The Concept and Methodology for Developing Effective Human Reliability Databanks in Road Transportation

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Abstract

For many years, there has been increasing concern about the effects of human error in safety and the reliability of complex systems, such as road transportation. In the vast majority of critical accidents on roads, 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. As part of the human reliability assessment (HRA) process, it is usually necessary not only to define what human errors can occur, but how often they will occur by assigning human error probabilities (HEPs) to identified human errors. These data can originate from various sources, such as incident and accident reports, records, near-miss reports, violations, simulators, experts, automatic data recorders, human data recorders, and experiments. Lack of data is probably the single most important factor impeding the development of human reliability assessment and subsequently prediction of road accidents and taking proactive measures by authorities to reduce risks and improve reliability of transportation systems. However, what can be noticed from all these databanks is their attention to the consequences of road accidents on humans rather than to the causes of human error and the detailed characteristics and analysis of conditions leading to the error. The authors examined the status and conditions of available human reliability databanks. This paper discusses the necessity of effective human reliability databanks for reducing the casualties of road accidents and proposes a required structure and framework for future road transportation databanks.

Introduction

Failures of transportation systems affect the economy, the environment, and people's lives [1]. About 0.8 million fatalities and 20 to 30 million injuries occur each year around the globe as the result of road accidents [2, 3]. It is projected that, due to the growth in global population and subsequently denser traffic flow, road casualties will rise by 65% over the next 20 years unless there is an increased commitment to accident prevention [4].

Human error is now considered the most significant source of accidents or incidents in safety critical systems [5]. Various surveys have estimated that human error is the primary cause of 60-90 % of major accidents in complex systems such as nuclear power, process control, aviation, and road, sea, and rail-based transportation systems [6-7, 28-32].

Human error is defined as 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 [8]. Human reliability

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assessment (HRA) aims to assess and reduce human error potential in a system [9]. However, human error data collection, which should arguably underpin the entire approach to HRA, has generally been an unfruitful area [10]. HRA has three basic functions: the identification of human errors, prediction of probability or likelihood of human errors (HEPs), and the reduction of their likelihood, if required [11]. The ideal sources of HE data for these HRAs are empirical studies on human performance and accidents, but availability of such data is limited [12]. This has led to reliance on assessments by experts solely and/or with use of probability compounding methods that are based on expert judgment and available collected data, and this procedure has been used successfully in various areas [13]. However, several problems are associated with expert judgment for HRA, including inconsistency and the difficulty in systematically considering performance-shaping factors, which are factors that influence human performance [9].

The recognition that human errors affect competitiveness, customer satisfaction, well-being and incurring costs to society has persuaded auto companies and transportation authorities across the globe to dedicate programs for the systematic reduction of human errors [14]. Concurrent with the increase in size and complexity of road transportation systems, there have been increased risks associated with drivers on the roads [10]. There is no systematic program across the world to identify and understand road user errors, causes, recovery strategies, and their role in accidents and incidents [15]. However, there is no doubt that every day rich data are being collected, maintained, and analyzed individually by various organizations (law enforcement, transportation ministries and councils, health care and emergency services, auto manufacturers, repair shops) throughout the world. Unlike the aviation and nuclear industries, the data for road accidents are not collected, organized, and analyzed acceptably and scientifically by most countries for the purpose of identifying and analyzing root causes and taking remedial measures in response to these findings [16]. There are currently no available and widely applicable human error databases similar to physical components reliability/failure databases (e.g., OREDA, RAC-PRISM/MIL-HDBK-217) [10, 17-19].

In their research, the authors have highlighted the significance of human reliability on road transportation, the need for development of effective databanks on road transportation safety, and have examined the requirements of, and proposed a concept for, developing such databases.

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Available General and Road Specific Human Reliability Databanks

One of the most difficult aspects of addressing human performance reliability is obtaining the data. The existing data fall into two categories: human factors and human error [14]. For the most part, human factors data are in the form of design guidelines that are not reliability-explicit [14]. Williams suggests that "many of the organizations operating in the reliability world already have partial human reliability databases of the sort necessary" [20].

Datastore, developed by the American Institute for Research, is the first human reliability database containing time and human performance reliability estimates for human-engineering design features [21]. This database contains very fine scale data containing the motions of the human body, which is not generally applicable for studies in road HRA studies.

