi-Nejad N et al[17] applied Hierarchical Task Analysis (HTA) method to an oil refinery unit for four positions including shift controller, head operators, control room's operators, and outside operators tasks are analyzed and human errors in the considered positions are identified and assessed using Technique for Retrospective and Predictive Analysis of Cognitive Errors (TRACEr). Electricity transmission Substation control room operators' tasks, as main human errors sources in the process of work permit issuance, were analyzed using HTA. Errors related to tasks were then predicted using Systematic Human Error Reduction and Prediction (SHERPA) technique[18]. The application of these methodologies requires a high level of training and expertise.

2. CREAM Approach

CREAM methodology was developed by Eric Hollnagel[19] in 1998 following an analysis of already in place HRA methods. It is the most widely utilized second generation HRA technique and is based on three primary areas of work; task analysis, opportunities for reducing errors and possibility to consider human performance with regards to overall safety of a system.

This methodology is a technique used in HRA for the purposes of evaluating probability of a human error occurring throughout completion of a specific task. From such analyses measures can then be taken to reduce likelihood of errors occurring within a system and therefore lead to an improvement in the overall levels of safety. There are two versions of CREAM: basic version and extended version. Basic version, to understand the error probability

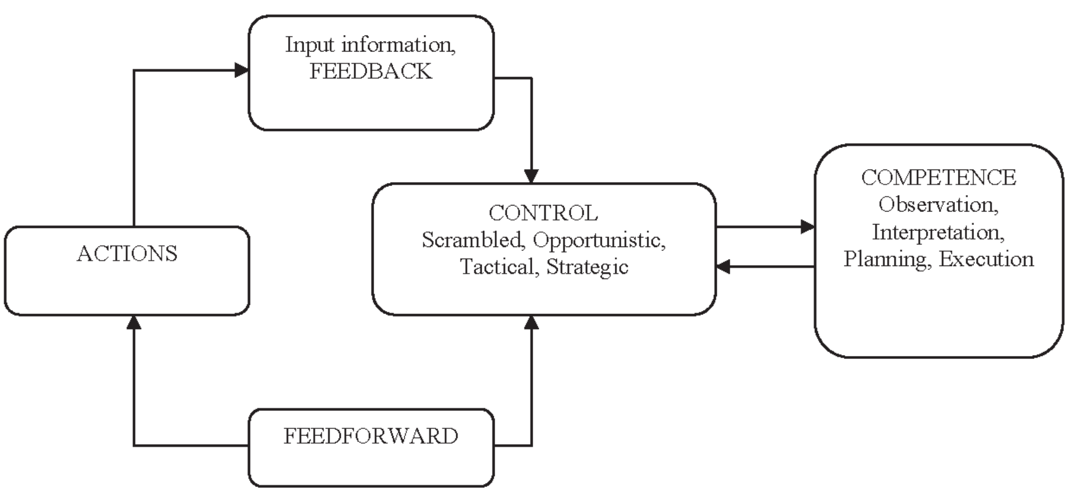

Figure 1. Contextual Control Model 'CoCoM'.

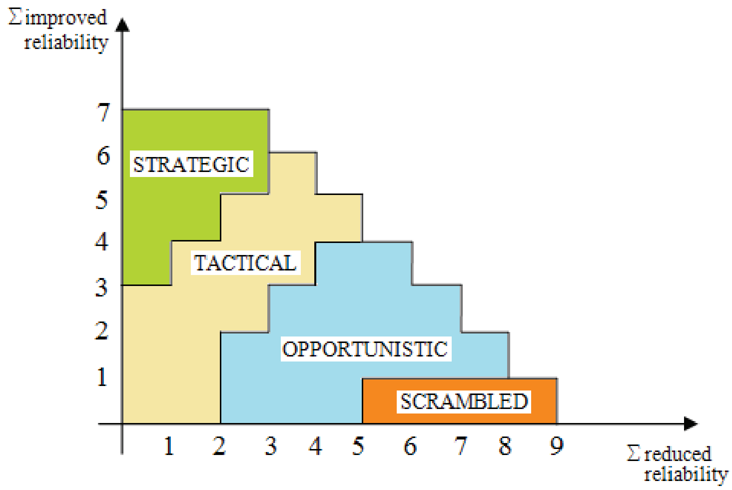

Figure 2. Relations between Common Performance Conditions (CPCs) Score and Control Modes.

