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# A Simulator for Human Error Probability Analysis (SHERPA)

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ABSTRACT

A new Human Reliability Analysis (HRA) method is presented in this paper. The Simulator for Human Error Probability Analysis (SHERPA) model provides a theoretical framework that exploits the advantages of the simulation tools and the traditional HRA methods in order to model human behaviour and to predict the error probability for a given scenario in every kind of industrial system. Human reliability is estimated as function of the performed task, the Performance Shaping Factors (PSF) and the time worked, with the purpose of considering how reliability depends not only on the task and working context, but also on the time that the operator has already spent on the work. The model is able to estimate human reliability; to assess the effects due to different human reliability levels through evaluation of tasks performed more or less correctly; and to assess the impact of context via PSFs. SHERPA also provides the possibility of determining the optimal configuration of breaks. Through a methodology that uses assessments of an economic nature, it allows identification of the conditions required for the suspension of work in the shift for the operator's psychophysical recovery and then for the restoration of acceptable values of reliability.



## 1. Introduction

Human error is here to stay [1]. This perhaps obvious statement has a more profound implication if we consider how common human errors are in everyday life and in the working environment. The vast majority of current catastrophes arises by a combination of many small events, system faults and human errors that would be irrelevant individually, but – when combined in a special time sequence of circumstances and actions – can lead to unrecoverable situations [2]. For this reason, wrong and inappropriate human actions are source of great concern and create efficiency and safety issues for every kind of working context.

Valid values are difficult to obtain, but estimates indicate that errors committed by man are responsible for 60–90% of the accidents; the remainder of accidents are attributable to technical deficiencies [3–6]. The percentage of incidents connected with human error in several industries is listed in Table 1. These complex systems tend to show a low probability of a negative incident occurring, but the consequences are high if an event occurs. The accidents are, of course, the most obvious human errors in the industrial systems, but minor faults can seriously reduce the operation performance in terms of productivity and efficiency. For example, human error has a direct impact on productivity because errors affect the rates of rejection of a product, thereby increasing the production costs and reducing subsequent sales [7,8].

Several researchers have focused on the concept of human error in order to understand, evaluate and identify possible actions to limit it.

The evidence that human actions are a source of vulnerability for industrial systems gave birth to the Human Reliability Analysis (HRA), which aims at further examination of the human factor through the prediction of when an operator is more likely to fail. The standard definition of human reliability is the probability that a person will perform according to the requirements of the task for a specified period of time and not perform any extraneous activity that can degrade the system [9].

The starting point of this work was to study the state of the art of current HRA methods, beginning with the quantitative methods of the first generation and the qualitative methods of the second one and extending to the third generation HRA approaches and new dynamic HRA methods. All these methods have the purpose of assessing the likelihood of human error – in working systems, for a given operation, in a certain interval of time and in a particular context – on the basis of models that describe, in a more or less simplistic way, the complex mechanism that underlies the single human action that is potentially subject to error [7,8].

Special attention has been paid to dynamic HRA methods that use cognitive modelling and simulation to produce a data framework that may be used in quantifying human error probability (HEP). Human performance simulation reveals important new data sources and possibilities for exploring human reliability [10]. Many efforts have been recently directed towards simulation, in order to assess human behaviour and calculate the reliability for the performed activity. Trucco

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**Table 1**
Estimates of human error in various sectors as percentages of all failures.

| Sectors | Human error (% ) |
|---|---|
| Automobile | 65 |
| Heavy truck | 80 |
| Aviation | 70–80 |
| Jet transport | 65–85 |
| Air traffic control | 90 |
| Maritime vessels | 80–85 |
| Chemical industry | 60–90 |
| Nuclear power plants (US) | 50–70 |
| Road transportation | 85 |

and Leva [11,12] developed a new probabilistic cognitive simulator (PROCOS) for approaching human errors in complex operational frameworks, while Mosleh and Chang [13–18] have presented an Information, Decision, and Action in Crew (IDAC) context model for Human Reliability Analysis. Despite the efforts of HRA experts to develop an advanced method, many of the limitations and problems of these approaches have not yet been resolved due to the complexity of human nature and the difficulty in predicting and simulating human behaviour.

