Methods of Human Reliability Analysis

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Abstract— The article considers the methods of Human Reliability Analysis, which can be divided into qualitative and quantitative. First, the goal and the process, that consists of a series of steps of Human Reliability Analysis is described. Then some specific qualitative methods are described and it is pointed out that qualitative methods are not sufficiently investigated.

Keywords— human factor, Human Reliability Analysis, Reliability Engineering

I. Introduction

People and systems are not error-proof, and that improved reliability requires an understanding of error problems, leading to improved mitigation strategies and therefore it is necessary to follow the concept of Human Reliability Analysis (HRA).

A number of HRA techniques have been developed for use in a variety of industries. Quantitative techniques refer to human tasks and associated error rates to calculate an average error probability for a particular task. Qualitative techniques guide a group of experts through a structured discussion to develop an estimate of failure probability, given specific information and assumptions about tasks and conditions [12].

Most techniques in HRA are qualitative. It is caused by the specific of initial data for human factor analysis. This data are often incompletely specified and ambiguous. There are complications to represent this data according to mathematical models that are used in Reliability Engineering, for example as structure function, reliability block diagram, Markov model, Universal Generation Function, Petri network, etc. Therefore typical method for quantitative reliability evaluation cannot be used without special adaption for the specific of human factor analysis.

II. Human reliability analysis (HRA)

A. Definition of HRA

Human error is an important factor to be considered in the design and risk assessment of large complex systems, especially when the human is a crucial part of the system, such as nuclear power plant operations, air traffic control, and grounding of oil tankers [1]. There is a special area in the Reliability Engineering named *Human Reliability Analysis* that investigates the influence of Human into different system. *HRA is a comprehensive and structured methodology that applies qualitative and often also quantitative methods to assess the human contribution to risk* [2]. In HRA there is already developed many methods for estimating and analyzing the behavior and impact of a human factor on system performance or its error rate. The HRA aims to identify a potential system failure resulting from human error, to analyze the causes and identify appropriate countermeasures to prevent as much as possible and reduce the associated risk. Human errors affect between 60% and 90% of all industrial and transport accidents [3].

B. Basic conception of HRA

The HRA process consists of a series of steps that includes problem definition, task analysis, human error identification, human error representation, and human error

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quantification. How each step of the HRA is conducted depends on the HRA method used and the purpose of the analysis. The results of the HRA may reveal the need for error management to reduce errors or mitigate their effects [2].

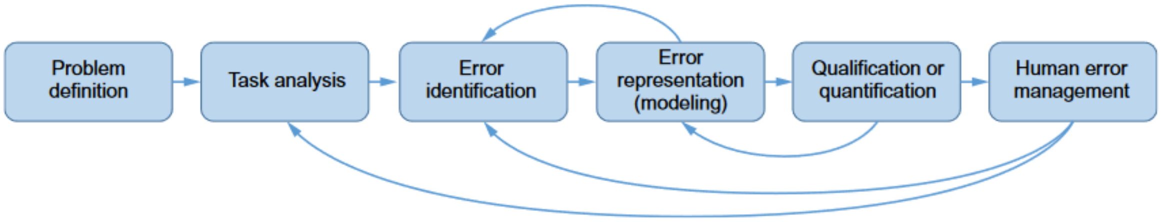

Fig. 1 Basic steps in the HRA process

1)Problem definition

The first step in the HRA process is used to determine the scope and type of qualitative or quantitative analysis, the tasks that will be evaluated and the human actions that will be assessed.

Scope of the HRA - Two factors need to be considered to determine the scope of the analysis: the purpose of the analysis and the system's vulnerability to human error. An optimal system design is less complex (less prone to error), is error tolerant (provides the capability to detect and correct errors), and allows the user flexibility to recover from failures.

Type of HRA – analysis of HRA can be qualitative or quantitative. In analyses as accident investigations, problem report evaluations, and general process improvements, the severity of the consequences and likelihood of occurrence are expressed for example through words like high, medium, or low, in other words qualitatively. In quantitative assessments, the consequences are expressed numerically for example the number of people potentially hurt or killed and their likelihoods of occurrence are expressed as probabilities or frequencies.

2)Task analysis

Second step in the HRA process is task analysis - a method that consists of systematically identifying and breaking down each task into the steps and substeps that constitute the human activities necessary to achieve a system's goal. Human activities can include both physical actions, such as installing a device; and cognitive processes, such as diagnosis, calculations, and decision making. The goal of task analysis is to decompose the functions into tasks, tasks into subtasks, and subtasks into human actions. There are over 25 variations of task analysis, each designed to accomplish different goals including task data collection, task description, simulation, behavior assessment, and task requirement evaluation.

3)Human error identification

The identification of human errors is third and the most important step of the HRA because failing to identify a critical human error will result in the omission of that error's contribution to risk in the HRA and to the underestimation of the overall system risk. This part of the analysis should include all of the actions that could adversely affect the system's reliability. This is done through the evaluation of the basic human actions to determine what errors can occur, and which can potentially contribute to undesired outcomes. The analyst must determine not only the types of human error that can occur, but also the factors that could contribute to the errors' occurrence.

4)Human error representation

Human error representation is often described as modeling because it helps illustrate the data, relationships, and conclusions that cannot be as easily described with words. Human error representation allows the analyst to look deeper and develop a better understanding of the causes, vulnerabilities, recoveries, and possible risk mitigation approaches that could be used to address accident scenarios. Tools available for human error representation include master logic diagrams (MLD), event sequence diagrams (ESD), event trees, fault trees or generic error models, and influence diagrams.