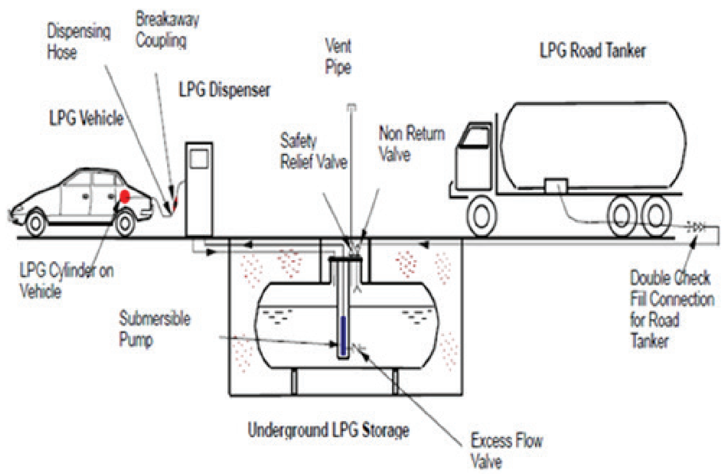

Figure3. LPG Dispensing Station.

range by providing an initial screening of human error. While as, extended version provides the detailed value of error probability by using the results of basic version. The application of the extended version is needed when the probability of action failures is acceptably low.

CREAM methodology is based on a cognitive model which presents an error classification that provides a step by step description of operator performance analysis while integrating organizational, technical and individual factors. In particular, classification is based on two principles (Figure1):

- Human error may be related with its manifestations, called phenotypes, and its causes, called genotypes;
- Phenotypes are result of interaction between genotypes and environment.

The identified cognitive model for CREAM methodology is called "CoCoM" (Contextual Control Model). In Figure 2 is shown Contextual Control Model. Through this model it is possible to determine the requested cognitive functions level in order to implement the analysed performance. The cognitive model application takes place via the individuation of total occurrence of CoCoM functions in performance. Cognition concept is included in the CoCoM model through use of four basic "control modes", which identify differing levels of control that an operator has in a given context and characteristics which

Table 1. Error probability intervals

Control modes	Error probability interval
Strategic	0.5e-5 < p < 1e-2
Tactical	1e-3 < p < 1e-1
Opportunistic	1e-2 < p < 0.5e0
Scrambled	1e-1 < p < 1e0

Table 2. Task Analysis of Unloading Process

S.NO.	GOAL	ID	ACTIVITY
1	UNLOADING	1.1	Check the position of the truck to be on marked space
		1.2	Check the engine is in off position
		1.3	Place chuck under the truck tyre
		1.4	Fire extinguishers are positioned near the unloading activity terminals
		1.5	The earth connection wire is clipped on the vessel
		1.6	The earth connection wire is clipped on the chasis
		1.7	Plunge and lock the LPG hose one end for storage tank
		1.8	Plunge and lock the LPG hose to the truck
		1.9	Plunge and lock the vapour line hose to the tank
		1.10	Plunge and lock the vapour line hose to the truck
		1.11	Check the dial in main control panel for overfill protection
		1.12	Take gauge reading of the existing quantity of the tanks
		1.13	Turn the lever to open position in truck
		1.14	Turn the lever to open position in tank
		1.15	Switch ON the pump.
		1.16	Check the value leakages if any smell from the hose
		1.17	Fill the tank not to exceed 80 % by using gauge and stop the process
		1.18	Pump is switched OFF, if storage tank is filled to 80% or the pump gets noisy
2	AFTER UNLOADING	2.1	Turn the lever to close in truck
		2.2	Turn the lever to close position in tank
		2.3.	Unlock and pull the LPG hose for disconnection of tank
		2.4	Unlock and pull the LPG hose for disconnection of truck
		2.5	Unlock and pull the vapour hose for disconnection of tank
		2.6	Unlock pull the vapour hose for disconnection of truck
		2.7	Unclip the electrical binding for chases
		2.8	Unclip the electrical binding for vessel
		2.9	Close the pipe lines outlet by using cap
		2.10	Record all gauge readings
		2.11	Take out the chucks placed under truck tyres

highlight occurrence of distinct conditions. The control modes which may occur are as follows (Figure 2):

- Scrambled control: The choice of next action is unpredictable or random. These modes indicate minimum control over the system that the operator have;
- Opportunistic control: The choice of next action is ascertained by characteristics of the situation which is due to lack of time, operator inexperience, etc. Situation is characterized by lack of planning possibly be due to the lack of available time;
- Tactical control: performance typically follows planned procedures with ad-hoc deviations still possible;
- Strategic control: plentiful time to consider actions in light of wider objectives and within the given framework is available. This mode enables an operator to perform better and more efficient than the other modes.

