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REVIEW ARTICLE

HUMAN RELIABILITY DATA BANKS

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ABSTRACT

Modern systems have four basic components: hardware, software, organizational, and human. With the development of new technologies and systems, the hardware and software reliability has increased dramatically during the past decades, while in many cases the human reliability has remained either unchanged or even deteriorated over the same period as the result of complexity of systems. Human interactions are an important factor during the design, installation, production and operation, and maintenance phases of a product or system. The capacity of human beings to make mistakes and errors has been recognized since the beginning of recorded history. The new view on human error is that you can see the human error as the symptom of deeper trouble, in this case, human error is not a cause of failure. Human error is the effect, or symptom, of deeper trouble inside a system. It is not fair, logical and professionally ethical and sound for experts in the field of human factors and safety to say that human is recognized as the cause of as the matter of fact it is the failure of design and operation team and those who were unable to predict and mitigate source of human failure. This paper review was examined and summarized the history, significance, concepts, contributing factors, and all invented analytical methods and procedures in a systematic human reliability assessment (HRA). Furthermore, available human reliability data banks were introduced and elaborated. The challenges and issues in the field of human reliability field were later highlighted and emphasized. Lastly, the expected directions for future works by researchers and practitioners were suggested.

KEYWORDS: *Human Reliability, Databank, Accident, Human Error, Probability, Prediction, Safety*

INTRODUCTION

This research was aimed to introduce the significance, concepts, methodologies, and available data banks in the field of human reliability assessment (HRA) and to make a thorough and detailed review and conclusion on the latest developments in the field and outstanding challenges and issues.

This research was based on collection, review, and analysis of each and every scholarly paper published or presented in recognized worldwide journals, conferences, technical documentation, information, and thesis works in the fields of safety,reliability, human factors, ergonomics in academia, and various industries. The work was to go through more than 1000 pieces of sources and selecting more than 100 out of those with the most relevant and relaying information. The research work on another front was to make comparison and deduction among the findings and to build the potential connections and trends. The work was further enriched by multiple scientific deep interviews and research collaboration with some of the most renowned and pioneers in human reliability in the world level. The research was also inspired by

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the hand-on experience and cases that the author was directly involved in this subject locally and internationally in the automotive, rail, defense, oil, communication, and service sectors.

Reliability engineering was originally developed to handle rationally the failures of the components of the first type [1]. Nowadays, reliability analysis of complex systems is no longer restricted to the hardware aspect only, but also shall take into consideration other aspects, such as reliability of the human element [2]. It was not until the late 1950s that it was clearly stated that realistic system reliability analysis must include the human aspect [3]. Many times engineering systems fail because of human errors rather than because of hardware or software failures [4]. In 1962, a first human reliability database (i.e. Data Store) containing time and human performance reliability estimates for human-engineering design features was established [5] and since then much new human error data generation and methods have been created and several new databanks have been developed as mentioned in this report.

For many years, there has been increasing concern about the effects of human error in complex system safety and reliability. This concern has been increased owing to accidents such as Chernobyl, Bhopal, Herald of Free Enterprise, Three Mile Island, and the Kegworth air disaster [6].

In the vast majority of these accidents, human error has played a critical role in the events precipitating the accident. Such accidents can in theory be predicted and prevented by risk assessment, in particular assessing the human contribution to risk. However, the collection of human error data has proved a difficult field for the past 30 years, and yet industry would benefit from the existence of a robust human-error database [6].

Human error is now considered as the most significant source of accidents or incidents in safety-critical systems [7]. As large-scale human-machine systems become more complex, and as automation plays a greater role, accidents are increasingly attributed to human error in many contexts [8].

Although the degree of human interactions may vary from one product to another and from one production phase to another, they are subject to deterioration because of human error. While human error has existed since the beginning of humankind, only in the past 50 years has it been the subject of scientific inquiry. In regard to engineering products, human error is the failure to carry out a specified task (or the performance of a forbidden action) that could result in disruption of scheduled operations or damage to property and equipment [9-10-11].

