Review Article

A Narrative Review of Human Reliability Analysis (HRA) Techniques in Various Industries in Iran

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Abstract

Human error is a significant factor contributing to occupational accidents across various industries. To address this issue, Human Reliability Analysis (HRA) techniques have emerged as valuable tools for evaluating and mitigating the risks associated with human error. These methods allow for a thorough assessment of how and why errors occur, the likelihood of these errors leading to accidents, and the potential consequences of such incidents. This research comprehensively examines several HRA techniques, detailing their applications in a wide array of sectors, including railway, healthcare, petrochemical, and engineering. By analyzing literature sourced from reputable databases such as the Web of Science, Scopus, Islamic World Science Citation, and Scientific Information Database core collection from 2009 to 2023, this review highlights key findings and trends in HRA studies. Interestingly, the investigation of HRA in Iran has been relatively limited, with most studies concentrated on the health and petrochemical industries. Recognizing the potential for improvement, this review advocates for the broader implementation of HRA methods across all sectors to enhance safety protocols and minimize the likelihood of human errors leading to accidents.

Keywords: Human error, human reliability analysis, human reliability assessment

Introduction

Human error is defined as inappropriate or undesirable decisions or behaviors by individuals that reduce a system's efficiency, safety, or performance.[1] It is inevitable and can stem from negligence, lack of preparation, or mistakes that lead to unintended results.[2] Common examples of human errors in various industries include failing to perform a task, incorrectly completing a task, performing tasks out of order, or not completing a task within the specified time.[3] Researchers have proposed various classifications for the causes and factors contributing to human errors. For instance, Niles T. Welch has identified six primary causes of human error: complexity, stress, fatigue, environment, training, and experience.[4] Similarly, Kirwan have highlighted several effective factors contributing to human error, including time, controller and indicator usage, training and experience, instructions, task organization, and the complexity of tasks.[5] Studies on industrial accidents indicate that human error accounts for over 90% of nuclear accidents, more than 80% of accidents in the chemical industry, over 75% of marine accidents, and more than 70% of air accidents.[6] Notable historical accidents, such as the Flixborough incident in England (1974, chemical industry), the Three Mile Island accident in the USA (1979, nuclear power plant), the Bhopal disaster in India (1984, chemical industry), and the Chornobyl disaster in the former Soviet Union (1986, nuclear power plant), highlight the prevalence of human error in these cases.[7-10] Various studies support these findings, including reports by Heinrich, which suggest that approximately 88% of accidents are due to human errors,[11] and Drew, which estimates that between 80% and 90% of accidents are caused by similar mistakes.[12] In addition, Billing and Reynard identify human errors as the cause of 70% to 90% of accidents.[13] While the immediate reaction after an accident is often to blame human operators, research indicates

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that other factors also play a significant role.[14] These factors include a lack of consideration for human–system interactions during design, inadequacies in managerial decision-making, deficiencies in planning, improper management methods, and weak safety culture throughout the lifecycle of large industrial systems. These issues can significantly increase the likelihood of accidents occurring.[15] To recognize and control human errors, more than 200 different techniques have been invented, each of which is used based on a special method and mechanism and for a specific purpose.[16] The complexity of industry errors is such that without using systematic techniques, it is impossible to control them in the phases of design, installation, commissioning, and operation.[17] Studies have shown that the analysis of human error before the occurrence of accidents can prevent the occurrence of many incidents.[18] In recent years, various methods of examining human capacities and functional ability in complex tasks have received more attention than in the past, and most of these methods are under the Human Reliability Analysis (HRA) method.[19] HRA aims to predict the possible failure in performing a task due to human error. Human Reliability Assessment (HRA) methods for risk assessment and identification of important human errors related to job tasks, their quantitative modeling, and providing the necessary solutions to prevent errors or reduce their consequences.[20] HRA techniques are crucial in understanding and mitigating human error in various fields. Each technique has unique limitations and advantages, making it essential to consider the context, in which they are applied carefully. Depending on the specific circumstances and requirements, choosing the appropriate assessment method can greatly impact the effectiveness of error prevention strategies.[21] This study seeks to provide a comprehensive introduction and review of several key features and applications of some of the most prevalent methods used for evaluating human error. By examining these methods in detail, we aim to highlight their strengths and weaknesses and the scenarios, in which they are most effectively implemented.