On the basis of the various control modes, error probability intervals are classified in the following Table 1. The

Table 3. CPCs Representation and Evaluation

CPCs	Qualitative Level	Expected effect
Adequacy of organisation	Very efficient	Improved
	Efficient	Not significant
	Inefficient	Reduced
	Deficient	Reduced
Working conditions	Advantageous	Improved
	Compatible	Not significant
	Incompatible	Reduced
Adequacy of man-machine interaction and operational support	Supportive	Improved
	Adequate	Not significant
	Tolerable	Not significant
	Inappropriate	Reduced
Feasibility of procedures and 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	Day time	Not significant
	Night time	Reduced
Adequacy of training and preparation	Adequate (high experience)	Improved
	Adequate (low experience)	Not significant
	Inadequate	Reduced
Crew collaboration quality	Very efficient	Improved
	Efficient	Not significant
	Inefficient	Not significant
	Deficient	Reduced

particular control mode determines level of reliability, expected in a particular setting and this determined by collective characteristics of relevant CPCs.

CREAM methodology (basic and extended version) consists in the following steps:

BASIC VERSION

- Step 1. Hierarchical Tasks Analysis (HTA);
- Step 2. CPCs evaluation;
- Step 3. Control Mode/error interval determination;

EXTENDED VERSION (if needed)

- Step 4. Requested cognitive profile construction;
- Step 5. Possible failure modes of cognitive functions;
- Step 6. Error probability definition.

The main advantages of this methodology are: the technique uses the same principles for retrospective and predictive analyses; the approach is very concise, well-structured and follows a well laid out system of procedure; the technique allows the evaluator to tailor the use of technique to a frame work and quantification of human error probability[20,21]. Instead, the main criticisms are: this technique requires a high level of resource use, lengthy time periods and expertise in field of human factors for completion.

3. A Case Study of a Human Reliability Analysis

In this paper the CREAM methodology applied in a real case study is presented. Here below the methodological approach is presented.

3.1 System Studied: Liquefied Petroleum Gas Dispensing Station

Liquefied Petroleum Gas (LPG) is delivered in LPG bullets to the sites via trucks. A Positive displacement sliding

Table 4. CPCs Characterization

Common Performance Conditions	∑Improved	2
	∑Reduced	0

Table 5. Methodological Matrix of Cognitive Activities

Cognitive Activity	CoCoM Functions			
	Observation	Interpretation	Planning	Execution
Coordinate			X	X
Communicate				X
Compare		X		
Diagnose		X	X	
Assess		X	X	
Execute				X
Identify		X		
Maintain			X	X
Monitor	X	X		
Observe	X			
Plan			X	
Set		X		X
Adjust	X			X
Examine	X			
Verify	X	X		

vane pump is used to transfer LPG from bullet to High pressure LPG storage tank. The pump mentioned above is driven by a three phase induction motor. The output flow of pump is 200 L/min at 90 to 100 psi. The bullet has two outlets, one is to transfer LPG from bullet to high pressure LPG tank and another line is to transfer vapor from the tank to the bullet. Two earth connections are provided near the pump in order to protect structures and equipment from the effects of stray electrical current, and electrostatics discharges by the provision of a safe path of electrical charges to ground. Regulated power supply of 415 V, 3-Phase, 50 HZ is provided to the system by means of servo controlled voltage stabilizer.

A high pressure storage tank with 10000 liters capacity, storing at 90 to 100 Psi is used to store LPG which is transferred from bullet. A bank of two high-pressure storage vessels with a total capacity of 10000 liters of LPG is normally present.

LPG dispenser is used to transfer LPG to vehicles from storage tank via nozzle. The LPG dispenser is of flameproof type and all components comply with the requirements of applicable standards. Remote operated shut-off valve is provided for the LPG return line of the dispenser. A pump control mechanism is provided in the dispenser such that the submersible pump of the filling system can be switched on/off automatically when the dispensing nozzle is in and out of its receptacle. A break-away coupling is provided between the excess flow valve in the dispenser and the outgoing flexible dispensing hose to protect against excessive leakage of LPG liquid in the event, the driver drives away the LPG vehicle when the dispensing nozzle is still engaged to the vehicle. The LPG Fueling Station outlet studied has its common design bases as follows; Number of vehicles refueled=120 per day; Number of vehicles per hour= 5No's & Vehicle refueling time= 2 min/vehicle.

