HUMAN FACTORS FOR SAFETY IN THE RAILWAY INDUSTRY REVIEW

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ABSTRACT

In the railway industry, the human factor for safety has become a serious issue because, the high cost of energy on roads and airplanes, rising energy costs with scarcity, and a desire to decrease pollution have necessitated a switch from vehicle to rail transportation. That being the case, the congestion on the railway has led to numerous accidents pushing many researchers to address several issues regarding work place safety, cognitive problems, reliability, Availability and maintainability safety RAMS. This paper presents the literature study on the human factors for safety in the railway industry using requirement engineering (RE) processes for gathering information needed to optimize sustainable railway operation. Additionally, early traditional models for human reliability analysis (HRA) and railway standards were developed to solve human errors arising from these man-made systems as delineated in this work. Apart from some traditional HRA generation models which are unable to solve complex human-machine problems, a third generational model has been developed to handle such task because of its dynamic modelling system. Finally, the railway operation system necessitates a huge number of stakeholders and individuals, which leads to more human errors and, as a result, serious consequences.

Keywords: Railway RAMS, Safety, Human Factors, Stakeholders, Requirement Engineering processes, Human-machine interaction, HRA.

INTRODUCTION

The purpose of incorporating the human factor into the safety management of systems in the railway network is to improve safety, reliability, and efficiency by avoiding human error while also improving the working conditions of employees. Worker's surroundings, workplace culture, and occupational aspects, together with human and personal qualities, can influence job behaviour which might have an impact on safety and health. As a result, they must be carefully documented because they connect the essential points of the project's flow, such as the job, the people, and the organization. However, the focus should be on improving understanding of railway safety management systems. EN 50126-1 is the most significant and well-known standard for railway technical component system design. It requires the integration of human factors. Despite emphasizing the relevance of human factors considerations for railway system workers, the standard gives limited guidance on how to integrate. The most common reliability, availability, maintainability and safety (RAMS) model found in the standard has been retrofitted [1]. Human elements are particularly noticeable in the design and building, operation, and maintenance phases, as shown in Figure 1. It's vital to note that systematic (human) failings in the design phase manifest themselves in the operational period as a collection of internal disturbances.

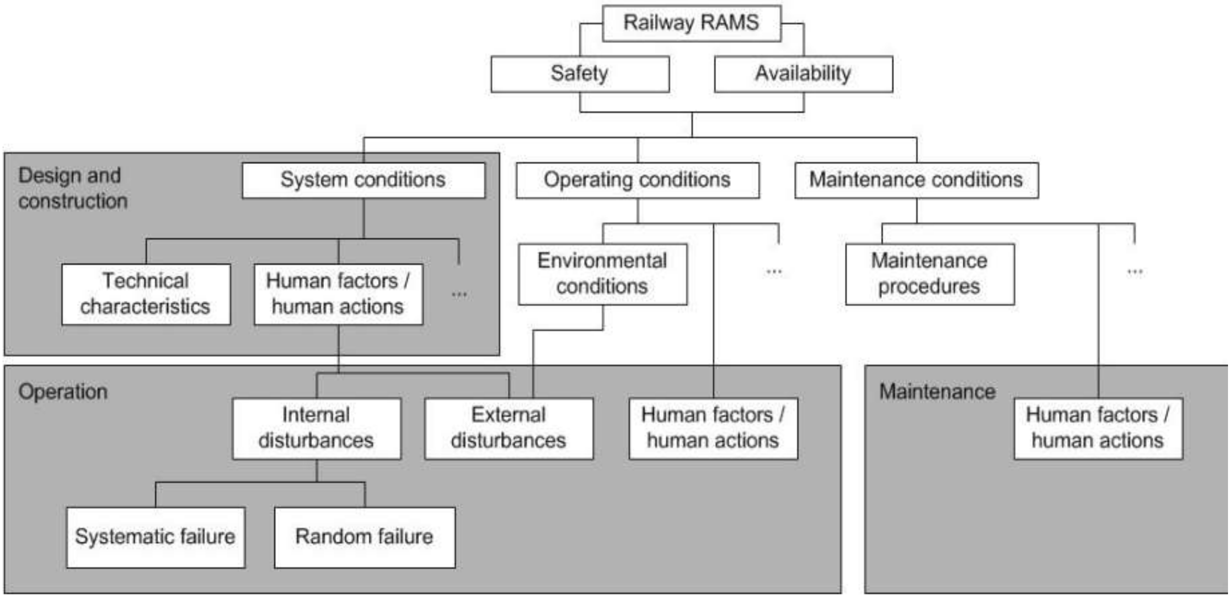

Figure 1: Human factors in the railway life span and cycle[2].

Human factor usability and its relation to Error

According to ISO 9241-11, the human usability factor is the ability of a new product to be used by specified users to fulfill stated goals with competency, effectiveness, and happiness in a given usage environment (railway) [3].

Almost all of the recent high-profile accidents have involved human fault. There has been a lot of workplace accident due to error from humans, thus individual strengths and limitations must first be understood in order to handle human aspects in occupational safety contexts. Attention, perception, memory, logical reasoning, environmental, organizational, and employment aspects are all human traits that might lead to issues interacting with the workplace. Human mistake is thus evaluated either in terms of its negative implications on man, the system, and the environment, or in terms of its positive consequences by investigating the mechanisms that explain its occurrence. The first factor leading to the occurrence of train accidents and incidents has long been acknowledged as human error. Rather than criticizing the human operator, who is frequently confronted with a more sophisticated system while ignoring the system's latent circumstances, human error must now be understood as the result of poor human reliability, which is influenced by a number of performance factors, including organizational, professional, and individual factors. Human error is frequently defined as the impossibility of an operator dealing with an unusual scenario, such as a device failure or an unanticipated collection of conditions.