It has been estimated in various surveys that human error is the primary cause of 60 to 90 percent of major accidents in complex systems such as nuclear power, process control, and aviation [12]. As an example, according to statistics regarding railway accidents in Korea from 1998 to 2007 [13], 68% of the train accidents involving collisions, derailments, and fires were attributed to human error or as per data provided in [14], the human factor was 74% in the main causes of accidents at sea.

In consumer product manufacturing, assembly problems due to human error, if they are not life-threatening, can increase production costs and delay deliveries. Design-induced human errors occasionally are the source of expensive product liability lawsuits. The recognition that human errors affect competitiveness, as well as customer satisfaction and well-being, has persuaded some companies to dedicate programs to the systematic reduction of human errors [15].

In 1962, a first human reliability database (i.e. Data Store) containing time and human performance reliability estimates for human-engineering design features was established [5]. In 1986, the first book on human reliability was published [3]. Since then many other researchers contributed to this field and many other databanks have been developed as presented in this report.

Main Body:

Human Error:

The economic advantages accruing from increasingly large plants has meant that complex systems such as nuclear power stations, chemical, and manufacturing plants have grown in size and complexity at a rapid rate. Concurrent with this increase in size, there has been an increased tendency to centralize control and to concentrate critical decision making into the hands of a small group of controllers. Many of these complex and high-risk systems are potentially highly destructive if allowed to proceed in an uncontrolled manner. The combination of these potentialities with the occurrence of human errors has given rise to catastrophic failures such as Chernobyl, Bhopal, and Flixborough [6].

The experience accumulated in the last few decades has shown that human factors play a significant role in the risk of system failures and accidents, throughout the life cycle of a system [16]. This explains a significant focus on human reliability analysis (HRA) and on its full integration within systematic risk analysis and reliability assessment procedures [1]. Since the Three Mile Island (1979) and Chernobyl (1986) accidents, extensive research on human error has been conducted especially in the nuclear power industry [7].

Human error may be described as the failure to perform a given task (or the performance of a forbidden action) that can result in disruption of scheduled operations or result in damage to property and item (equipment)" [17]. In reference [18], the human error was defined as the failure to perform a prescribed act (or the performance of a prohibited act) which could result in damage to equipment and property or disruption of scheduled operations.

Dhillon [19] stated that the Human error rate for a particular task follows a curvilinear relation to the imposed stress. He stated that at very low stress, the task was dull and unchallenging; therefore, most operators will not perform effectively. He added when the stress at a somewhat moderate level, the operator performs at his optimum level. He concluded that moderate stress may be interpreted as high enough to keep the operator alert. At a higher stress level, human performance begins to decline. This decline was mainly due to fear, worry, or other psychological stress.

Human errors may be grouped under six distinct categories including operating errors, assembly errors, design errors, inspection errors, installation errors, and maintenance errors [9-3-11].

Some of the causes of human error included poor design, poor work environment, poor work layout, improper work tools, inadequate training, and poorly written equipment maintenance and operating procedures [20].

Researchers have developed a variety of taxonomies for human error, such as *omission*, or failure to act, versus *commission*, or failure of action taken; error in *sensing*, *remembering*, *deciding*, and *responding;* and *slip* versus *mistake*, where a slip is an unintended execution, and a mistake is an execution as intended that turns out to be incorrect [8].

Human performance varies under different conditions and some of the factors that affect a person's performance were time at work, reaction to stress, social interaction, fatigue, social pressure, morale, supervisor's expectations, idle time, repetitive work, and group interaction and identification [21].

Human Reliability:

Human Reliability Assessment (HRA) aims to assess and reduce human error potential in a system, "HRA has been used since the 1980s, and came of age following Three Mile Island accident in 1979, from which the approach became commonplace in the nuclear industry, and spread to industries such as oil and gas, and the chemical industry" [22].