Materials and Methods

A comprehensive and systematic literature search was conducted to investigate various techniques related to Human Reliability Assessment (HRA). This search was designed to be inclusive, covering all industries, Persian and English languages, and all forms of studies that discuss human error. In addition to the initial database searches, references from eligible articles were diligently hand-searched to uncover any additional relevant studies that may not have appeared in the primary search. A set of well-defined keywords was utilized to guide this search. These keywords included "human error(s)," "human reliability," "human error assessment(s)," "performance shaping factor(s)," "human reliability assessment," "HRA," and "accident(s)." The search was conducted in various databases, including Web of Science, Scopus, Islamic World Science Citation, and Scientific Information Database. The time range considered was between 2009 and 2023. Each of these keywords was first combined using the Boolean operator "OR," ensuring that any articles containing any specified terms were included. Subsequently, the results from this combination were further refined by combining them with "AND" to focus specifically on studies that addressed human reliability assessment techniques. The inclusion criteria for this search encompassed all types of empirical studies that employed HRA techniques, ensuring a wide array of perspectives and findings. However, to maintain the quality and relevance of the literature reviewed, we excluded certain types of publications, such as reviews, letters to the editor, conference papers, opinion pieces, reports, and editorial articles. This focused approach allowed for a more thorough examination of original research and insights into HRA methodologies.

Results

Various Human Reliability Assessment (HRA) methods have been developed to evaluate human reliability. A literature review of 115 articles identified 14 distinct HRA methods. The most commonly implemented methods include Human Error Assessment and Reduction Technique (HEART), Cognitive Reliability and Error Analysis Method (CREAM), Systematic Human Error Reduction and Prediction Approach (SHERPA), Standardized Plant Analysis Risk-Human Reliability Analysis (SPAR-H), the Technique for Human Error Rate Prediction (THERP), and A Technique for Human Error Analysis (ATHEANA). A few of these selected methods are briefly described below.

Human Error Assessment and Reduction Technique

Williams introduced the HEART in 1986.[22] This technique is extensively used across various sectors, including nuclear power, aviation, railways, medicine, and chemistry.[23] It is considered a first-generation Human Reliability Assessment (HRA) method aimed at estimating the likelihood of errors within a system and pinpointing aspects of a task that can be modified to enhance overall safety levels. The HEART method allows for a quick assessment of human error. It consists of a questionnaire that addresses common task categories and Error-Producing Conditions (EPCs). According to this approach, 38 identified EPCs, and nine Human Error Probability (HEP) values are associated with typical task types. Human reliability evaluation is based on the specific task being assessed. EPC values can relate to the worker's or their colleagues' experience, education, stress levels, age, ambient sound, and the duration of task performance. HEART is among the few HRA methods that have been experimentally validated.[24]

Cognitive Reliability and Error Analysis Method

The CREAM was proposed by Eric Hollnagel in 1998.[25] It represents a second-generation Human Reliability Analysis (HRA) methodology, with both basic and expanded versions available. These versions present two significant improvements over first-generation methods: the integration of a cognitive model to assess the significance of mental processes in human performance and the capability to conduct both prospective and retrospective analyses at each stage. The prospective analysis identifies possible human errors, whereas the retrospective analysis evaluates the outcomes of human errors that have already occurred. CREAM focuses on three primary areas of study: analyzing subtasks, minimizing chances for error, and improving human performance. Specific task-setting characteristics known as Common Performance Conditions (CPCs) have been recognized.[26] Although CREAM aims to address the shortcomings of earlier human reliability analysis methods, it also has its weaknesses. The most notable issues include a lack of data regarding CPCs and uncertainty about how they relate to operator control modes. The method is predominantly used in the energy and chemical industries, as well as in the maritime and transportation sectors.[27]

Systematic Human Error Reduction and Prediction Approach

The SHERPA, created by Embrey in 1986, was initially applied in the nuclear power generation sector.[28] Like other first-generation techniques, SHERPA breaks down a comprehensive process into smaller subtasks and offers a classification system to identify possible error types. Practical experience demonstrates that it yields valid, beneficial, cost-efficient, and manageable outcomes. While it adopts a methodology grounded in the analyst's knowledge and judgment, it has been found to possess strong validity and reliability.[29]