The NUCLARR (Nuclear Computerized Library for Assessing Reactor Reliability) is an automated database management system used to process, store, and retrieve human and equipment reliability data for nuclear power plants [22]. It is directly applicable to probabilistic risk analysis (PRA) and human reliability analysis (HRA), which is part of the PRA. The US Department of Energy's Idaho National Engineering Laboratory manages NUCLARR and consistently updates and maintains the data [14], which tend to be plant- and equipment-specific with limited applicability outside the nuclear power industry [14]. The data are nuclear-based and therefore have no applications in reliability assessment of drivers in road transportation.

CORE DATA, a database of HEP data and associated background information, was created in the 1990s to aggregate all usable existing data with new data into one single database [23, 24]. The aim of CORE DATA 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 [25]. 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 data come from non-road transportation sectors and are based on human error probabilities of questionable accuracy because the definition of the number of opportunities for error is hard to determine.

Road crash data are collected and stored electronically by police and transportation authorities in many developed countries across the globe [26]. These data, at best, include the following information that does not meet all of the needs for a human reliability assessment. These data appear to be more applicable for insurance, law enforcement, health care, and economics effects on society purposes than for the systematic decision-making needed for the elimination or reduction of the risks of accidents:

- Crash location
- Road environment
- Vehicles involved
- Vehicles drivers
- Vehicles passengers
- People injured or killed in the crash and the circumstances including notes and a diagram indicating the movements of the vehicles involved
- Factors that contributed to the crash (e.g., driving too fast for the conditions or failing to stop at a stop sign)
- Integrative statistics on casualties, monthly accident indicators, etc.

Requirements and Framework for HRA Databanks in Road Transportation

There are two major types of human error data, qualitative and quantitative, that can be collected [19]. These data in general can originate from various sources, such as incident and accident reports, near-miss reports, violations, simulators, experts, automatic data recorders, human data recorders, experiments, and prediction models [27].

As stated previously, the data available in general human reliability databases are not usable for road transportation safety analyses as the data are neither extracted nor related to road transportation, nor are they processed in a manner required for typical human reliability assessments for road transportation systems. Road-related data that are currently being collected and processed by the authorities in many countries and regions are limited and related to recognition of immediate causes of accidents, their consequences/effects, and the conditions immediately surrounding the accident, and not their root or latent causes [26, 28-32]. These data are also not tabulated and processed for the benefit of quantitative and qualitative human reliability assessments in a systematic manner. Thus, the complete benefit of these data cannot currently be attained.

To make road transportation data for human reliability assessment useful, they should be collected and processed by transportation authorities according to a developed fault tree analysis (FTA) chart as shown in Figure 1 [28-32]. Figure 1 illustrates logically all the root causes and their dependencies for a severe accident caused by the driver. The authors have converted the FTA (Figure 1) into a proposed accident investigation procedure for collection of necessary human reliability related data as presented in Figure 2. The procedure shown in Figure 2 could be used by the crash investigators as a guideline to collect data necessary for human reliability assessments. Furthermore, it is expected that appropriate data collection form be developed by the authorities derived from the authors' proposed investigation procedure (Figure 2).

There is a need for various reliability data to be collected. Some data are qualitative concerning vehicle-road-driver-passenger system, causes of accidents, and modes of failures using the investigation procedure developed and presented in Figure 2. Other data, including the time to failure in quantitative form (i.e., from moment zero of the trip to the time of the accident), for each failure mode should be obtained subjectively and objectively in order to fit the right distribution for failure rate per each mode of failure.