Swain and Guttmman [23] defined human reliability as follows: human reliability means the probability that a person correctly performs an action required by the system in the required time and he/she does not perform any extraneous activity that can degrade the system. Any method by which human reliability was assessed may be called a Human Reliability Analysis (HRA) [24]. The general framework for the quantitative assessment of human errors was termed human reliability assessment (HRA), which was concerned with the difficult and complex area of how human error can impact on risk. As part of this HRA process, it was usually necessary not only to define what human errors can occur but how often they will occur, by assigning human error probabilities (HEPs) to the identified human errors. Such human-error probability data are, in theory, collectible from observations of human errors in real systems during incidents and accidents and could, therefore, be collected into a human-error database. However, human-error data collection, which should arguably underpin the whole approach to quantitative HRA, has generally been an unfruitful area [6].

As mentioned above, the predominant metric in HRA was the HEP. The HEP was generally simply defined as [25]:

HEP=Number of Errors Observed/Number of Opportunities for Error

HRA has three basic functions, namely (26)

- The identification of human errors
- The prediction of probability or likelihood of human errors (HEPs),
- And reduction of their likelihood if required

The exact HRA approach varies but fundamentally there are a number of steps as described bellow [27]:

1. Define the scope of the study.
2. Carry out task analysis.
3. Identify human error and error recovery potential.
4. Carry out screening analysis (optional).
5. Represent the human contribution to risk into the system risk picture (e.g. via Fault and Event Trees).
6. Quantify the required human error probabilities (HEPs).
7. Consider dependence.
8. Evaluate risk
9. Reduce the human error contribution if required.
10. Document the results.

In the afore-mentioned SAM toolkit [28], several techniques were already available to fulfil some of the steps mentioned above:

Steps 1, 8, and 10: did not require specialised techniques or tools, and step 4 was optional and not considered here.

Step 2: Task analysis techniques–hierarchical task analysis [27-29].

Step 3: Human error identification-two techniques [30-31] were developed/adapted for this purpose in ATM and have been validated as fit for purpose in the ATM context [32].

Step 5: Representation-fault and event trees were found to be able to represent human error contributions in ATM risk analysis [33].

Step 6: Use of most appropriate HEPs available in DATA BANKS and/or HRA DATA Prediction Methods or in house empirical data or simulations experiments

Step 7: An adaptation of the THERP dependence approach was applied in one risk assessment [33].

Step 9: An approach called the human factors case [34] was developed to help reduce human error contributions to risk in ATM.

Characteristics and Collection Sources of Human Error/Human Reliability:

There are two major types of human error data which can be collected [35]:

- Qualitative data: This information provides both general error reduction strategies based on human factors experimentation and also specific error reduction guidelines based on feedback from operational experience.
- Quantitative data: This information can be in the form of relative data, e.g. the probability of error *A* is half that of error *B;* or in the form of absolute data, e.g. the probability of error *A* is 0.1.

Both types of data are useful in the context of human reliability assessment, but there is in particular a need for the collection of absolute quantitative data for use in Probability Reliability Analysis (PRA). These human error probability (HEP) estimates can then be used either in the validation of techniques which have been developed to quantify human error, or more directly for quantification if enough useful data exist **[**35].

Lack of data is probably the single most important factor impeding the development of human reliability indices [36]. A major problem in meeting this growing importance of HRA is the lack of empirical plant-specific data needed for assessment of human reliability [37]. As Swain noted [38], investigators in human reliability technology have spent much time and effort in building models, but not nearly enough in developing usable human performance data.

These data types can originate from various data sources, such as incident and accident reports, maintenance reports, PSA reports, equipment records, interviews with plant personnel, near-miss reports, violation, plant logbooks, simulators, experts, published literature, automatic data recorder, human data recorder, and experiments [39-40]. In an ideal world, all data would preferably be abstracted from relevant operating experience or robust, industrially relevant experiments. Unfortunately, there are difficulties in collecting these types of data, and, consequently, we have to assimilate data from a variety of other sources to complement real data or missing data for specific task scenarios. It is generally agreed throughout the reliability engineering domain that there is no readily available, truly believable, comprehensive compendium of human-reliability data [40-35].