Standardized Plant Analysis Risk-Human Reliability Analysis

The SPAR-H is an advanced human reliability analysis method developed by the US Nuclear Regulatory Commission during the 1990s, culminating in its final version as SPAR-H in 1999.[30] The SPAR-H approach classifies human activities into one of two primary task categories: actions and identifications. Actions refer to tasks such as operating equipment such as pumps or conducting calibration and testing. In contrast, identifications involve understanding system conditions through knowledge and experience, planning tasks, and deciding on appropriate actions. The SPAR-H framework is based on an information processing model of human performance, which draws from behavioral sciences literature and is tailored for the operation of nuclear power plants. Eight factors are utilized to quantify human performance, including available time, stress influences, training and experience, task complexity, ergonomics (which encompasses human–machine interface design), standardized procedures, and working processes. When compared to other human reliability analysis methods, SPAR-H performs favorably. SPAR-H offers distinct practical benefits: it is user-friendly and quick to implement, without the need for users to possess expertise. It is adaptable and beneficial in situations that do not necessitate a more in-depth analysis.[31]

The Technique for Human Error Rate Prediction

The THERP, created by Swain and Guttmann in 1983, is a foundational human reliability analysis (HRA) method.[32] It aims to forecast human errors in the nuclear power sector both quantitatively and qualitatively. This method evaluates HEPs by utilizing a comprehensive human reliability database that encompasses literature reviews, interviews, and observations with workers from nuclear plants, along with operational data. The "incident tree" methodology facilitates the quantitative modeling of the relationship between actions and errors. For each node in a task, branches are developed from binary decision points. The resulting incident tree outlines the sequence of incidents and the likely errors that might occur at each node. It illustrates how each HE*P* value reacts to alterations in Performance Shaping Factors (PSFs), especially in relation to nuclear plant operations; its primary goal is to identify the stages with high error rates within a broader process and to concentrate efforts on methods to reduce errors.[33]

A Technique for Human Error Analysis

ATHEANA was created by Cooper *et al*.[34] to generate both qualitative and quantitative results related to Human Reliability Analysis (HRA) for the nuclear energy sector. As a second-generation method, ATHEANA emphasizes the cognitive elements of decision-making and takes into account both prospective and retrospective perspectives on incidents. Its goal is to offer a robust psychological framework that can identify and evaluate PSFs. The primary focus of ATHEANA is to recognize Error-Forcing Contexts where human mistakes and unsafe behaviors are prone to occur. The approach highlights that significant human errors stem from conditions that are particular to the facility, combined with performance-shaping elements such as fatigue, stress, and noise, using PSFs defined by specialists. In addition, experts have analyzed the way in which PSFs influence the estimation of HEPs using the ATHEANA approach, which is similar to various other human reliability analysis methods. Its dependability for comprehensive Probabilistic Risk Assessment remains a topic of debate precisely because it depends on expert judgment.[35]

Table 1 illustrates the information regarding the 36 HRA articles carried out in different sectors in Iran.

In Table 2, various Human Reliability Assessment (HRA) methods are compared.[69]

Discussion

Human Reliability Analysis (HRA) is crucial in any domain that demands high reliability standards. HRA methodologies can identify, forecast, and establish a foundation for managing human errors that lead to accidents.[3] The review highlights the various benefits and drawbacks associated with various HRA methodologies. By employing simulation techniques, these methods are enhanced by revising and adapting first- and second-generation approaches or by amalgamating several first- and second-generation methods. HRA experts continue to create strategies to address the uncertainties

Table 1: Research conducted in Iran utilizing human reliability assessment methods

