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Application of SHERPA to Identify and Prevent Human Errors in Control Units of Petrochemical Industry

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Introduction. *Studying human errors as a risk factor in the occurrence of accidents is necessary. Thus, the aim of this study was to identify, predict and control human errors in industrial control units.* ***Method.*** *This is a case study carried out using SHERPA in the first unit of Zagros Methanol of Asalooyeh, Iran, and its subunits. To collect the required data, various methods were used: observing, interviewing processing specialists and control unit operators, and studying technical documents and records.* ***Results.*** *In total, 222 human errors were identified in various occupational tasks. This study showed that 48.62% of them were action errors, 31.97% were checking errors, 6.75% were retrieval errors, 11.70% were communication errors and 0.90% were selection errors.* ***Conclusion.*** *It can be inferred that this method is appropriate for different industries, and it is useful for identifying human errors leading to hazardous accidents.*

human factors human error SHERPA petrochemical

1. INTRODUCTION

The need for safety principles and the safe designing of equipment to prevent accidents and damage to the equipment and staff gains special importance due to the increasing development and appearance of modern technologies in industry. Several decades ago, some researchers tried to compare the components involved in the emergence of accidents including unsafe action and conditions. To this end, Heinrich (as cited in Brauer [1]) studied ~75 000 accidents and concluded that 88% of them were due to unsafe actions, 10% were due to unsafe conditions and 2% were due to inevitable factors. The results of studies in gas treatment, foundry and metal working companies in Iran indicated that the percentage of unsafe acts was significantly high. The main reasons of unsafe behaviours were awkward postures due to lack of an ergonomic design of workplaces (unsafe conditions). Moreover, those studies showed that there was a significant relationship between unsafe acts and conditions in previous accidents [2]. Basically, designing should be done in a way that limits the possibility of any type of human errors, thereby reducing the

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causes that lead to the occurrence of accidents. In the early decades of the 20th century, many authorities used Heinrich's law to criticize their personnel for accidents. Today, the same principles are applied to controlling the unsafe actions of individuals [3].

Though the role of human errors in the occurrence of accidents is obvious, and the catastrophic consequences due to not studying human errors as a risk factor are quite clear, these errors are unfortunately not considered in assessing safety parameters. So, all types of human errors, from the designing phase to the stress and exhaustion resulting from using improper techniques, should be considered. Regarding the effective guiding of resources to reach safety goals, some useful information can be provided through studying individuals' tasks. Such information and data enable industries to stabilize their actions, increase the quality and reliability of their products, reduce compensatory payments to their workers and, ultimately, increase the production of their company [4]. Systematic human error reduction and prediction approach (SHERPA) is one of the most applicable methods for studying human errors. Embrey made this systematic human error prediction method available in 1986 [5]. Lane, Stanton and Harrison reported that some studies explained the use of SHERPA in the chemical process. Also, SHERPA has been used to identify pilot errors, errors during laparoscopic or keyhole surgery and errors which occur during the use of consumer products such as ticket machines. Furthermore, the reliability and validity statistics of this technique are interesting, as most studies reported from .74 to .80 for validity and .65 to .90 for reliability [6].

One of the common characteristics of large industrial systems such as the oil industry and petrochemistry is the presence of large quantities of potentially dangerous materials in units controlled by several operators. The accidents in these processes not only threaten their equipment and personnel, but also highly affect the neighbouring areas and countries [7]. As critical responsibility of process control is continually imposed on control unit operators, human errors demand special attention. Hence, the following objectives were set forth in this research project:

- identification and prediction of human errors;
- recognition and prediction of error-inducing situations;
- identification of critical errors;
- provision of some controlling solutions to reduce human errors using SHERPA.

2. METHODS AND MATERIALS

This case study took place in the first unit of Zagros Methanol of Asalooyeh, Iran, and its related subunits. To collect the required data and fill in the SHERPA questionnaires, various methods were used: observing, interviewing processing specialists and control unit operators, and studying technical documents and records. To achieve the purpose of this study, critical occupational workstations and important units were identified. Among the tasks in the control units, the errors of the operators of units 100, 200 and 300 were categorized as highly critical, whereas those of the operators of units 100, 150, 200 and 250 as critical and harmful to human. SHERPA was used in these units. Five employees worked there in rotating 12-h shifts in cycles of 2 weeks of work followed by a week of rest.