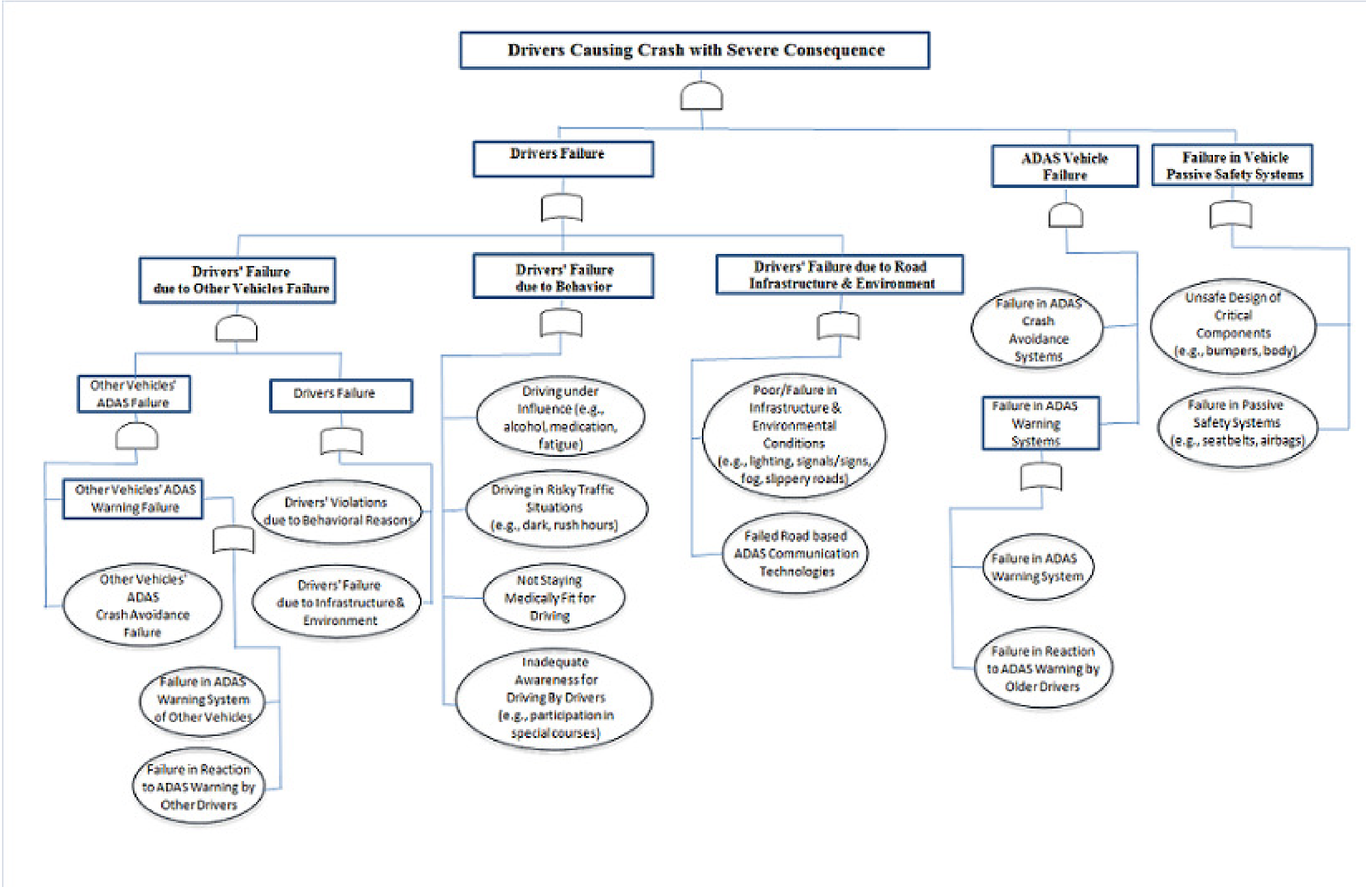

Figure 1. FTA of drivers causing crash with severe consequences

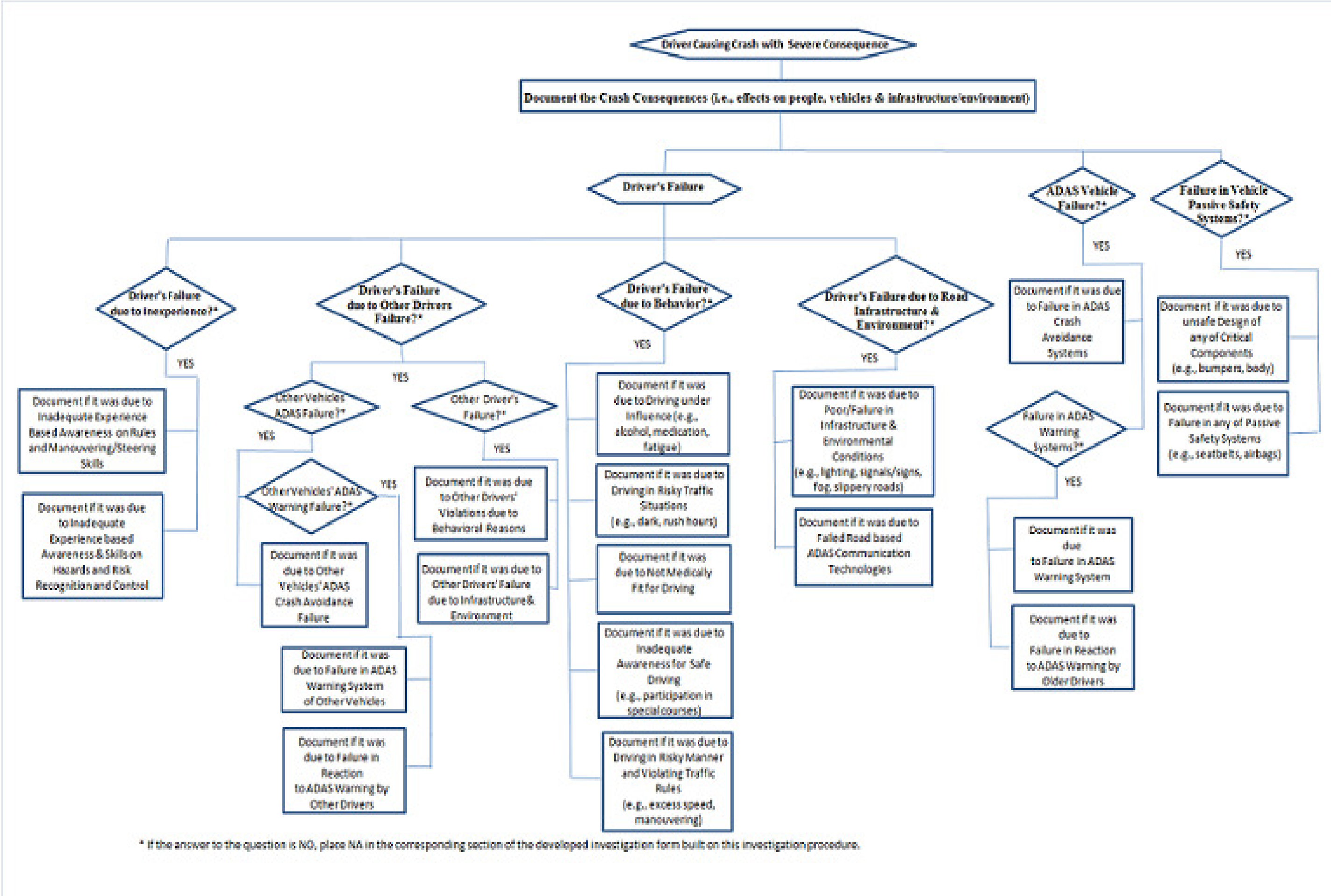

Figure 2. HRA-based investigation procedure of driver-cased crash with severe consequences

As the authors have suggested [30], the failure rates for experienced drivers (whether adult or elderly drivers) and younger drivers (containing a distinct learning phase) are expected to follow the distributions in Figures 3 and 4, respectively. The authors suggest that the data for time to accident should be collected and processed separately for various groups of drivers including young drivers, elderly drivers, and adult drivers. Mixing the data related to these three groups can skew the shape and parameters of the failure rate distribution and could lead to the wrong interpretation and use of data in the process of mitigating the risks. Furthermore, it is recommended that transportation authorities in various countries and regions should continually collect data and re-draws these distribution curves to monitor the results of mitigation and remedial action efforts taken for the betterment of drivers' safety subsequent to the investigation process. Each age group will exhibit differences in terms of failure rates. In the human factors discipline, the percentile concept in assessment and design analysis is used, whether for physical or cognitive characteristics of humans, and does not rely on averages.

Figure 3 illustrates that instantaneous failure rates of experienced drivers in a single trip should remain constant. However, as the driver reaches the exhaustion point, the failure rate can increase. The more experienced the driver, the less failure rate will be expected and vice versa