Author	Years	Method	Sector	Publisher	Reference
Hajiakbari *et al*.	2015	ATHEANA	Minefield cleaning operation	*Journal of Occupational Hygiene Engineering*	[35]
Karimi *et al*.	2018	ATHEANA	Mining operations	*Journal of Occupational Hygiene Engineering*	[36]
Jahani *et al*.	2022	ATHEANA	Petrochemical	*Occupational Hygiene and Health Promotion*	[37]
Mohammadfam *et al*.	2014	CREAM	Health	*Iranian Journal of Ergonomics*	[38]
Najafi and Arghami	2018	CREAM	Car driver	*Journal of Occupational Hygiene Engineering*	[39]
Karimie *et al*.	2019	CREAM	Petrochemical	*Journal of Health and Safety at Work*	[40]
Borgheipour *et al*.	2020	CREAM	Tower crane operators	*Journal of Health and Safety at Work*	[41]
Atashfeshan *et al*.	2021	CREAM	Engineering	*Iranian Journal of Ergonomics*	[42]
Bafandegan Emroozi and Fakoor	2023	CREAM	Engineering	*Journal of Industrial and Systems Engineering*	[43]
Ghalenoei *et al*.	2009	HEART	Petrochemical	*Iran Occupational Health*	[44]
Noroozi, Alireza *et al*.	2014	HEART	Engineering	*Process Safety and Environmental Protection*	[38]
Aalipour *et al*.	2016	HEART	Cable manufacturing	*International Journal of System Assurance Engineering and Management*	[45]
Pakdel and Omidvari	2017	HEART	Engineering	*Iranian Journal of Ergonomics*	[46]
Mollabahrami, *et al*.	2021	HEART	Electrical	*Journal of Occupational Hygiene Engineering*	[47]
Ramezanifar *et al*.	2022	HEART	Rail way	*Journal of Health and Safety at Work*	[48]
Jabbari *et al*.	2023	HEART	Gas power plant	*Iran Occupational Health*	[49]
Ghasemi *et al*.	2010	SHERPA	Petrochemical	*Iran Occupational Health*	[50]
Ghasemi *et al*.	2013	SHERPA	Petrochemical	*International journal of occupational safety and ergonomics*	[51]
Ghasemi *et al*.	2015	SHERPA	Health	*International Journal of Occupational Safety and Ergonomics*	[52]
Mohammadfam and Saeidi *et al*.	2015	SHERPA	Health	*Iranian Journal of Ergonomics*	[53]
Dadgar *et al*.	2017	SHERPA	CNG stations	*International Journal of Environmental and Science Education*	[54]
Dehaghi *et al*.	2017	SHERPA	Engineering	*Jundishapur Journal of Health Sciences*	[55]
Sarableh *et al*.	2023	SHERPA	Power plant	*Journal of Health Reports and Technology*	[56]
Karami *et al*.	2021	SHERPA	Rail	*Iranian Journal of Ergonomics*	[57]
Khaleghi *et al*.	2022	SHERPA	Health	*International emergency nursing*	[58]
Azariyan *et al*.	2022	SHERPA	Oil refinery	*Occupational Medicine*	[59]
Teymourzadeh *et al*.	2023	SHERPA	Health	*Iranian Journal of Nursing and Midwifery Research*	[60]
Mohammadfam *et al*.	2016	SPAR-H	Health	*Iranian journal of public health*	[61]
Aliabadi *et al*.	2019	SPAR-H	Pipeline	*Journal of Occupational Hygiene Engineering*	[62]
Akhtar *et al*.	2022	SPAR-H	Roofed crane	*Journal of Occupational Hygiene Engineering*	[63]
Pouya *et al*.	2019	SPAR-H	Health	*Shiraz E-Medical Journal*	[64]
Aliabadi *et al*.	2019	SPAR-H	Engineering	*Health Scope*	[65]
Abbassi *et al*.	2015	THERP	Engineering	*Process Safety and Environmental Protection*	[66]
Nezamodini *et al*.	2018	THERP	Pipe manufacturing	*Archives of Hygiene Sciences*	[67]
Ramezani *et al*.	2020	THERP	Engineering	*Progress in Nuclear Energy*	[68]