- Human-machine interaction mismatch occurs when a human agent is unable to make a decision or diagnose a problem when engaging with a machine due to design faults or non-adherence to user interface rules, for example. This could be due to weak feedback channels or usability issues.
- Human agents may be unable to communicate effectively or as desired to other human agents, resulting in a communication error known as human-human communication error. This could be due to a lack of coordination at the management level, or it could be owing to a single person being assigned to a large number of tasks.

Machine-machine misunderstanding can occur if the control system operator is not properly taught to regulate particular parameters or is not properly trained to accomplish the assigned responsibility.

In a nutshell, environmental, organizational, and occupational factors influence work behavior in ways that can compromise health and safety. Thinking at three aspects of human factors: the individual, the work, and the organization, and their impact on people's health and safety-related behavior, is a simpler approach to look at them.

Figure 2: shows that all three are interlinked and have mutual influence (see http://www.hrdp-idrm.in/e5783/e17327/e28013/e28938/).

Table 1: Human failures in railways: immediate causes and contributing elements

Individual Factors	**Job Factors**	**Organization and management Factors**
Low skill and competence level	Illogical design of equipment and instrument	Poor work planning, leading to high work pressure
Tired staff	Constant disturbance and interruption	Poor SOPs (Standard operating Procedure)
Bored or disheartened staff	Missing or Unclear information	Lack of safety systems and barriers
Individual medical problems	Poorly maintained equipment's	Inadequate responses to previous incident
Monotonous Task	Noisy and unpleasant working conditions	Poor management of health and safety systems
Attitude (It can't happen to me)	High workload	Poor health and safety culture
		Management based on one-way communication

Usability of Signaling Systems in Railway

We'll talk about a method for designing a railway-specific system in this part. Train signaling systems are extremely complex structures that must be closely monitored and controlled in order to avoid major breakdowns that interrupt railway traffic. Previously, each system or system group's maintenance inspection was done separately; however, as systems became more complicated and innovative and existing dependencies between them became apparent, it became important to consolidate all supervisory maintenance-related duties into one system. In the event of a disruption, such a system not only allows for the control and monitoring of many systems, but also for the coordination of all operations linked to these systems, with the goal of minimizing disruptions. Functional needs were traditionally the most important considerations while creating such a user interface. Because of the increased complexity, along with the fact that there are typically fewer people in charge, it is critical to focus not only on functional aspects but also on human factors in order to enable the user to complete the required activities with high quality. Furthermore, modern railway systems are extremely reliable, resulting in a low frequency of failures. As a result, the processes for recovering from these failures are not as readily available as they would be if they were encountered frequently. As a result, a supervisory maintenance system must be able to give specific processes and a sufficient amount of information to enable and help the user in troubleshooting and system repair. A complete list of needs appears at the start of most railway development projects. The whole list of requirements defines the project's scope and is used for verification and validation subsequently. The following is a collection of ways usability needs have been defined [4].

- Req1: determine which set of people will work with the system and how to divide them;
- Req2: Evaluate and control which information is required by which user/user group at various levels of detail.
- Req3: Determine which circumstances and environments/contexts the system will be used in;
- Req4: identify and monitor which systems are utilized and known by the future user for similar tasks/in similar contexts, as well as which characteristics of legacy systems1 must be considered.
- Req5: Determine which functions/tasks are relevant to safety and pay extra attention to them.

The Five Characteristics of Usability in Railways

Table 2Railway Planning and usability evaluations with important characteristics and testing in a realistic way**.**

Characteristic	Type of Usability Evaluation
Efficient	Time realistic tasks. Train driving must use working versions of easy software for navigation.
Effective	Evaluate tasks for how accurately they were completed, and how often they produce errors in all railway components.
Engaging	User satisfaction surveys or qualitative interviews can gauge user acceptance and attitudes in the railway industry.
Error Tolerant	Include framework with any relevant problems for testing
Easy to Learn	Control how much instruction is given to the railway staff participants, or carefully recruit users with different levels of domain knowledge and experience.

User Requirements Elicitation and Analysis in Railway.

It's a method of connecting with consumers and end-users to discover about domain requirements, services to deliver, and other limitations. It may also involve a different kind of stockholders; end-users, and requirement engineers. Abugabah and Alfarraj discovered that a high number of projects failed to meet the needs of their end users [5]. Furthermore, a bigger number were found to run over their budget. Finally, if a product fails to meet end-user requirements, the project is deemed a failure. [6]. As a result, gathering user needs has the potential to determine whether a project succeeds or fails [7]. If inaccurate data is acquired, needs are misread, or requirements change during development, projects may have to be abandoned or recovered, resulting in significant additional development expenses. Considerable factors are required to determine the elicitation process and its not only a matter of picking the right technique for gathering user needs. Many aspects influence the quality of the requirements acquired, including how the technique is implemented and even the mood of the users. In this chapter, the relevance of eliciting end-user needs will be highlighted. It will then move on to examine several approaches and tactics for gathering requirements, as well as how to overcome any problems that may arise during the process. Finally, this chapter will go over the methods for gathering end-user requirements.

Approaches in User Elicitation Techniques for Railway Settings.

Direct approach

Interviews, case studies, and prototype methodologies use a straightforward approach to improving understanding of the system's problem. The inquiry provides appropriate knowledge of the system and real information in a direct approach method. There is a lot of clarity in the requirements, which means there are a lot of expectations. The users meet experts one on one to discuss the system requirement.