The layout observes the separation distances of storage vessels between each other and from boundary line of the dispensing station stated as minimum safety distances between facilities associated with storage and dispensing of Liquefied Petroleum Gas in LPG dispensing/dispensing station as automotive fuel to motor vehicles in Static & Mobile Pressure Vessels (Unfired) Rules, 1981. The cathodic protection shall be complimentary to the protective surface coating on the LPG Tank and the sacrificial anode shall be either a Zinc or Magnesium anode. Figure 3 shows the process flow of a LPG dispensing station.

Table 6. Methodological Matrix of Cognitive Activities

Goal	ID	Activity	Cognitive Activity	Cognitive Functions			
				Observation	Interpretation	Planning	Execution
Unloading	1.1	Check the position of truck on marked space	Verify	X	X		
	1.2	Check the engine is in off position	Verify	X	X		
	1.3	Place chuck under the truck tyre	Set		X		X
	1.4	Fire extinguishers are positioned near the unloading activity terminals	Execute				X
	1.5	The earth connection wire is clipped on vessel	Set		X		X
	1.6	The earth connection wire is clipped on chasis	Set		X		X
	1.7	Plunge and lock the LPG hose one end for storage tank	Set		X		X
	1.8	Plunge and lock the LPG hose to the truck	Set		X		X
	1.9	Plunge and lock the vapour line hose to tank	Set		X		X
	1.10	Plunge and lock the vapour line hose to truck	Set		X		X
	1.11	Check the dial in main control panel for overfill protection	Verify	X	X		
	1.12	Take gauge reading of the existing quantity of the tanks	Observe	X			
	1.13	Turn the lever to open position in truck	Execute				X
	1.14	Turn the lever to open position in tank	Execute				X
	1.15	Switch ON the pump.	Execute				X
	1.16	Check the value leakages - any smell from hose	Verify	X	X		
	1.17	Fill the tank not to exceed 80 % by using gauge and stop the process	Adjust	X			X
	1.18	Pump is switched OFF, if storage tank is filled to 80% or the pump gets noisy	Execute				X
After unloading	2.1	Turn the lever to close in truck	Execute				X
	2.2	Turn the lever to close position in tank	Execute				X
	2.3.	Unlock and pull the LPG hose for disconnection of tank	Adjust	X			X
	2.4	Unlock and pull the LPG hose for disconnection of truck	Adjust	X			X
	2.5	Unlock and pull the vapour hose for disconnection of tank	Adjust	X			X
	2.6	Unlock and pull the vapour hose for disconnection of truck	Adjust	X			X
	2.7	Unclip the electrical binding for chases	Execute				X
	2.8	Unclip the electrical binding for vessel	Execute				X
	2.9	Close the pipe lines outlet by using cap	Set		X		X
	2.10	Record all gauge readings	Adjust	X			X
	2.11	Take out the chucks placed under truck tyres	Execute				X

3.2 CREAM Methodology Application

In the present phase CREAM methodology is applied. Basic Version and Extended version is analysed.

BASIC VERSION

Step 1 - Hierarchical Tasks Analysis (HTA)

In a logical time sequence, specific operators' tasks are ordered. In this example the unloading process of LPG refuelling station is analysed (Table 2).

Step 2 - CPCs Evaluation

CPCs evaluation is made. The expected effect on the reliability of performance is shown in Table 3.

Table 7. Cognitive Functions and Error Modes

Cognitive function	CoCoM functions	
	Error Modes	**Mode Description**
Observation	*O1*	Observation of wrong object
	O2	Wrong identification made
	O3	Observation not made
Interpretation	*I1*	Faulty (wrong or incomplete) diagnosis
	I2	Decision error (not making or wrong decision)
	I3	Delayed interpretation (not in time)
Planning	P1	Priority error
	P2	Inadequate plan formulated
Execution	*E1*	Execution of wrong type (force, distance, speed or direction)
	E2	Action at wrong time
	E3	Action at wrong object
	E4	Action out of sequence
	E5	Action missed (not performed)