Some of the guidelines for human performance reliability data collection/generation system development are as follows [41-42]:

- ensure that the data retrieval process is short and simple,

- ensure that the data system is flexible so that it can accept data from a variety of sources,

- ensure that the definitions and terms used are meaningful to system users

- ensure that the data system has the statistical analysis capability to analyze its own data,

- ensure that a significant part of the human performance reliability data can be integrated with product reliability predictive data,

- ensure that the performance data can be associated with various combinations of man-machine components, ensure that the data system is compatible with user circumstances, ensure that the output of the data system is in an effective format.

The reasons for the apparent deficiency are likely to be complex. Two of the simplest explanations are that human beings are so unpredictable that a definitive account of their general behavior could never be given, or the logistics of creating a compendium would render such an enterprise as practically impossible. Williams [43], however, suggested that many of the organizations operating in the reliability world already have partial human reliability databases of the sort necessary to operate in a commercially or politically sensitive fashion.

Human Reliability Data Generation/Prediction Methods:

The US Department of Defense and Atomic Energy Commission (AEC) was probably the first to provide an impetus to develop formal data collection and analysis methods for quantifying human performance reliability [44]. Their efforts were associated with weapon delivery systems and nuclear weapons, respectively. The study of Shapero et al., [45] was probably one of the first to quantify system malfunctions due to human error. They discovered that human error was the cause of about 39% of the missile malfunctions. The study conducted by Rook [46] in 1962 was also regarded as an important milestone in the history of human reliability data banks. This study was concerned with approximately 23000 defects in the production of nuclear components. He found that approximately 82% of the defects were due to the human element. In the same year, the American Institute for Research (AIR) Data Store was developed by Munger et al., [5]. It contained time and human performance reliability estimates.

A great majority of the work published on human reliability has been concerned with human performance reliability prediction. Almost everyone recognizes that human is extremely complex and difficult to model. Prediction models seem to come in "generations," with a new generation appearing each decade. Earlier work focused on probability compounding techniques. Some of these were linked with available data sources, which were never really available in great abundance. With the proliferation of computers, digital simulation models were developed and used. More recently, stochastic models have been proposed. However, despite the wide variety of technical approaches, there has been little convergence on the "right" model. One problem was that data, especially good error rate data, to support most models were limited. One observer noted that if two different analysts using the same model for a given situation, there would be two different results. Similarly, if the same analyst used two different models, then that person would obtain two different results. Although there were difficulties, designers must realize that prediction was needed to at least estimate the impact of the human on the system or process. Otherwise total system reliability will be overestimated [15].

There are three groups of human performance reliability prediction methods: probability compounding, digital simulation, and expert judgment. The total of models to date probably was close to 50. Of those, only the THERP probability compounding technique has persisted over the decades. For many years, digital simulation models developed by A. Siegel and J. Wolf were used and supported. Expert judgment methods are still used within the U.S. Nuclear Regulatory Commission [15].

Probability compounding methods are the easiest for most reliability engineers to understand because they use combinations of probabilities analogous to conventional hardware reliability prediction. The most popular method is the Technique for Error Rate Prediction (THERP) [24-15].

The ideal sources of HE data for these HRAs are empirical studies on human performance and accidents. Unfortunately, there is limited availability of such data [27]. This has led to a reliance on assessments by experts solely and/or with the use of probability compounding methods which are based on expert judgment and original data from fields and experiments, and this procedure has been used successfully in various areas [47]. However, several problems are associated with expert judgment for HRA. These problems can include inconsistencies of judgments and the difficulty in systematically considering performance shaping factors (PSFs), which are factors that influence human performance [23].

Since the advent of a Technique for Human Error Prediction (THERP) for nuclear power applications in 1983 [23], there has been continuous development and refinement of methods in human reliability analysis (HRA) [48]. HRA methods differ along with a number of dimensions, including their scope, underlying model, underlying data, and approach to quantification [49]. The history or evolution of HRA can be summarised as follows [50]:

1. Interest started in the US in the '1960s, with data collection programs, using the developing reliability paradigm that was in use relating to military defense systems (missiles in particular) [51-52].