Indirect approach

During the requirement elicitation process, an indirect strategy is used to gather information that was not gained through a direct technique. Indirect methods include questionnaires and document analysis. Document analysis, on the other hand, is a technique for gathering enormous amounts of data. Finally, facts and statistics are employed to define requirements.

User Requirements Elicitation Techniques

User requirements elicitation for railways can be an iterative process of refining low-level concepts into a highly detailed prioritised list of requirements. End user requirements gathering includes four stages[8] :

1. Elicitation – identification of the relevant stakeholders, reason(s) to develop the system, user roles and characteristics, external interfaces, non-functional requirements and specific quality and reliability targets and to establish a clear vision of the project
2. Analysis and specification – development of a conceptual model of the railway, prioritising the requirements and analysing the risks
3. Validation – verification that requirements correspond to users 'needs using iterative feedback from stakeholders
4. Management – monitoring that the process adheres to user requirements, including the measurement of defects and controlling modification in requirements. Others have separated these four phases into six stages, separating analysis and specification into their own disparate stages and adding a verification stage [9].

Classic/Traditional Techniques Interviews:

Interviews: Interviews are the most prevalent and popular method used by requirement engineers to elicit system requirements and comprehend system objectives by conversing with stakeholders verbally[10]. Structured or closed interviews (i.e., with pre-set questions), semi-structured interviews (i.e., with a mix of pre-defined and unplanned questions), and unstructured or open interviews (i.e., with no pre-defined questions) are all options (i.e., an informal interview that does not involve predefined questions). The first two approaches generally focus on quantitative data collection, whereas the third approach emphasizes understanding user expectations through open interactions with stakeholders and qualitative data collection [11].

Surveys: The strategies are used in requirement engineering (RE) to elicit a large number of requirements from a broader population that may be dispersed across multiple geographic regions. Surveys collect data from a huge number of people, and it is relatively inexpensive and quick to evaluate the data using designed surveys. The response rates may vary depending on how well the general public comprehends the questions that must be answered to achieve the standards.

***Questionnaires*:** The RE questionnaire is a basic way of requirement elicitation that takes less time and money. The questionnaire should be simple, concise, and structured to acquire true user needs, objectives, and restrictions in order to obtain precise results[4, 5]. However, this method lacks a mechanism for eliciting user clarification on the subject.

Task Analysis: This technique allows you to build a top-down job hierarchy of the system in a unique way to discover the information that was utilized or required during the system's development. The task and sub-tasks are organized at different levels in a tree structure or tabular way using this hierarchy.

***Domain Analysis*:** By studying existing applications and supporting documentation, it is used to gather early needs and capture a bird's eye perspective of the domain knowledge (railway). [12]. This method is frequently employed by railway professionals to thoroughly research the environment in which the train will operate. It's a useful technique for eliciting requirements from existing and new design documents, instruction manuals, templates, and forms that are used in the present system or business processes. The railway knowledge, as well as its reusable concepts and components, is included in domain analysis. When a project involves the replacement or upgrading of an existing legacy system, this strategy is often used.

Introspection:

The system analyst is expected to expose the requirements based on what the users and other stakeholders want and need from the system during introspection. Despite the fact that some analysts use it just in part, this technique is frequently used as a starting point for other requirement elicitation processes. Introspection is only truly effective when the analyst is not just well-versed in the system's domain and aims, but also knowledgeable about the users' business processes. When the analyst is forced to use this strategy more frequently, such as when the users have little or no prior experience with railway traffic systems in their workplace, a type of facilitation introspection should be conducted using other elicitation techniques like interviews and protocol analysis[5, 6].

Cognitive Techniques

***Card Sorting*:** Card sorting technique, requires sorting of a series of cards by stakeholders/customer according to the name of domain entities in to groups with respect to their own knowledge about the information gathering process. As a result, the stakeholder is asked to describe the explanation of the parameter used to order the cards. By organizing the cards, card sorting assists in prioritizing the most important requirements. To make this technique more effective, all necessary entities must be included in the process, and both the analyst and the participants should have significant expertise of the railway industry; otherwise, this technique produces wrong results. Group work can be utilized to identify these entities if the domain is not well established. [5, 6].

Class Responsibility Collaboration (CRC)*:* It's a derived technique of card sorting that's used to describe software needs in the form of classes, each with its own assigned duty for processing user requirements. CRC provides high level concepts and describes how classes are related. CRC cards, on the other hand, are limited in their ability to delineate details concerning software elicitation [11].

Laddering: It is an elicitation technique whereby stakeholders are asked a number of brief questions, known as probes, afterwards required to manage the overall answers in an organize format for clarity. At the developing stage of any system interviews are always elicited from the users to understand their expectation or ideas which can then be arrange in a hierarchical fashion. To make this technique effective the stakeholders involved must be an expert to some extent in in order to demonstrate a thorough comprehension of the subject and a logical organization of their thoughts. These concepts are frequently represented using a tree diagram, which may be reviewed and adjusted dynamically as more information is provided. Laddering, like card sorting, is primarily used to identify domain items and clarify user requirements [12].

Repertory Grids: Stakeholders are asked to uncover attributes and give values to a collection of unique and specialized domain entities in the repertory grid [13]. By classifying the system's constituents, outlining the occurrences of those classifications, and assigning variables with their associated values, the system's resultant is described in the form of a matrix. The purpose of the repertory grid is to find similarities and contrasts among the various domain elements. This technique is more abstract and not easily understood by users and consequently, it is applicable when eliciting requirements from domain experts. Repertory grids are limited when it comes to investigating certain qualities in complex criteria because they are more careful than card sorting and lower than laddering [14].