5)Human error qualification and quantification

Quantification is the process used to assign probabilities to human errors. The steps in quantification depend on the method used, and the method used depends mostly on the resources available (usually time and money), the experience level of the analyst, and the available relevant data. The data must be sufficient to allow the analyst to estimate the frequency with which the errors may occur and the number of opportunities for these events. Once the human errors have been modeled and quantified, and the HRA has been completed, risk calculations can be performed to evaluate the overall system risk.

6)Human error management

The HRA analysts rank the errors that significantly contribute to risk in decreasing order of importance and make decisions on whether and how to manage human error appropriately. The analysts can decide to include barriers to prevent errors, provide a means to detect and correct the errors or mitigate the negative effects of the error. The human error management philosophy is founded on two basic principles: that humans, no matter how well trained and how experienced, will make mistakes; and that potential human errors can be identified and be prevented, corrected, or their effects can be mitigated. As human error is effectively managed, human reliability improves and, consequently, system reliability improves. Conversely, when human error is not adequately managed, human reliability is lower and the overall system reliability suffers [2].

III. HRA TECHNIQUES

A. The range and scope of HRA techniques

There are two approaches in Reliability Analysis:

- Qualitative evaluation

  – aims to identify, classify and rank the failure modes, or event combinations that would lead to system failures

- Quantitative evaluation

  – aims to evaluate in terms of probabilities the attributes of dependability (reliability, availability, safety)

In broad terms, HRA consists of a qualitative phase followed by, if necessary, a quantitative phase. Different HRA methods have different approaches to completing the qualitative and quantitative phases of the analysis. Some methods, such as those associated with root cause analysis, are primarily qualitative; however, even those methods described as quantitative begin with a qualitative analysis. In most HRA methods, the qualitative phase consists of identifying potential human errors and analyzing them in terms of those factors that might contribute to a human making the error [2].

The techniques can be grouped into five categories spanning the principal types and purpose of HRA analysis. Some techniques are primarily descriptive or concern basic data gathering (Table 1). These are often used as a prelude to more sophisticated approaches involving simulation, human error analysis and human error quantification. Techniques may be used separately, but more often in combination [4].

TABLE I

The range and scope of HRA techniques

Type of technique	Description
Data Collection	Collection of information on incidents, goals, tasks, etc.
Task Description	Taking the data collected and portraying this in a useful form
Task Simulation	Simulating the task as described and changing aspects of it to identify problems
Human Error Identification and Analysis	Uses task description, simulation and/or contextual factors to identify the potential errors
Human Error Quantification	Estimated the probability of the errors identified

B. HAZOP (Hazard and Operability Study)

The HAZOP method is mainly used in the chemical industry. It is a very flexible method that is used for large technological units but can also be used for small devices. This is a method suitable for large and small organizations [5].

The HAZOP study is used to identify hazard scenarios that impact receptors such as people, the environment and property, as well as operability scenarios where the concern is with the capacity of the process to function properly. The HAZOP method is based on an assessment of the likelihood of threats and the resulting risks. Its main goal is to identify possible risk scenarios - thus enabling it to identify the dangerous conditions that may occur on the investigated device. The method looks for so-called critical locations, and then evaluates potential risks and hazardous situations. This is a team-based multidisciplinary method where team members look for scenarios in a joint discussion, for example, using the brainstorming method. The results are formulated in the final recommendation that aims to improve processes or systems [6].

Steps of the HAZOP method:

1. Identify causes
2. Estimation of possible consequences and risks
3. Proposals for risk elimination measures
4. Valuation

C. FTA (Fault Tree Analysis)

The FTA method was first used in 1962 by Bell Telephone Laboratories and was perfected by Boeing. The method has been used wherever complex systems have to be solved, and to find or reduce failures or improve quality, especially in sectors such as energy, space research, aviation, nuclear power and others [7].

FTA is the analytical technique used to evaluate the probability of failure or the reliability of complex systems. Because of its versatility, it is well-known in many areas, particularly in the areas of risk management and quality management, and safety management. It is applicable as a preventive method as well as a method of analyzing an already existing problem (for example, a crash). The FTA usually follows an FMEA analysis and is designed for complex systems.

The FTA method is based on an analysis of a peak event or a problem (a generally negative phenomenon such as crash, failure, poor quality, high costs) and helps to systematically identify the factors causing the problem or negatively affect the functionality of the system. Its aim is to analyze in detail - to find the causes of the negative phenomenon and further reduce the likelihood of its occurrence. For a simple system, it is preferable to use FMEA or HAZOP methods. FTA is a systematic method for analyzing the cause of risks by adopting a deductive method, in which a specific risk that is only qualitatively recognized from a relevant primary system is placed as the top event in the tree for deductive reasoning [8].

IV. Conclusion

Most techniques in HRA are qualitative. It is caused by the specific of initial data for human factor analysis. This data, as a rule, incompletely specified and ambiguous. Typical approach for the data collection is expert evaluation [9], [10]. There are complications to represent this data according to mathematical models that are used in Reliability Engineering, for example as structure function, reliability block diagram, Markov model, Universal Generation Function, Petri network, etc. [11]. Therefore typical method for quantitative reliability evaluation cannot be used without special adaption for the specific of human factor analysis. For example, techniques of FTA used for analysis of technical system have specifics in HRA application.

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