2. Initial 'data store' approaches failed because they were too 'microscopic' in their breakdown of human performance (e.g. finger movements), and their 'taxonomies' failed to capture the goal-directed' or intentional aspects of human performance. Work split into two main camps, data-driven approaches and simulations (e.g. using Monte Carlo modeling techniques) [53-54].

3. The Three Mile Island nuclear power plant accident happened in 1979, and the best available technique at the time was the developing technique for human error rate prediction (THERP) [23]. This enabled proper treatment of human error and recovery in risk assessments.

4. THERP has been viewed a too much de-compositional approach, with limited consideration of the goal-driven aspects of human performance, so several other 'camps' developed expert judgment approaches that enabled experts to capture the 'reality' of human performance, these techniques themselves splitting into 'holistic' techniques (e.g. absolute probability judgment (APJ) [55], and paired comparisons (PC) [56], and 'structured' expert judgment techniques such as success likelihood index method (SLIM) and influence diagrams approach [57]. These two latter approaches focus on specific 'performance shaping factors' (PSF) evident in the scenario being assessed in terms of how they could affect human reliability, whereas APJ and PC do not 'decompose' the human error event being assessed to such an extent (and hence are more 'holistic'). Notably two of these expert judgment techniques (SLIM and paired comparisons) require a small amount of 'real' data to calibrate their predictions and translate relative likelihood predictions into actual probabilities, using a logarithmic relationship based in psychophysics known as Stevens Law see [56]. Another 'data-driven' technique (like THERP) that makes significant usage of key performance shaping factors is the human error assessment and reduction technique (HEART) [43-58]. Early simulation approaches included e.g. MAPPS [59]. The last category of HRA approach in this epoch was the family of time-based correlations of human performance, where the dominant PSF was time, its most notable example being the human cognitive reliability (HCR) technique [60].

5. From the mid-1980s there came a realization that 'quantifying' human error was critically dependant on having correctly and comprehensively identified the errors that could happen in the first place. This led to the development of a range of techniques such as systematic human error reduction and prediction approach (SHERPA) [61], and the borrowing of hardware reliability techniques such as hazard and operability study (HAZOP) [30], to ensure that HRA quantification approaches were dealing with the right errors in the first place.

6. In the late 1980s, there was thus a number of techniques available, and so a series of 'validations' took place to try to discern which ones were acceptable [62-63-64-65]: see [66] for a summary of 20 validations. Certain techniques appeared inappropriate, namely the time-based correlation approaches (in particular HCR) which were invalidated [67-68], and paired comparisons and SLIM, which suffered from an acute sensitivity to calibration problems (i.e. if experts wrongly assessed the calibration data, then the resulting predictions could be wildly inaccurate) [62].

7. This narrowed the 'playing field' down to a few techniques such as THERP and HEART, which had their own 'data-base', which was modified by the assessor according to the state of various PSF in the situation or scenario being assessed. Meanwhile work continued in the area of simulations, notably in cognitive simulations [69-70], which aimed to predict human performance via complex cognitive science-based representations of the human mind. However, whilst this remains a very interesting area, these techniques did not successfully make the transition from academic models to usable tools in practical industrial risk assessments.

8. In the early 1990s, there was a residual concern that the existing techniques were not really capturing the full impact of 'context' on human performance, and so might be misrepresenting human reliability [71]. This was particularly in relation to what became known as 'errors of commission', where a human does something that is unrequired. This was of concern because although such errors are rare, systems are often poorly defended against them. A number of initiatives were therefore started to develop so-called 'second generation' techniques [72-73] that would be more sensitive to the contextual effects on performance, and also would be more rooted in actual data and their fully analyzed context. Some techniques have appeared, e.g. connectionist approach to human reliability (CAHR) [74-75] and Mermos [76], but the most awaited technique with most development time and effort was undoubtedly ATHEANA (A Technique for Human Error Analysis) [77-78], which aimed to be the new second-generation panacea for the nuclear power industry. Unfortunately, although ATHEANA has been heavily developed to focus on how context affects human performance, its most recent quantification 'engine' is based on expert opinion so that the resulting status of the tool and its credibility for detailed PSA remains in question.