Modern and Group Elicitation Techniques

Group work:

In a group meeting, group work is an elicitation technique used to elicit requirements from various stakeholders. Groups are important because they directly involve and commit a large number of stakeholders while also encouraging peace and collaboration. However, due to the large number of diverse stakeholders involved in the project, it is difficult to plan these sessions. Managing these meetings necessitates knowledge and experience in order to monitor and control individual personalities so that they do not impact the conversation. Aspects of group work include the makeup of the participants and group cohesion. Despite political segregation that might pose a problem for group work Stakeholders must feel free to speak and express their minds openly and confidently in all honesty [6, 8].

Brainstorming: Brainstorming [15] is a technique used to generate numerous ideas rapidly from different stakeholder groups through informal discussion without focusing on a particular topic. During this group work, individuals speak of their knowledge based on their research and experiences. However, no room is allowed to critiquing ideas as brainstorming does not resolve issues or make key decisions. The goal of this technique is to define the project's mission statement as well as the system's target. Brainstorming has the advantage of promoting free expression of thinking and allowing for fresh and imaginative solutions to existing challenges [12].

Joint Application Development**:** This is an elicitation technique that involves stakeholders and users to engage through dialogue on the design of the proposed system and discover both the problems to be solved, and the available solutions to those problems. Since it is an organized and structured technique with all participants involved and not exceeding 30, decisions can be made faster and problems resolved quickly. JAD differs from brainstorming in that the system's core aim is already established before the stakeholders and users get involved, JAD sessions are also usually well-structured, with clearly defined steps, actions, and roles for all participants. The main focus of JAD sessions is on the business and user goals and aspirations rather than technical difficulties. Due to its dynamic nature, a requirement engineer is often required to give general overview of the system while stakeholders and users discuss until final requirements are gathered [4, 6, 8].

Requirements Workshops**:** Requirements workshops [16] is a general name for developing and discovering requirements for a system by the stakeholder using different types of group meetings. This technique is feasible for large and complex solution and provides a comprehensive set of requirements compared to brainstorming and group meetings but is relatively slow in the elicitation process. The needs that result from collecting several requirements in various sessions are unchangeable. Meanwhile, it is very costly in terms of time and money and is unfeasible for small projects [12].

Protocol Analysis**:** Protocol analysis[17] is a technique in which people engage in an activity to discuss customer requirements aloud, defining the actions taken and the thinking processes that underpin them. This technique provides detailed information and justifications for the procedures that the system must support to the analyst. Because walking through an operation isn't always the most common method, it's possible that you won't be able to accurately depict the genuine procedure.

Prototyping: The technique involves providing a prototype to the system's stakeholders and customers in order to aid in the exploration of possible solutions and to collect thorough information and feedback. Prototypes are often used in conjunction with other elicitation techniques such as JAD and interviews, and are derived from preliminary requirements or existing instances of similar systems. They are especially useful when developing human-machine interactions or when stakeholders and customers are unfamiliar with the available solutions. Storyboards, executables, throwaways, and evolutionary prototyping are examples of prototyping methodologies with varying levels of effort. Prototypes are time and cost intensive to construct, but they offer the advantage of encouraging stakeholders and users to participate actively in the development of requirements. The prototype's main flaw is that consumers may become fixated on it and unwilling to consider other options. This technique is critical for designing systems with novel applications [10, 11].

Use cases: This technique aims to define needs by describing the entire flow of an event to stakeholders in the form of a story. Use cases are a simple and informal way of understanding and validating needs with stakeholders. Certain notations are used in Use case, its best way to collect the requirements from user. Show step by step input and its process.

Scenarios: Scenarios are used in requirements elicitation as narratives, specifically for descriptions of current and future processes that take into account the user's activities and interactions with the system. Scenarios, like use cases, require a repetitive and interactive design to development. But don't think about the system's fundamental structure. When employing scenarios, it's also critical to collect all possible exceptions for each phase. Furthermore, a great deal of effort is being put in by both the academic and practice sectors to develop organized and Scenario elicitation approaches are rigorous, and they're useful for understanding and validating requirements like test case development [12].

Contextual Techniques

Ethnography**:** Ethnography[18] is the study of individuals in a given cultural setting in their natural domain, and it entails the analyst actively or passively participating in the users' everyday activities over a set period of time while collecting data on the operations they perform. Ethnography is necessary when addressing factors in the domain (railway) such as usability and group work settings where the knowledge of interaction amongst many users and the system is vital. This technique is effective when a new system is required due to current problems with processes and procedures, as well as identifying social trends and difficulties in human stakeholder relationships [12].

***Observation/Social Analysis*:** One of the numerous sorts of ethnographic approaches is observation, often known as social analysis. The analyst only observes the actual performance of the existing processes through the customers or users without interference. However, observation is a technique often used alongside task analysis and interviews though very expensive to perform and the analyst must have sufficient competence and effort to grasp and translate the actions being performed. In most cases, observation and ethnographic procedures are altered because users shift their behavior when they are aware that they are being observed [6, 7].

Common Barriers in Requirements Elicitation and Possible Solutions

Even with meticulous planning prior to the requirements gathering activities, it is still possible to encounter unforeseen issues. A number of frequent concerns are listed below, along with ideas for how to avoid or overcome them.

Language barriers Questions should be structured in simple language, leaving out technical terminology (if this terminology is vital, a clear and concise explanation is mandatory). The questions should be asked in the mother language of participants where necessary to allow the participants to express themselves in their local language. If this is not possible, questions should be presented in both written and spoken formats as people may feel more relaxed reading in foreign languages.