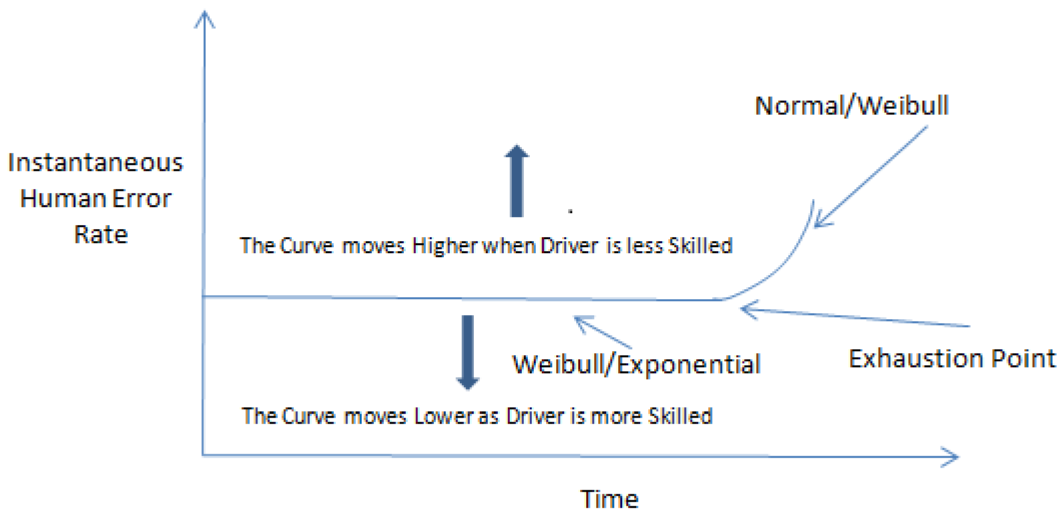

Figure 3. Expected characteristic of experienced drivers' error rate when driving

Figure 4 illustrates that the instantaneous failure rates of younger drivers in a single trip may vary if they are in the initial learning period (the first part of curve), remain constant (second part of curve when the infant/burning period of bathtub distribution passes), and increase (third part of curve when the driver reaches the exhaustion point). The more experienced the driver becomes, the less failure rate will be expected during trips and vice versa.

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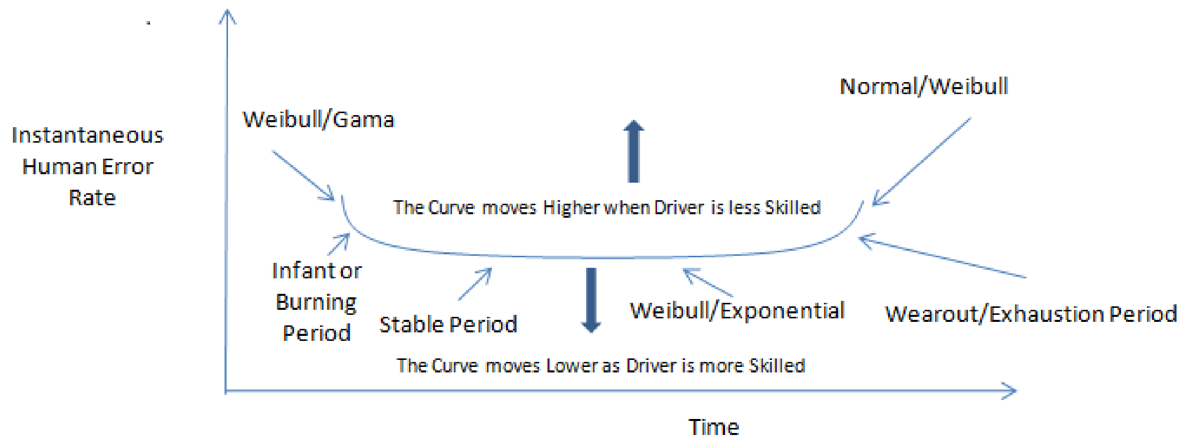

Figure 4. Expected characteristics of younger drivers' error rates when driving

Finally, the authors also suggest that the modern databanks in road transportation should contain a description of mitigation and follow-up actions taken for each individual failure mode identified in the accident investigation process, so that efficacy of mitigation efforts can be evaluated and documented over time.

Discussions and Conclusion

The new view of human error is that it is a symptom of deeper problems. In this view, human error is not a cause of failure but is the effect, or symptom, of deeper trouble inside a system [33].

All the available HRA databanks focus on quantification, in terms of success/failure of action performance, with lesser attention paid to the effects of individual human error on a system. This focus results in limiting the discovery of real critical human error modes and does not satisfy the objective of system safety or risk assessment. Qualitative data are of great use with respect to incident follow-up and in determining the means to prevent an incident from recurring [19]. The reliability of results of risk assessment highly depends on the correctness of the risk model and the availability and accuracy of risk data [34, 35].

The authors' work is proposed as a novel and customized concept and methodology for use by law enforcement and transportation authorities in the systematic investigation and assessment processes of road accidents. The data collected and processed as per the concept and proposed methodology should be fed into a well-designed, computerized database for ease of access, maintenance, and processing. It should be noted that the data and information available in such databases are valid for use within the context that the data were collected. Therefore, they should not be generalized and used by others when there are dissimilarities to the original context. From the results of this research, it is expected that the latent causes of each and every crash will be better identified, documented, shared with all road safety stakeholders, and appropriately addressed.

The authors do not prescribe any mechanisms and procedures using special shaping factors and expert judgment in this study to facilitate the flexible use of data from one database to another one. However, further research in this area can be conducted in future work.

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