CREAM: Cognitive reliability and error analysis method, THERP: Technique for human error rate prediction, HEART: Human error assessment and reduction technique, SHERPA: Systematic human error reduction and prediction approach, SPAR-H: Standardized Plant Analysis Risk-Human Reliability Analysis, CNG: Compressed natural gas

stemming from incomplete data and to implement known methods across different fields, adjusting the PSFs to fit the unique circumstances of each sector.[69] Each Human Reliability Assessment (HRA) method has its advantages and disadvantages, making it challenging to select an appropriate method for evaluating human reliability in various jobs and industries. To address this issue, some researchers have compared different techniques. For instance, Shirali *et al*. compared the SHERPA and HET methods for evaluating human error in gasification operations. Their findings indicated that the SHERPA method is more suitable for this type of evaluation. The study suggests that when comparing HRA methods, the following criteria can be used: accuracy, sensitivity, the number of identified errors, applicability, time, and required training.[70] In certain situations, assessing the impact of human errors on the system becomes challenging due to the structures' complexity. Researchers then work to address these challenges through probabilistic approaches such as fuzzy logic, decision-making, and Bayesian Network analysis, which simplify intricate processes and accommodate incomplete information through qualitative assessments.[71] For example, Karimie *et al*. combined CREAM and Bayesian Networks to assess human errors in one of the control rooms of a petrochemical industry.[40] Mirzaei Aliabadi *et al*. use

Table 2: Comparison of various human reliability assessment methods

HRA method	Main theoretical framework	Predefined data	Nature of data	Processing approach	Analysis target	Coverage of PSF	Type
HEART	Cognitive	Tables	Quantitative	Frequentist	Operator and crew	Human Task	First generation
CREAM	Cognitive	Nominal HEP	Quantitative	Frequentist	Operator and crew	Human task	Second generation
SHERPA	Behavioral	Tables	Quantitative	Frequentist	Operator and crew	Human task	First generation
SPAR-H	Cognitive	Nominal HEP	Quantitative	Frequentist	System	Task system	Second generation
THERP	Behavioral	TRC curves and tables	Quantitative	Frequentist	Human task	Operator	First generation
ATHENA	Behavioral and cognitive	Nominal HEP	Quantitative	Frequentist	Human task System Environment	System	Second generation

HRA: Human reliability assessment, PSF: Performance shaping factor, HEP: Human error probabilities, CREAM: Cognitive reliability and error analysis method, THERP: Technique for human error rate prediction, HEART: Human error assessment and reduction technique, SHERPA: Systematic human error reduction and prediction approach, SPAR-H: Standardized Plant Analysis Risk-Human Reliability Analysis

the Best-Worst method to improve the HEART method for determining HEP in the blasting process of an ore mine.[72]

The results of this study reveal numerous articles discussing the application of HRA methods across the railway, health care, oil refinery petrochemical in Iran. The emphasis has been on techniques such as HEART and SHERPA in health care, CREAM in the petrochemical industry, HEART again in health, THERP and SPAR-H in engineering and other processing areas, and ATHENA within the petrochemical sector. Iran has a diverse range of industries, including construction, steel and iron smelting, dam building, and chemicals. However, there have been relatively few studies utilizing Human Reliability Analysis (HRA) techniques in these sectors. Given the high incidence of occupational accidents in these industries, assessing human reliability and identifying potential improvements is crucial.[73] This study focuses exclusively on the most commonly utilized Human Reliability Analysis (HRA) methods, which means that various other HRA methodologies have not been explored or discussed. This limitation suggests that there may be significant insights and findings from alternative approaches that could contribute to a more comprehensive understanding of human reliability in various contexts. Therefore, it is recommended that future research undertake a systematic review that examines the application of these prevalent methods within Iran and expands the scope to include international perspectives. By comparing the outcomes of this future research with the findings presented in this study, researchers can identify trends, similarities, and discrepancies that could enhance the overall body of knowledge in the field of Human Reliability Analysis.

Conclusions

The human element contributing to accidents requires thorough research and analysis, aiming to improve reliability in the workplace and minimize the occurrence of accidents caused by human mistakes. It is proposed that creating Human Reliability Analysis (HRA) techniques and tailoring them to fit occupational health and safety practices across various sectors of the economy could be beneficial in decreasing the human errors that lead to accidents. This review aims to serve as an extensive resource on the HRA methods that are currently available but seldom utilized, and it seeks to promote further investigations into human reliability within businesses in Iran and other countries.

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Ethics code

This is personal research, and no institution supports it.

Conflicts of interest

There are no conflicts of interest.

Authors' contributions

Ehsanollah Habibi: Conceptualization, Supervision, Review and editing; Seyed Mahdi Mousavi: Methodology, Writing – review & editing; Mahsa Jahadi Naeini: Data curation, Formal analysis, Investigation, Visualization, Writing – review and editing;

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