Lack of common understanding – By regularly summarising the information that has been obtained from the participants allows the opportunity to correct misunderstandings and gaps early in the process and ensures that all of the information has been interpreted as intended.

Scope of information Techniques of elicitation requirements gathering such as interviews and focus groups often bring to light a large amount of information. These can be hard to analyze and draw conclusions, especially in terms of prioritizing needs and requirements. When dealing with enormous amounts of data, collating the data into common subjects can help to summarise and translate the data. At this stage, it is also good practice to go back to customers for validation of summaries.

Volatility **–** It is not uncommon that requirements change over time. A series of customers requirement studies will keep the contact with the customers and guarantee that they are informed about developments and content with the work that is being produced.

Bias – Unconscious way of thinking might be difficult to prevent. It is important to pay close attention to the wording of questions and directions, as it is simple to make mistakes. to ask leading questions or provide examples which may inflict opinions and views on participants. Good practice is to pilot questions, surveys, prompts and examples with a different group from the intended end users to make sure they are easy to understand. Further, interpretations should be checked by participants and against additional sources to avoid narrow or selective representations of results.

Participants feel uneasy – Participants should feel comfortable enough to express their views and opinions free from judgements of other participants or moderators. Interviews and focus groups can be an uncomfortable experience for participants if they feel they are being judged for giving an 'incorrect' or 'embarrassing' answer.

Losing focus – The moderator should ensure that the focus is kept on appropriate subjects and discussions do not veer off into irrelevant top.

Work Representation -Hierarchical Task Analysis in Railway (Driving).

For complicated task analysis, hierarchical task analysis is a cost-effective approach of acquiring and organizing data[19]. The most used technique for analyzing work representation is the HTA [20] it is use to: (1) comprehend how tasks divide up job activities and safety duties; and (2) develop a scientific understanding of rail driving teamwork. HTA are a well-proven and approved method for capturing this type of information[20]. The task is segmented, starting with an overall aim and then breaking it down into subordinate goals, each of which has a set of specific procedures that together comprise important components in the work's effective completion [21]. In continuation, it can capture and link physical and cognitive aspects of the task together which are to comprehend how a task is shared in terms of work activities and safety duties, it is vital to understand how it is divided. It also explains how the driving responsibility is divided among team members. According to a study completed by ERTMS Driver Task Analysis and Operational Specification in the United Kingdom under the Railway Safety Rserv241/T084 program. A train driver task was modeled using HTA. This format organizes task data into a hierarchical structure that explains the driving task in terms of top-level goals and underlying operations that must be done to meet the goal. Each objective and its underlying branch are accompanied by a plan that specifies the order in which actions are carried out, as well as any problem on the sequence or application of executions. For instance, the activities covered in driving actions includes:

1 Prepare for service
1.1 Prepare driver for driving duty
1.2 Assemble train (shunting)
1.3 Prepare train for service
2 Drive service
2.1 Start from scheduled service stop
2.2 In accordance with the transport official authority, drive to the planned service stop.
2.3 Stop for scheduled service stop
2.4 Perform service operations at stop
2.5 Perform operations for failed train
3 Close out train after service
3.1 Relinquish possession of train
3.2 Perform formalities after service.

Advantages:

- Gives detailed insight into the task being analyzed.
- Forecast an output that is useful for several other human factors analysis methods and tools.
- Provides a comprehensive task description.
- Applicable almost in any domain.

Disadvantages:

- Typically, not directly useful for determining design solutions.
- Primarily descriptive instead of analytical.

- Complex or sizeable tasks can cause an HTA to be time and labor exhaustive.

Human Factors in Railway Safety Principles of Designing and Prototyping

This section covers general human factors principles for design and prototype, as well as system and equipment selection. Firstly, we shall discuss about the principles of designing for a railway system and the consideration required for its long-term operation.

Human Factors in Railway Safety Principles of Designing

Basic design elements: The railway system and equipment should be easy to operate and maintain while performing their intended functions for which it was designed or procured for adequate functioning of the system. To achieve reliable performance with the required sensitivity, precision, time, and safety, all staff and equipment should be assigned a defined task, and the minimum level of skill required to be cost-effective to utilize the system [22]. Furthermore, systems and equipment that take into account the human aspect in railway design must conduct early and ongoing testing with real users in a realistic environment. In addition, the railway system should be reliable to render its services to the users and not wait until the users/customers notice a breakdown[23].

Simplicity: The railway design system interface of the human-machine interaction should be kept as simple as possible, and compatible with expected maintenance and operational procedures. Minimal training shall be carried out on the environment where the train system operates inclusively repairs, maintenance and operational activities[22]. The design of the system should be clear and user-friendly to every operator[24].

Consistency: This is the process of adhering to the same concepts and procedures with little variations[25]. The railway system and equipment should be designed in such a way that they retain consistency in look, behavior, and response across the board [23]. Also, to make learning simple for operators and users, systems should be designed to offer consistency for mental model in understanding. Designers should minimize the level of the inconsistency with the rest of the user interface if an occasional divergence from consistent design is required to enhance user task performance [22].

Standardization: The process of standardizing user-interface features across many applications is known as standardization[26]. During the design of railway system hardware and software processes, standardization shall apply to the degree necessary with compatibility for system functions and purposes. The same standards for identical interfaces shall employ the same functioning in the system and equipment. Controls, displays, marking, coding, labeling, and layout schemes must all be consistent. The appearance of equipment with different units or modules shall be distinctive in their identification within the system[27]. The railway system should be standardized with terminology, look, and feel [28], However, equipment that has the same form and function shall be interchangeably throughout the system and related systems. If equipment is not operationally interchangeable, it must not be physically interchangeable.