SHERPA human errors analysis method consists of common questions and answers which discern similar errors at each step of the occupational task analysis [5]. SHERPA involves eight steps:

1. Hierarchical task analysis. This step focuses on individuals' perception of task to reach goals set by operational programmes or designs and principles to reach those goals. It plans all phases of work from bottom to top to reach those objectives (Figure 1).
2. Task classification. Each step of work is considered for error classification from the lowest level of analysis:

    - action: pulling a switch or pressing a button to open a door;
    - retrieval: receiving information from a monitor or guideline, etc.;

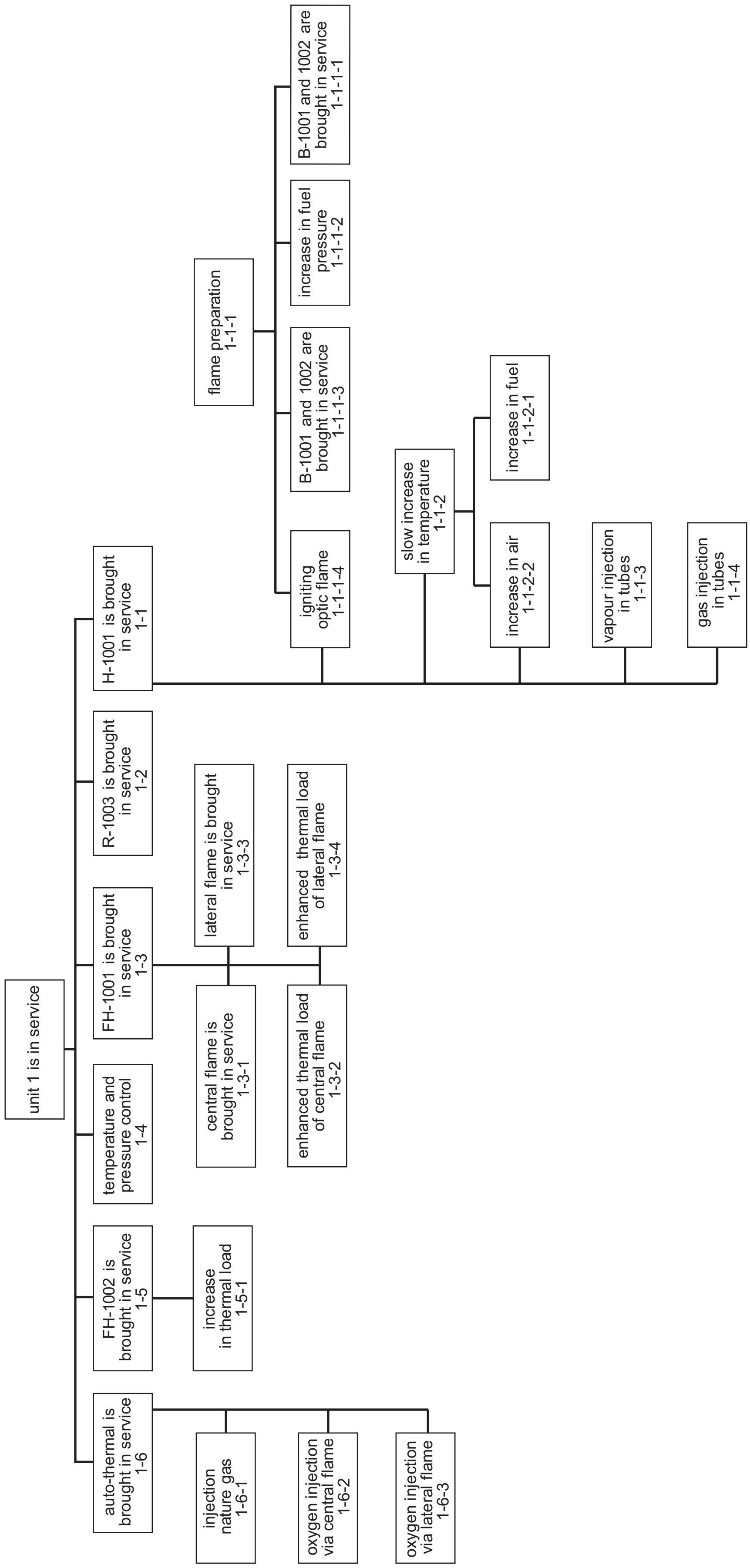

Figure 1. Hierarchical operatory task analysis of units 100 and 150.

- checking: leading and managing a checking process;
- selection: selecting another strategy on the basis of orders from higher authorities;
- information communication: talking to other departments or groups.

The following errors can be studied with this method:

- action: this error is in fact related to the actions of individuals, i.e., the individuals do not do their task appropriately or promptly;
- retrieval: the immediate action after an error to return the system to its original state;
- checking: an error in which individuals do not do the checking timely or properly;
- communication: an error in the process of communicating with other sections, i.e., wrong information is received;
- selection: the operator selects the wrong choice or forgets to select a step in the process of controlling the system. In this step, using a special checklist (Table 1), the error code is determined and recorded in the error mode column of the sheet (Table 2). For example, the error code is read from Table 1 as A1 (e.g., an action is too long or too short) and recorded in the worksheet (Table 2).