This paper proposes a new use of HRA methodologies for HEP calculation through implementation of a Simulator for Human Error Probability Analysis (SHERPA), which aims to predict the likelihood of operator error not only about the performed activity but also as a function of time working. In this way, the simulator can dynamically analyse a whole shift to identify the moments of highest operator unreliability in order to organise the scheduling of breaks. The most important objective of this work is to provide a simulation module for the evaluation of human reliability that can be used in a dual manner [8], as follows:

- In the preventive phase, as an analysis of the possible situations that may occur and as evaluation of the percentage of pieces discarded by the effect of human error.
- In post-production, to understand the nature of the factors that influence human performance in order to reduce errors.

SHERPA assesses human reliability and uses this information to estimate the results obtained from different configurations and distributions of work breaks, thereby offering the possibility of determining the optimal configuration of breaks, in terms of both duration and distribution in shifts.

## 2. State-of-the-art HRA methodologies

The study of HRA is approximately 50 years old and has always been a hybrid discipline, involving reliability personnel, engineers and human factors specialists or psychologists [1] The goals defined by Swain and Guttmann in discussing the Technique for Human Error Rate Prediction (THERP) approach, one of the first HRA methods developed, are still valid: the objective of a Human Reliability Analysis is to evaluate the operator's contribution to system reliability. More precisely, the aim is to predict human error rates and to evaluate the degradation to human–machine systems likely to be caused by human errors in association with equipment functioning, operational procedures and practices, and other system and human characteristics which influence the system behaviour [2].

HRA has three basic functions: the identification of human errors, the prediction of their likelihood, and, if required, the reduction of their likelihood. To achieve this, HRA techniques estimate the probability of human error of the overall risk of the system, which can be expressed in the following simple formula [19]:

$$HEP = (\text{Number of errors occurred})(\text{Number of opportunities for error}) \quad (1)$$

The central tenet of HRA is that the HEP estimation process must be reasonably accurate, or at least conservative (i.e. tending more towards pessimistic estimates of failure probability rather than optimistic ones). If it is not accurate, or if it is too optimistic, then the risk may be underestimated.

The development of human reliability methods occurred over time in three stages. The first one lasted twenty years (1970–1990) and was the first human reliability method generation that focused on human error probabilities and operational human error [20]. First generation methods include 35–40 methods for human reliability, many of which are variations on a single method [6]. Many of these methods – such as Technique for Human Error Rate Prediction (THERP) [4–6,19–22], Accident Sequence Evaluation Programme (ASEP) [1,22] and Human Cognition Reliability (HCR) [5,6,9,22] – have the basic assumption that the natural deficiencies of humans cause them logically to fail to perform tasks, just as is seen with mechanical or electrical components. Each approach of this generation focuses on quantification in terms of success/failure of actions, with less attention paid to in-depth causes and reasons of observable human behaviour, which for these techniques is borrowed from psychological studies in behavioural sciences [8,23]. These traditional approaches determine the human error probability (HEP) by using established tables, human reliability models or expert judgment. The characterisation of human failure modes is usually very simple, such as in terms of *error of omission* and *errors of commission*.

The second phase (1990–2005), known as the second human reliability method generation, focused on human performance factors and cognitive processes. Human performance factors are internal or external and in general are everything that influences human performance, like workload, stress, sociological issues, psychological issues, illness, etc. [20]. The focus of the second generation shifted to cognitive aspects of humans, causes of errors rather than their frequency, study of factor interactions that increase the probability of error, and interdependencies of PSFs [8]. Advanced cognitive models have been developed, which represent the process of logic operator and synthesise the dependence on personal factors. One of the more widely used second generation techniques, Cognitive Reliability and Error Analysis Method (CREAM) [5,6,9,22,24–28] has an operator model that is more significant and less simplistic than in the first generation methods; HEP is derived from four Contextual Control Modes (CoCoMs): Scrambled, Opportunistic, Tactical and Strategic. CoCoM is based on the assumption that human behaviour is guided by two basic principles: the cyclical nature of human cognition and the dependence of cognitive processes from context and working environment. The Standardized Plant Analysis Risk-Human Reliability Analysis method (SPAR-H) [4,20,22,29–35] is instead built on an explicit information processing model of human performance derived from the behavioural sciences literature.

Additionally, second generation considers the context in which humans make errors and derive relative PSFs. A major difference between two generations can be simply stated as consideration of the PSF impact on operators. PSFs in the first generation were mainly derived by focusing on the environmental impacts on operators, whereas the PSFs in the second generation were derived by focusing on the cognitive impacts on operators. The context is carefully incorporated into the behavioural patterns, considering all the factors that may affect human performance. This is evident in SPAR-H, where its eight operational factors can be directly associated with the human performance model and show the human information processing model with which they are associated (see Fig. 1).