Safety: Safety [29] is an unintentional harm. Railway systems and equipment should be designed to contain the necessary and personal safety aspects for human performance, taking into account the minimization of human error in normal, deteriorated, or emergency settings as well as hazardous environments. Firstly, the system shall be provided with a fail-safe design to avoid failures that can cause severity, damage, injury to personnel, catastrophic, or unintended operation on equipment. Secondly, the system should be made error resistant to protect operators and users from making errors to the maximum possible extent by providing simple information during operations. On the other hand, the system should be a human error-tolerant design[30], with the ability to mitigate the errors committed to a certain threshold. Therefore, tolerance to these errors can be made low by adding monitoring capabilities[31]. Thirdly, the system and equipment should alert users before they begin a task that could have catastrophic repercussions [30]. Fourthly, there shall be a clear identification for safe and unsafe operating states and actions throughout the railway system and equipment phases. Fourthly, there shall be a clear identification of safe and unsafe operating states and actions throughout the railway system and equipment phases. Furthermore, the provision for emergency procedures in critical systems shall require description in a step-by-step manner, conducted in the event of failure regarding the railway system and equipment[32]. In addition, redundant mechanisms in the railway system and equipment that offer important functions must be provided to reduce failure.

System and equipment design should be modular. The rationale is that if the system components are standardized or uniformly designed in the case of any failure, it is easier to replace them with another. Meanwhile, there should be a provision of warning labels in the design, location, procedural guidance to prevent damage to equipment during handling, installation, operation, or maintenance. Finally, for equipment having physical features, avoid misalignment and poor attachment. Also, labels or codes need to have proper alignment and mounting.

User-centered perspective: Throughout the design and development stages, a user-centered perspective[30] involves attention on the wants, qualities, and requirements of consumers or end users, as indicated below.

Provide timely and informative feedback: The system and equipment must offer timely and informative feedback in response to user activities in order to keep the user informed about current events.

Provide predictable results to user actions: There should be a predictable results through users actions[24].

Use familiar terms and images: The user should be familiar with the phrases and graphics used on the systems and equipment.

Design within User abilities: To be effective, the system, equipment, and facilities must adhere to the user's capabilities and constraints in order to perform operation and maintenance in their working environment without surpassing those capabilities [33].

Maximize Human performance: Systems and equipment should be designed in such a way that they promote effective work patterns, personal safety, and health while minimizing factors that decrease human performance. [33].

*Minimize training requirements***:** Within the constraints of time, cost, and performance trade-offs, systems and equipment should be designed to reduce human and training requirements [33].

*Design to meet user requirements***:** The design of systems and equipment should be such that it satisfies the unique needs of users while also ensuring that those needs are addressed in terms of functioning [34].

*Minimize User actions***:** The design of systems and equipment should minimize the movement of eyes and hands, so as to achieve better efficiency.

Facilitate transfer of skills: The design of systems and equipment should allow for the transfer of skills learned in one situation to another through consistency and uniformity.

Design for 5th to 95th percentile: Starting with the 5th design to the 95th percentile levels of the human physical features that make up the population, System and equipment design must be as simple as possible [22].

Accommodate physical diversity: The system and equipment should be designed such that it accommodates and addresses all the users in the given population.

Design to accommodate people with disabilities: For easy operation of the system and equipment with users having disabilities, a reasonable arrangement should be made were necessary.

Provide enough flexibility for different user skill levels: For flexibility use of the system and equipment, the level of people's experience and skill interaction must be good enough. Also, different styles are used to perform operation depending on their experience and skill obtained.
Maximize user subjective satisfaction: The design of a system should be such that users will like the new system or equipment to ease them perform their work quickly and safely without causing unnecessary workload.

Support: In the event that a worker has difficulty operating or maintaining software, systems, or equipment, assistance should be available. This assistance could take several forms, including a customer care hotline for technical assistance, on-line help, and user guides.

Maintenance
Design for common tools: Unless the use of specialist tools gives a considerable advantage over common hand tools or is required by security concerns, maintenance of the system or equipment should be designed to use just conventional hand tools.
Make system easy to maintain: Maintaining the system or equipment should take the least amount of time, cost the least amount of money, and require the least amount of support resources [22].

Human Factors in Railway Safety Principles of Prototyping
The representations or visualizations of the real system pieces are known as prototypes [34, 35].
During the commencement of a railway project, a prototype is often represented. It gives a general concept of how the system works and how the work is done. Prototyping is a technique for gathering user needs by displaying graphic user interface (GUI) -based system functions [37].
Requirements Elicitation's main purpose is to gather needs before creating a product however, unless it is in use or someone is actually utilizing it, it is impossible to find the additional requirements [37, 38] The method of obtaining needs from stakeholders and end users is limited, and it's tough to learn about their expectations and requirements for the new product without delivering a model that looks like the real thing.
In both a functional and graphical sense, a prototype represents the actual product [39, 40] It allows users and stakeholders to work with the initial version of the product to have a better understanding of the system and discuss any extra or missing requirements. Prototyping is the most expensive of all the approaches for gathering requirements [42].
Typically, prototypes are built at the start of the railway development process. These prototypes are used by software developers in circumstances such as,

1. When consumers are unable to communicate their needs
2. When it comes to needs analysis and feasibility studies, it's always a challenge.
3. Anytime requirement analysis and feasibility assessments are challenging.
   Prototypes can be classified into two categories. [1, 4, 31, 32],

Throw-away prototypes: This form of prototype is not reusable after the eliciting the requirements.

Evolutionary prototypes: This style of prototype can be used again and again. They are improved or evolved in response to customer feedback and then distributed as the original product.