9. In parallel, from the late 1980s to the mid-1990s interest resurfaced in developing a human error database again, and two databases arose, the NUCLARR database [79] and CORE-DATA (computerized operator reliability and error database) [80-81]. NUCLARR's human error data however tended to remain at the 'synthetic' level (e.g. using values from THERP and some studies of Licensee Event Reports (LERs). CORE-DATA on the other hand did attract some new 'real' data from several industries (discussed in more detail later), which could be used as calibration data, or as data for technique validations, or possibly for some assessments themselves. CORE-DATA has in fact recently been used to 'upgrade' the original HEART technique to produce a new nuclear-specific version called NARA (nuclear action reliability assessment) [82].

10. The current situation is therefore that after 40 years or so of exploring HRA approaches, in Europe data-driven and expert judgment approaches are most often used, with techniques such as THERP and HEART and APJ (sometimes 'checked' with PC [83], and a few uses of simulation approaches [84]. There has also been a resurgence of interest in actual data (i.e. objective human error data recorded from industrial situations). The so-called second-generation techniques have largely failed so far to appear and make a significant impact in actual risk assessments of real industrial systems, though they are still being refined and explored [85], and one technique called CREAM, a simplified second-generation HRA approach [72- 86], is starting to be used more often in assessments. There is still however a significant emphasis on 'context' when carrying out HRA, and a strong sense of the need for detailed task and human error analysis (understanding the task context and the human errors and their pathways) in order to predict what can go wrong and prevent the error and/or its consequences from occurring. Meanwhile, HRA has spread from its initial 'home base' of nuclear power to other industries such as offshore oil and gas [87], military applications and interest [88], and new industries such as space and medical, and more recently, ATM and rail industries [89].

Available Human Reliability Databanks:

One of the most difficult aspects of addressing human performance reliability is obtaining good data. The existing data fall into two categories: human factors data and human error data. For the most part, the human factors data are in the form of design guidelines that are not reliability-explicit. There are some probability data that can be construed as reliability [15]. Easily accessed current human factors data sources are the revised MIL-HDBK-1472 and the FAA Human Factors Design Guide at http://www.tc.faa.gov/act-500/hfl/hfdg. They cover a broad range of human factors topics that pertain to automation, maintenance, human interfaces, workplace design, documentation, system security, safety, the environment, and anthropometrics [15].

The United States Department of Defense and Atomic Energy Commission (AEC) was probably the first to provide an impetus to develop formal data collection and analysis methods for quantifying human performance reliability [17]. In 1962, the American Institute for Research (AIR) was probably the first organization to establish a human unreliability data bank called Data Store. Over the years many other data banks have been established [10- 17].

Dhillon [90] lists some of sources for human error data as follows:

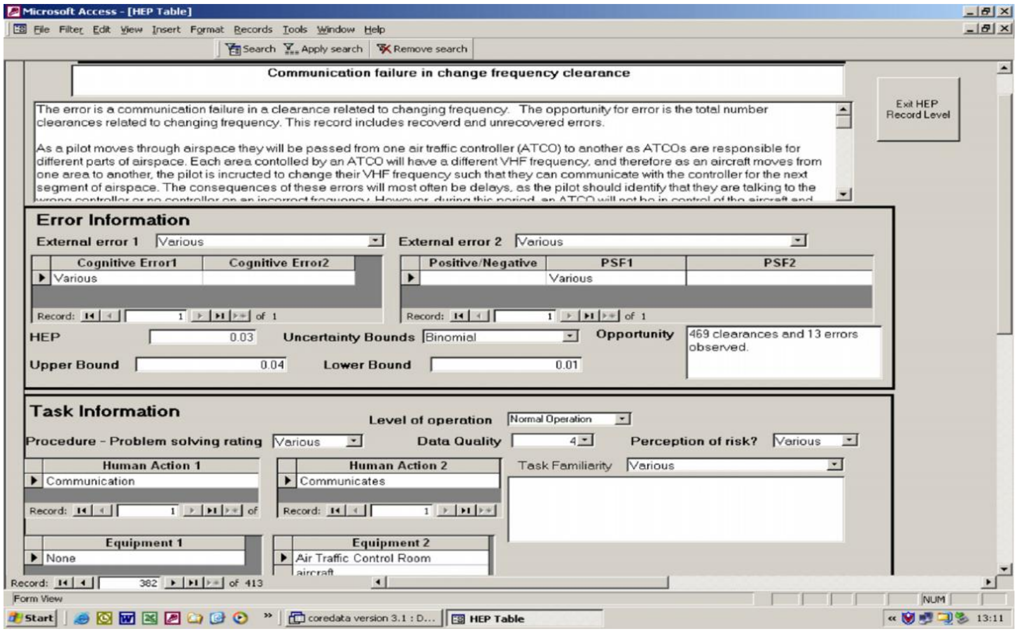
1. Data Store [5]. The important database (DATA STORE)