TABLE 1. SHERPA Error Mode Checklist

Error Mode	Code	Error Category
Operation too long/short	A1	action
Operation mistimed	A2	
Operation in wrong direction	A3	
Too little/much operation	A4	
Misalignment	A5	
Right operation on wrong object	A6	
Wrong operation on right object	A7	
Operation omitted	A8	
Operation incomplete	A9	
Wrong operation on wrong object	A10	
Check omitted	C1	checking
Check incomplete	C2	
Right check on wrong object	C3	
Wrong check on right object	C4	
Check mistimed	C5	
Wrong check on wrong object	C6	
Information not obtained	R1	retrieval
Wrong information obtained	R2	
Information retrieval incomplete	R3	
Information not communicated	I1	communication
Wrong information communicated	I2	
Information communication incomplete	I3	
Selection omitted	S1	selection
Wrong selection made	S2	

TABLE 2. Sample Results of SHERPA in Zagros Petrochemical

Task Step	Task Type	Error Mode	Description	Consequence	Recovery	Risk Level	Remedial Measure
1-1-1-2	increase in fuel pressure of flames	A1	increase in fuel pressure of flames is performed too early or too late	furnace is out of service as a result of increase or decrease in output temperature of H-1001	5-1-4[a]	2B	1. Modify the siren sound of the alarm system. 2. Prepare procedures and checklists for starting the flames; use the experience of the operator of unit 100.
		A5	change in fuel pressure is not performed properly	H-1001 is out of service	5-1-4	2B	1. Use simulator to improve operator skills. 2. Introduce structural changes in controlling software H-1001, so it requires operator confirmation if altering is over 10%.

Notes. a = in the Recovery column, 5-1-4 means controlling flame output temprature.

3. Human error identification. The classification of task steps leads the analyser to checking action errors through classifying lower-level errors. A description of the occurrence of each error is presented [8].
4. Consequence analysis. Examining the consequences of each error for the system is the next critical step, which brings about applied consequences of the critical error. It is necessary for the analyser to give a full description of results along with identification of error.
5. Recovery analysis. The analyser should determine the recovery of potential identified errors in this step, i.e., the analyser decides which action is necessary to prevent this type of error. First, this action, obtained in the hierarchical task analysis, is determined and the next step is entered. For example, we have referred to 5-1-4 code, which is recorded in the sixth column of the worksheet (Table 2); this error code was obtained in the hierarchical task analysis and can be considered as an error recovery action to prevent the determined error (A1).
6. Ordinal probability analysis. Results and recovery necessary to estimate the probability of the error have been obtained. So, in this step, the probability of the error is determined with regard to Table 3.
7. Criticality analysis. In this step, the severity of damage caused by human error is determined on the basis of Table 3. After combining it with the probability of error, the relevant risk level is determined and recorded in the seventh column of the worksheet (Table 2). As indicated, the risk level is 2B, meaning that the occurrence of the error is probable and damage is critical.
8. Remedy analysis. The final step in this method consists in strategies for reducing human errors. They have the form of suggested changes and modifications in the system as a way to prevent human errors and come in four categories:
   - equipment (redesigning or modifying the present equipment);
   - training (developing new educational and training curricula or programmes, modifying the course of training);
   - guidelines (providing new guidelines and instructions or revising old guidelines and instructions);
   - organizational and management modifications.

3. RESULTS

In this study, 222 human errors identified in occupational tasks were investigated with SHERPA. The errors were documented in SHERPA worksheets. Of these, 108 errors were action errors (48.62%), 71 errors were checking errors (31.97%), 15 errors were retrieval errors (6.75%), 26 errors were communication errors (11.70%) and 2 errors were selection errors (0.90%). Figure 2 demonstrates the status of identified human errors, the most important of which were not doing one's tasks, doing a tasks later than necessary, incomplete performance of tasks

TABLE 3. Risk Assessment Matrix: Risk Level

		Catastrophic	Critical	Marginal	Insignificant
Risk		**1**	**2**	**3**	**4**
Frequent	A	1A	2A	3A	4A
Probable	B	1B	2B	3B	4B
Occasional	C	1C	2C	3C	4C
Remote	D	1D	2D	3D	4D
Improbable	E	1E	2E	3E	4E

Notes. Shading indicates risk level; the darker the shade, the higher the risk level.

and forgetting the checking process. Each error had a high probability of occurrence regarding the accidents. They are especially critical in emergencies.