Advantages of Prototyping
- Lessen the time it takes to develop
- Development cost is reduced
- Users are given a visual depiction, which makes system implementation easier.

- It is obvious how the system could be improved.
- Provides a high level of satisfaction for users.

Disadvantages of Prototyping

- There is a probability of users thinking the final product will be like that of the prototype.
- It's possible that developers may be persuaded to end with the prototype.
- It's possible that this will result in an incomplete system implementation.

Errors and Principles Relating to Human Reliability

Majority of railway accidents accounts for human errors and deteriorated performance [43], Most people in contact with the railway are the train driving crew, maintenance team, signalling and controllers, usually referred to as operators, plays an important role on the rail safety [44]. As a result, evaluating the operator competence together with the surrounding settings in which they perform their activities is critical for ensuring railway safety [45]. This has been recognized by the railway industry; for example, international railway bodies states that railways are required by law to develop and implement a standardized, effective safety management system (SMS) to ensure that their operations are managed safely. Having a human operator perform is especially advantageous. When creating an effective SMS, human operator performance must be considered. Also, railway performance shaping factors (R-PSFs) was advanced after a thorough review of the literature in the disciplines of human factors (HFs) and human reliability analysis (HRA) methodologies, In addition, 479 railway accident and incident reports from around the world were investigated. Finding where reinforced by Subject Matter Experts (SMEs). This procedure yielded a list of 43 components that were divided into seven groups [45,46]: dynamic personal factors, personal factors, task factors, team factors, organizational factors, system factors, and environmental aspects.

Another study showed that maintenance error decision aid (MEDA) of human errors on the work place can be further classified categorized as follows [48];

1. Design error: this flaw is caused by poor design.
2. Operator error: This happens when operating employees cease to work properly to follow proper procedures or when there are no proper procedures in place.
3. Fabrication error: This error comes from the fabrication stage because of poor craftsmanship, the use of inappropriate materials, or the fabricator failing to follow the blueprint criteria.
4. Maintenance error: In the field, this type of error occurs usually as a result of improper equipment installation or repair.
5. Contributory error: Source of error is hard to predict.
6. Inspection error: using substandard materials or machines over the correct ones.
7. Handling error: This issue happens as a result of improper storage or transportation facilities that do not follow the manufacturer's instructions.

MEDA outlines 11 primary human error criteria and how they might be avoided. [49];

a. Tiredness and inability to sleep - take breaks to avoid weariness;
b. In case you're angry or disturbed take time to calm down;
c. lack of skill- consult instruction manuals and ask the assistance of others;
d. faulty equipment – regular check of equipment;
e. if you find yourself daydreaming or unable to concentrate, change your routine to avoid boredom.
f. Eat well in order to stay sober and combat letdown caused by low blood sugar.

g. Extreme heat or cold - work indoors or restrict your time outside in extreme temperatures; If you have drunk alcohol, taken medication, or are under the influence of a controlled substance, you should not operate machinery or undertake dangerous duties.
h. Working too quickly - don't operate equipment if you're fatigued, stressed, or sick;
i. Don't panic in an emergency; learn first aid so you'll know what to do.
j. Taking chances and big risks – don't brag about it or believe you're immune to mishaps.

Assessment and reduction technique (HEART) [50] is also used in railway to quantify errors, regarding guidance for the approach has been produced with support from railway operations specialists.

Human Reliability Analysis in Railway

HRA is the likelihood that a person would complete a task according to its criteria for a specific period of time while avoiding any extraneous activity that could disrupt the system [51]. Several investigations on human variables and potential HRA procedures have been carried out because of the significant danger involved, the majority of these procedures originated and were developed for use in the nuclear sector. There are a variety of strategies and methods for assessing reliability as stated below:

HRA: First Generation Methods:

Have been established to support risk assessors in predicting and quantifying human error in the rail system [51] below are some methods widely used:

6.1.2. Operator Action Tree (OAT):

The OAT approach to HRA is founded on the idea that there are three stages to responding to an incident: observing or noting the occurrence, diagnosing or thinking about it, and responding to it.

6.1.3. Technique For Human Error Rate Prediction (THERP)

The goal of this method is to figure out how likely it is that essential activities will be completed successfully in order to complete a task.

6.1.4. Success Likelihood Index Method (SLIM)

It's a technique used in the field of human reliability assessment (HRA) to determine the likelihood of human error occurring during a task's completion [52].

6.1.5. Systematic Human Action Reliability Procedure (SHARP)

The SHARP can be use by a specialist to assess human reliability, and good for PSA. It can be used in combination toother methods.

6.1.6 Empirical Technique to Estimate Operator's Error (TESEO)

The technique is simple, but it is constrained in some ways, and it is used in HRA is used to determine the likelihood of a human error occurring during the execution of a task.

6.1.7 Human Cognitive Reliability (HCR)

It is a cognitive technique and the method considers the PSFs of operator experience, stress, and interface quality, as well as Rasmussen's idea of rule-based, skill-based, and knowledge-based decision making to assess the likelihood of failing a particular task[53].

6.1.8. Human Error Assessment and Reduction Technique (HEART)

The HEART method is use for error probability occurrence on a stated task with PSF. HEART is one of the most widely employed strategies in the United Kingdom nowadays [54].

HRA: Second Generation Methods

The goal of creating second-generation tools is to improve HRA strategies. The advantages are not very clear as they haven't been experimentally validated yet [55]. To address the limitations of previous methods, second generation methods are used.

6.2.1 A Technique for Human Error Analysis (ATHEANA)

When compared to other first-generation approaches, the most notable advantage of ATHEANA is that it provides a considerably suitable information about the human factors known to cause accidents.