Table 8. Cognitive Functions and Error Modes of LPG unloading Operations

Goal	Activity	Cognitive Activity	Cognitive Functions												
			Observation			Interpretation			Planning		Execution				
			O1	O2	O3	I1	I2	I3	P1	P2	E1	E2	E3	E4	E5
Unloading	1.1	Verify		X		X									
	1.2	Verify		X		X									
	1.3	Set				X									X
	1.4	Execute													X
	1.5	Set				X					X				
	1.6	Set				X					X				
	1.7	Set				X									X
	1.8	Set				X									X
	1.9	Set				X									X
	1.10	Set				X									X
	1.11	Verify		X		X									
	1.12	Observe			X										
	1.13	Execute												X	
	1.14	Execute												X	
	1.15	Execute												X	
	1.16	Verify		X			X								
After Unloading	1.17	Adjust		X											X
	1.18	Execute													X
	2.1	Execute													X
	2.2	Execute													X
	2.3.	Adjust		X											X
	2.4	Adjust		X											X
	2.5	Adjust		X											X
	2.6	Adjust		X											X
	2.7	Execute													X
	2.8	Execute													X
	2.9	Set				X								X	
	2.10	Adjust		X							X				
	2.11	Execute													X

Table 9. Nominal Value of CFPs (Cognitive Failure Probability)

Cognitive function	CoCoM functions		
	Error Modes	**Mode Description**	**Nominal value**
Observation	O1	Observation of wrong object	1.0E-3
	O2	Wrong identification made	7.0E-3
	O3	Observation not made	3.0E-3
Interpretation	I1	Faulty (wrong or incomplete) diagnosis	2.0E-1
	I2	Decision error (not making or wrong decision)	1.0E-2
	I3	Delayed interpretation (not in time)	1.0E-2
Planning	P1	Priority error	1.0E-2
	P2	Inadequate plan formulated	1.0E-2
Execution	E1	Execution of wrong type (force, distance, speed or direction)	3.0E-3
	E2	Action at wrong time	3.0E-3
	E3	Action at wrong object	5.0E-4
	E4	Action out of sequence	3.0E-3
	E5	Action missed (not performed)	3.0E-2

Table 10. CPCs Characterization

CPCs	Performance reliability	Cognitive functions			
		Observation	**Interpretation**	**Planning**	**Execution**
Adequacy of organization	Not significant	1.0	1.0	1.0	1.0
Working conditions	Improved	0.8	0.8	0.8	0.8
Adequacy of MMI and operational support	Not significant	1.0	1.0	1.0	1.0
Feasibility of procedures and plans	Not significant	1.0	1.0	1.0	1.0
No. of simultaneous goals	Not significant	1.0	1.0	1.0	1.0
Available time	Improved	0.5	0.5	0.5	0.5
Time of day	Not significant	1.0	1.0	1.0	1.0
Adequacy of training and preparation	Not significant	1.0	1.0	1.0	1.0
Crew collaboration quality	Not significant	1.0	1.0	1.0	1.0
Total Influence Of CPCs		0.4	0.4	0.5	0.4

Step 3 - Control Mode/Error Interval determination

In the present activity CPCs characterization is made. Considering the relations between CPC score and control modes (Figure 3), it was possible determine the control mode. According to the previous results, the Control Mode is 'Opportunistic/Tactical' and it is necessary to apply the extended version.

Extended Version

Step 4 - Requested Cognitive Profile Construction

The purpose of this step is to define the Cognitive Profile considering dependencies between cognitive activities and CoCoM functions as shown in the following Table 5 (Table 5):

In the specific case, it is developed as below (Table 6):

Step 5 - Possible Failure Modes of Cognitive Functions

In the present activity, the error of cognitive function is identified through the use of the following error modes, relating unloading operations (Table 7 and Table 8):

Step 6 – Cognitive Failure Probability (CFP) Definition

Final values of Cognitive Error Probability (Table 9) are determined from nominal values of CFPs (Table 9), and the 'weighting factors' (Table 10) to adjust nominal values of CFPs. The weighting factors are determined from the CFPs corrective factors described by Hollnagel.