Containing time and human performance reliability estimates as well as identification of specific design features associated with degradation of human performance for human engineering design features was publicized in 1962 [5],

2. Book: Human reliability with human factors [10],
3. Book: Human reliability and safety analysis data handbook [91],
4. Operational Performance Recording and Evaluation Data System (OPREDS) [92],
5. Bunker–Ramo tables [93],
6. Aviation Safety Reporting System [94],
7. Technique for Establishing Personnel Performance Standards (TEPPS) [95],
8. Aerojet General Method [96],
9. Book: Mechanical reliability: theory, models, and applications [97], and
10. Air Force Inspection and Safety Center Life Sciences Accident and Incident Reporting System (Life Sciences Accident and Incident Classification Elements and Factors) [98].

More recently another Human error databank in the 1990s was created by the U.S. Nuclear Regulatory Commission and nuclear power industry called NUCLARR. The Nuclear Computerized Library for Assessing Reactor Reliability (NUCLARR) is an automated database management system used to process, store, and retrieve human and equipment reliability data for nuclear power plants. It is directly applicable to the probabilistic risk analysis (PRA) and human reliability analysis (HRA), which is part of the PRA. PRA is used in the analysis of nuclear power systems. The US Department of Energy Idaho National Engineering Laboratory manages NUCLAAR and consistently updates and maintains the data. The data tend to be plant- and equipment-specific with limited applicability outside the nuclear power industry [15].

Finally, CORE-DATA [81] as a database of HEP data and associated background information was created in the 1990s to aggregate all usable collected data with new data into one single database. The aim of COREDATA has been to collect HEP data and to support those probabilities with associated background information. This has entailed creating a taxonomic structure, gathering existing data from nuclear power and process control domains, and collecting new data via studies over the past decade in offshore, military, rail, and air traffic domains. The CORE-DATA database was initially developed at the University of Birmingham [80] in 1992–1994, and then fully computerized as a database with the support of the UK Health and Safety Executive [99]. CORE-DATA remains at the University of Birmingham, and further data collection to populate the database has been sponsored by a consortium of industry groups representing UK-based nuclear, air traffic control, and railway industries. This database also includes data collected from the offshore oil & gas, manufacturing, chemical, aviation, and defense industries [50]. CORE-DATA has two main objectives [50], the first is to support and strengthen the consideration of human error in risk assessments, particularly through the validation of HRA techniques, and provision of data that can help ‘calibrate’ such techniques, or in some cases can be used directly or with minor modification in actual risk assessments. Secondly, the process of collecting and normalizing data on error in a specific industrial task develops an understanding of that task such that, where necessary, suggestions for practical improvements can be made. The computerized database currently contains 4400 HEPs. An example of data held in the CORE-DATA system is shown in Figure 1. CORE-DATA contains taxonomies of industry, error, performance shaping factors, tasks, etc. to classify any data received or developed for inclusion in its database. The basic approach for generating new data has been either to carry out observation studies, e.g. of offshore drilling operations, or to analyze incident records and estimate the opportunity rates, or to use some form of simulation or experiment of an industrial task where errors can occur and be recorded [50].



