Doctoral Dissertation

Quantifying the Influences of Human Factors on Safety Improvement in Marine, Aviation and Road Systems

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1. Background and motivations

The emergence of mechanized transportation ushered in a new era of complex sociotechnical systems. As technology progressed and transportation systems became more complex, the methods of accident investigation and risk assessment had to change. These changes paralleled changes in thinking about the role of people in transport systems for reducing accidents and improving safety management, in order to achieve the system safety.

Human factor has been emphasized as an important issue with system safety. The studies of human factors in transport systems have proven that at least 70% of transport accidents are associated with human. As the technical aspects of transport systems are highly improved at present, the role of the humans and their correlations with vehicle/machine, environment and management became more important.

Literature review indicates that research questions and methodologies vary significantly among marine, aviation and road systems. However, several similarities can be observed: both marine and aviation accidents have low probability but high consequence; the major accident type for marine and road accident is collision/crash; drivers or crews' drowsy behaviors should be paid enough attention, etc. Meanwhile, previous researches have largely focused on the association between factors and human performance in single transport sector, which has resulted in a comprehensive understanding of factor influences in single system. However, it may be unrealistic to treat human, technical factors, and environmental factors as independent, because the cause of accident is always a combination of these factors. Therefore, an overall assessment of human factors' influences to transport accidents from systematic considering i.e., treat human factors and external factors (organizational and environmental) as dependent and interactional is needed.

2. Research questions and objectives

This research aims to gain a better understanding of the roles of human factors in the improvement of safety in different transport systems, by clarifying the similarities and dissimilarities of human factors influencing mechanisms.

Research questions are raised as follows:

Q-1 What role does human factor act in marine, aviation and road systems?

Q-2 How to evaluate human's performance during their operational process?

Q-3 Can professionals' awareness be used to overcome the issues of data availability?

Q-4 Can big data provide useful information of drivers' decision output based on their daily driving performance?

To answer these questions, several specific tasks are proposed:

(1) To gain a systematic understanding of human factors mechanism in different transport systems.

(2) To propose a modified Fault Tree Analysis (FTA) model dealing with various uncertainties caused by lack of data and human reliability quantification, from a perspective of risk analysis.

(3) To provide an operational survey and innovative modeling methodology for dealing with aviation accident which has low rate but high consequence, from a perspective of accident investigation.

(4) To identify different types of commercial truck drivers according to their daily driving performances at the macro level, and to excavate the variation properties of speeding behavior across different types of drivers at the micro level, from a perspective of safety management.

3. Major findings

(1) For marine system, the overall evaluation of LNG carrier spill accident indicated that pool fire, Vapor Cloud Explosion (VCE) and Boiling Liquid Expanding Vapor Explosion (BLEVE) are all within the tolerate region while further risk control measures might be in need for pool fire in terms of its relatively higher risk level. Human failure probability ranged from 5×10-5 to 8.697×10-4 in LNG carrier loading operation and from 5×10-5 to 9.49×10-4 in LNG carrier's unloading operation, respectively.

(2) For aviation system, the questionnaire survey of HFACS in aviation accidents confirmed that a majority of respondents evaluated many human factors to have a middle- or high-effect of aviation accidents. Meanwhile, the factors at the Unsafe Acts level are most influential to accident risks among all factors at the four levels, and the Unsafe Supervision level has the least influence.

(3) For road system, results of machine leaning techniques and multilevel modeling approach suggested that 40% of the truck drivers tend to drive in a substantially dangerous way, meanwhile the explained variance proportion of potentially extremely dangerous truck drivers (79.76%) is distinctly higher than that of truck drivers from other clusters (14.70%~29.32%). Driving time and driving distance have a positive impact on speeding behavior among all driving types.

4. Contributions

This thesis makes an initial attempt to examine the roles of human factors in the improvement of transport safety from a cross-sectoral and comparative perspective by targeting three types of transport systems (i.e., marine, aviation, and road) simultaneously and focusing on different stages in human information processing. Both

primary data (collected via questionnaire survey and digital tachograph) and secondary data (partially collected via literature review) are used. Simulation, machine learning techniques, statistical and econometric modeling approaches are utilized in response to different types of data and safety issues. Various professionals' experiences and awareness are also reflected in the analysis. Details are summarized below.

(1) For marine system, the proposed novel FTA model and flexible methods are able to understand and estimate LNG carrier's spill risk with limited data. Taking the advantages of CREAM and MCS methods for their strengths in dealing with uncertainties which may result from the lack of reliable data source, industries experience, or academic bias, the results can offer stakeholders with helpful reference for the decision making. Moreover, the proposed model can be further tailored for the evaluation of other transport accident scenarios. With the improvement of fundamental probability statistics and accident data, the proposed model can become a useful tool for risk assessment of human's operations in transport systems.

(2) For aviation system, a hybrid HFACS-BN model is proposed for understanding human factors mechanism involving in aviation incidents or accidents based on professional opinions from experienced stuffs working in the Ulaanbaatar International Airport, Mongolia People's Republic. First, it has provided a systematic and operational approach for aviation safety research by taking advantage of the HFACS framework and BN modeling techniques. Second, it has proposed to make full use of knowledge of aviation professionals to overcome the issues of data availability and to derive effective countermeasures against human errors by considering local contexts. Third, it has presented unique insights into aviation safety policymaking in the contexts of not only Mongolia but also other developing countries.

(3) For aviation system, it proposes an innovative approach to extracting useful information about commercial truck driver behavior from widely available big data sources. The detailed contributions are: 1) adopting a real-world truck-driving data and considering multiple factors; 2) using a large-scale dataset that records truck drivers' driving speed-related data with an interval of 0.5 s and GPS data with an interval of 1 min, and 3) building a multilevel model that reflects the influences of unobserved heterogeneities.