Table 11. Adjusted CFPs for Cognitive Function Failures

Id	Activity	Error mode	Nominal value	Weighting factor	Adjusted CFP
1.1	Check the position of the truck to be on marked space	O2	7E-3	0.4	2.8E-3
		I1	2E-1	0.4	8E-2
1.2	Check the engine is in off position	O2	7E-3	0.4	2.8E-3
		I1	2E-1	0.4	8E-2
1.3	Place chuck under the truck tyre	I1	2E-1	0.4	8E-2
		E5	3E-2	0.4	1.2E-2
1.4	Fire extinguishers are positioned near the unloading activity terminals	E5	3E-2	0.4	1.2E-2
1.5	Earth connection wire is clipped on vessel	I1	2E-1	0.4	8E-2
		E1	3E-3	0.4	1.2E-3
1.6	The earth connection wire is clipped on the chasis	I1	2E-1	0.4	8E-2
		E1	3E-3	0.4	1.2E-3
1.7	Plunge and lock the LPG hose one end for storage tank	I1	2E-1	0.4	8E-2
		E5	3E-2	0.4	1.2E-2
1.8	Plunge and lock the LPG hose to the truck	I1	2E-1	0.4	8E-2
		E5	3E-2	0.4	1.2E-2
1.9	Plunge and lock the vapour line hose to the tank	I1	2E-1	0.4	8E-2
		E5	3E-2	0.4	1.2E-2
1.10	Plunge and lock the vapour line hose to the truck	I1	2E-1	0.4	8E-2
		E5	3E-2	0.4	1.2E-2
1.11	Check the dial in main control panel for overfill protection	O2	7E-3	0.4	2.8E-3
		I1	2E-1	0.4	8E-2
1.12	Take gauge reading of the existing quantity of the tanks	O3	3E-3	0.4	1.2E-3
1.13	Turn the lever to open position in truck	E4	3E-3	0.4	1.2E-3
1.14	Turn the lever to open position in tank	E4	3E-3	0.4	1.2E-3
1.15	Switch ON the pump.	E4	3E-3	0.4	1.2E-3
1.16	Check value leakages if any smell from the hose	O2	7E-3	0.4	2.8E-3
		I2	1E-2	0.4	4E-3
1.17	Fill the tank not to exceed 80 % by using gauge and stop the process	O2	7E-3	0.4	2.8E-3
		E5	3E-2	0.4	1.2E-2
1.18	Pump is switched OFF, if storage tank is filled to 80% or the pump gets noisy	E5	3E-2	0.4	1.2E-2
2.1	Turn the lever to close in truck	E5	3E-2	0.4	1.2E-2
2.2	Turn the lever to close position in tank	E5	3E-2	0.4	1.2E-2
2.3	Unlock and pull the LPG hose for disconnection of tank	O2	7E-3	0.4	2.8E-3
		E5	3E-2	0.4	1.2E-2
2.4	Unlock and pull the LPG hose for disconnection of truck	O2	7E-3	0.4	2.8E-3
		E5	3E-2	0.4	1.2E-2
2.5	Unlock and pull the vapour hose for disconnection of tank	O2	7E-3	0.4	2.8E-3
		E5	3E-2	0.4	1.2E-2
2.6	Unlock pull the vapour hose for disconnection of truck	O2	7E-3	0.4	2.8E-3
		E5	3E-2	0.4	1.2E-2
2.7	Unclip the electrical binding for chases	E5	3E-2	0.4	1.2E-2
2.8	Unclip the electrical binding for vessel	E5	3E-2	0.4	1.2E-2
2.9	Close the pipe lines outlet by using cap	I1	2E-1	0.4	8E-2
		E4	3E-3	0.4	1.2E-3
2.10	Record all gauge readings	O2	7E-3	0.4	2.8E-3
		E1	3E-3	0.4	1.2E-3
2.11	Take out the chucks placed under truck tyres	E5	3E-2	0.4	1.2E-2

4. Results and Discussion

The unloading process consists of 29 sub-tasks which shall be conducted correctly in order to complete the whole sequential process in a auto LPG dispensing station. From Table 11 is possible determine the value of Cognitive Failure Probability. The probability value for most of the control modes are included in the "tactical" control mode range 1.2E-3<P<8E-2 (1.0E-3 < p < 1E-1), as shown by the basic version of methodology. It means that if any of 29 sub-task operations fails, will lead to the malfunction of the unloading operations. Since the subtasks have high dependency, overall human error probability value can be assigned as the maximum value of the sub-tasks which is 8E-2. Further decrease in failure rate due to precautionary measures like educating/training the operator periodically further reduces the failure probability in the ranges of tactical control mode.

5. Conclusion

It is quite difficult to attain error data for most of HRA methods. Therefore, cognition method is an alternative solution to overcome scarcity of data. The CREAM extended version apparently gives satisfactory result since the methodology based on cause and effect classification scheme. Thus, the method can be utilized as guidance for data collection and assessment

6. References

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