Figure 3 presents the predicted risk level obtained from 75 worksheets in this research.

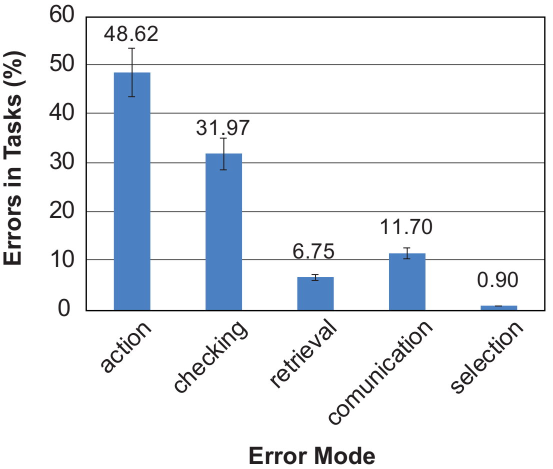

Figure 2. Indentified errors in tasks in units 100, 150, 200 and 300.

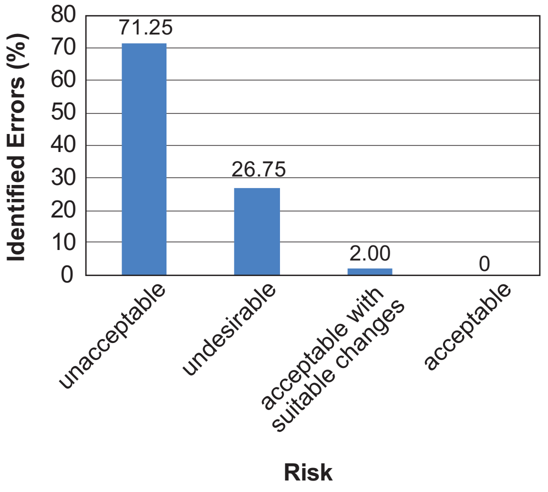

Figure 3. Risk acceptability associated with identified errors.

4. DISCUSSION

The present study focused on human errors in the petrochemical industry. Its findings can be used in preventing human errors in similar industries. The occupational task under study was "increase in fuel pressure of flames" (Table 2). This task identified types of human errors; they were recorded in the third column of the table (error mode). In the first error mode, i.e., A1, the act of increasing the fuel pressure of flames was done either too early or too late. In the second error mode, i.e., A5, change in fuel pressure of flames was not performed properly and accurately. Putting H-1001 out of service, as the fifth column of Table 2 indicates, was the consequence of those errors.

The technique was completed with standard MIL-STD-88213 in the seventh column. The standard was introduced in 1984 in the U.S. military industries [9]. Risk was grouped into four categories according to the intensity of danger: catastrophic, critical, marginal and insignificant (Table 3). The eighth column presents the controlling strategies for preventing and reducing human errors; modifying the siren sound of the alarm system was one of them. Software modifications and improving the alarm system were also considered. According to Ghalenoei, Asilian, Mortazavi et al., the probability of error due to the alarm system is .43 [10].

Another method of error control is the use of checklists. It has been estimated that the probability of error occurrence due to the operator's forgetting to do one stage of the task is .100, if no reminding instrument is used. If a checklist or guidelines are used at that stage of the task, the probability of the occurrence of that error is reduced to .003. This point clearly shows the importance of checklists [11].

The use of digital simulators is another method of controlling errors [12]. Simulating systems can be used to identify the weak points of control unit operators and to improve their skills and abilities. A plan for removing the weak points through identifying individuals' shortcomings can be prepared and administered [13].

One further highly significant point is the inclusion of the identified errors in designing a simulating system. By applying those errors in the course of training, not only are the trainees' abilities of controlling a situation evaluated, but also their action skills are improved. This can be considered part of their training programme [3]. One of the shortcomings of the present method is the lack of risk level evaluation after performing the controlling measures, i.e., the risk level cannot be assessed after modification measures. An action that can be highly effective in identifying the probability of error occurrence in industry is the accurate and exact recording of human errors. In the course of the present research, such an exact recording was not available. So, it is recommended that an accurate and exact method of error recording be devised and administered to reach accurate information on the probability of error occurrence in industry.

5. CONCLUSION

In conclusion, the method this article presents is applicable in different industries including chemical, oil, petrol and petrochemical industries. It is useful for identifying human errors leading to risks and hazardous accidents. Moreover, it works very well in presenting controlling procedures. Finally, it can offer operational strategies suitable for the identified errors.

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