6.2.2. Cognitive Reliability and Error Analysis Method (CREAM)

The CREAM approach is an HRA technique for determining the possibility of human error during the completion of a certain operation [51]. Contextual control model is the methodology used by CREAM. This model has 4 cognitive functions: observation; interpretation; planning; and execution. The CREAM technique goes much farther, establishing other corrective elements such as the likelihood of cognitive failure (CFPs).

6.2.3. Task Analysis for Error Identification (TAFEI)

The first step is to create a state-space diagram that describes the user's interaction with the product. The sequence of activities are represented and adequate for achieving a certain goal[56].

6.2.4. Standardized Plant Analysis Risk-Human Reliability Analysis (SPAR-H)

The method's major purpose is to evaluate cognitive human failure processes such as detection, understanding, decision, and action[57].

6.3. HRA: Third Generation Methods (A Simulation Approach)

Simulation-based HRA is distinct from its predecessors in that it is a dynamic modeling system that uses human decisions and actions to estimate performance[58].

6.3.1. Simulator for Human Error Probability Analysis (SHERPA)

SHERPA stands for "model simulator for human error probability analysis." It is a theoretical framework that combines the benefits of simulation tools with traditional HRA methodologies. The model attempts to forecast the likelihood of human mistake in a railway system or other sort of working environment for a particular scenario. The model incorporates three HRA elements:

- The HEART technique suggests task classification as one of the generic tasks.
- SPAR-H techniques performance shaping factors analysis;
- Computer simulations for dynamic implementation

6.3.2. Probabilistic Cognitive Simulator (PROCOS)

The simulator is designed to look at both mistake prevention and recovery. It is based on a "semi-static method" and tries to investigate how PSFs affect the operator cognitive process and the likelihood of human error[59]. The simulation model calls for the following:

1. A risk assessment that is preventative
2. An operator's cognitive model and
3. Classification of the possible error type

The main cognitive flow charts used in this simulation model was as follows: firstly, to mimic, the behavior and processes of an industrial operator, and lastly, a time-dependent simulation process is not performed by the simulator.

Human Error Analysis in Railway

Railway employees are responsible for a variety of responsibilities within their shifts because human mistake is more likely in some of these activities than in others. However, some of the duties carried out by railway staff are prone to substantial human error[60].

Although there are many potential locations for human mistake in railway operations, the following three are the most common [6]:

Signal passing

Trains passing at a signal displaying stop is very dangerous since it could collide with another train it is often referred to as signal passed at danger (SPAD)

Train speed

The train is built to travel at a certain speed on the track, and if the driver does not adhere to these speed regulations, an accident is likely to occur. Speed restrictions are imposed because of track curves and other infrastructure along the line; nonetheless, there are three sorts of speed restrictions: permanent, temporary, and conditional. The speed limits are determined by the type of activity being carried out on the railway.

Signalling or dispatching

In past times, railway was prone to accidents due to poor dispatcher of signalling men. Fortunately, the use of advanced devices has considerably reduced the occurrence of human errors.

Five categories of faults can be recognized based on this collection of possible interactions with the railway: (i) human error (HE), (ii) machine error (ME), (iii) error arising from human-machine interaction, (iv) communication errors from machine-machine, and (v) communication errors from human-human communication. Other than these five types, a sixth type, organizational errors, which are produced by organizational structure, can be included [61].

Classification of Human Errors

Human errors occur for a variety of reasons, necessitating a variety of responses to prevent or reduce the various types of errors [61]. They are:

7.1.1. Errors that occur when one is unsure of what to do

The intent is incorrect. They're commonly referred to as mistakes. Some of these mistakes are caused by a lack of fundamental information and training about the qualities of the materials or equipment in question.

7.1.2. Those that occur when someone knows what they should do but chooses not to.

It is commonly known as violation or not complying in accordance to commands. Many mishaps have happened as a result of operators, maintenance staff, or managers refusing to perform procedures that they deemed inconvenient or unnecessary. People are lured to employ the incorrect way because it is easier than the correct method.

7.1.3. Those that arise as a result of the task being beyond the operator's physical or mental capabilities.

Mismatches are what they're called, and they happen when people aren't right for the position. More occur as a result of people being asked to perform things that are physically or intellectually tough or impossible for them to complete.

7.1.4. Slip Errors or A Momentary Lapse in Attention.

Although the intent is correct, it is not carried out.

The different methods which have been developed to solve most of these human errors are stated in the HRA section above.

CONCLUSION

In the railway industry, the human factor for safety has become a serious issue because, the high cost of energy on roads and airplanes, rising energy costs with scarcity, and a desire to decrease pollution have necessitated a switch from vehicle to rail transportation. This paper describes the need for human factors integration in several phases of the railway system life span supported by international codes such as European standards. Usability of the railway is so wide in the transportation industry and requires the processes of requirement engineering to elicit requirements needed for long term operation. Meanwhile, considering only the human performance isn’t enough and must be overcome; international union of railways offer the possibility to adopt RAMS and HRA consideration for human factors.

Favourably different HRA models and personal shaping factors have been used to address human errors on the rail industry but have steadily developed over time respective. Despite most of the drawback on the traditional HRA models a dynamic modeling for complex human-machine analysis has been developed through simulations as described in brief in this work. Additionally, design standards have been addressed regarding rail monitoring and maintenance works as well.

The assessment of human interaction with the railway often called human- machine interface is still a major topic to address with the development of new models to solve bottlenecks on these human systems. However, future work is needed on human-barrier interaction for railway systems with some quantitative validation and further analysis of the influencing factors.

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