Communication failure in change frequency clearance

The error is a communication failure in a clearance related to changing frequency. The opportunity for error is the total number clearances related to changing frequency. This record includes recoverd and unrecovered errors.

As a pilot moves through airspace they will be passed from one air traffic controller (ATCO) to another as ATCOs are responsible for different parts of airspace. Each area contolled by an ATCO will have a different VHF frequency, and therefore as an aircraft moves from one area to another, the pilot is incructed to change their VHF frequency such that they can communicate with the controller for the next segment of airspace. The consequences of these errors will most often be delays, as the pilot should identify that they are talking to the

Error Information

External error 1: Various
External error 2: Various

Cognitive Error1	Cognitive Error2
Various	

Positive/Negative	PSF1	PSF2
	Various	

HEP: 0.03
Uncertainty Bounds: Binomial
Opportunity: 469 clearances and 13 errors observed.
Upper Bound: 0.04
Lower Bound: 0.01

Task Information

Level of operation: Normal Operation
Procedure - Problem solving rating: Various
Data Quality: 4
Perception of risk?: Various
Task Familiarity: Various

Human Action 1
Communication

Human Action 2
Communicates

Equipment 1
None

Equipment 2
Air Traffic Control Room
aircraft

Figure 1. Snap shot of CORE DATABANK window

CONCLUSION

In practice, the choice of which HRA method to use for a particular safety assessment will remain a difficult problem. This calls for procedures of comparison and validation in order to guide the choice of an adequate approach for a given situation [50]. In order to perform a comparison of the available HRA methods, the best approach may be Virtual Reality Simulation [50]. A study is being undertaken at the Halden Man-Machine Laboratory’s (HAMMLAB) facility of the OECD Halden Reactor Project with the aim of providing the technical basis for the comparison of the performance and findings of different HRA methods [1].

All the methods of HRA focus strongly towards quantification, in terms of success/failure of action performance, with lesser attention paid to the effects of individual human error on the system. These result in limitations in the discovery of real critical human error modes and do not satisfy the objective of system safety or risk assessment. However, qualitative data are of great use, e.g. with respect to incident follow-up and in the determination of means to prevent the incident from recurring. As will become apparent later, qualitative data enrich the meaningfulness of the HEP and ultimately enhance the determination of its range of applicability to various PRA scenarios [35].

Human error risk assessment is a process to determine the risk magnitude of each human error mode to assist decision-making. The risk assessment results' reliability highly relies on the correctness of the risk model, the availability and accuracy of the risk data. However, risk assessors often face circumstances

where the risk data are incomplete or accompanied by high uncertainty. For example, one of the major criticisms of current HRA techniques is the need for expert judgment to evaluate HEP [100-101]. Additionally, in many circumstances, the effects of human error modes on the system cannot be explicitly evaluated because of the complex structures and functions of the system, and the complex interactions between humans and machines. Therefore, it is necessary to develop a new human error risk assessment method that can model the uncertainty to identify critical human errors. Under such conditions, fuzzy logic approaches are very practical. The fuzzy logic method can better simulate the complicated process and treat qualitative or imprecise or vague knowledge and information [102].

Human error is not random. It is systematically connected to features of people's tools, tasks, and operating environment. Human error is not the conclusion of an investigation [103].

Lasla K.P. [15] stated that the accuracy and stability of the available prediction methods depend on the method is used, the situation to which the method is applied, and the analyst that uses the method.

There is no question that there is a need to incorporate human performance reliability into the estimation of system or process reliability. Without considering the human, there will be overestimated of reliability and possibility of hazards to humans. Closely related to the prediction method situation is the data problem. With the exception of highly specific data kept by several sources and industries, widely applicable human reliability data are not available. Several attempts were made in the past to establish human performance data banks. The data banks lasted for a few years and then failed due to a lack of maintenance [104-110]. There are some data banks for manpower and human factors but widely applicable human reliability data banks are still lacking.

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