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A structured method for the traffic dispatcher error behavior analysis in metro accident investigation

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ABSTRACT

Identifying the traffic dispatcher error behaviors that frequently result in the occurrence of metro accidents is beneficial to prevent error behaviors and mitigate their consequences. Yet, there is no theoretical framework available for metro safety officers in investigating and classifying traffic dispatcher error behaviors. This article presents a structured procedure to analyze traffic dispatcher error behaviors in emergency based on the human information processing theory and the modified task analysis framework. In order to make the proposed method be more applicable to practical use, a detailed task list of traffic dispatcher in case of emergency is given by considering the characteristic of equipment in operation control center (OCC) to simplify the task analysis procedure. And the traffic dispatcher error behavior classification with an error degree value scale derived from the VACP model is built to identify the error behavior type, which defined human behaviors according to the information processing stages. Finally, the validation and reliability studies have been carried out to assess the reasonability of the proposed method. The grey relational analysis (GRA) of the data from 98 traffic dispatcher error related accident reports indicates an acceptable validation of the proposed error behavior classification. And the reliability analysis suggests an adequate inter-coder consensus of more than 70% percentage agreement of the proposed method in practical use.

1. Introduction

Metro emergency refers to such kind of events which happen suddenly within the scope of the operation, cause or may cause casualties and property loss, affect or even destroy the normal operation and must be dealt with timely by powerful measures (Shu et al., 2010). Due to the overcrowded feature and the situation of underground space, there are a lot of potential risks during the metro operation (Shi et al., 2012). If emergencies were not prevented in time, casualties, property loss and grave social consequences would happen easily.

It is well known that human error contributes to the majority of safety accidents (Reason, 1990), and these systems which are similar to the metro traffic dispatching system are no exception. In the railway system (Baysari et al., 2009) and the air traffic control system (Shorrock and Kirwan, 2002), human error has been identified as a causal factor of all accidents around 90% or more and 80–90% respectively. Despite the presence of automated metro operation control system, which lets the dispatcher's routine work be largely replaced by system functions, the emergency management is still heavily dependent upon the capabilities of traffic dispatchers. According to the Modular Urban Guided Rail System approved by all major rail industry suppliers and European rail operators, the basic system function of detection and management of hazardous situations still cannot leave the traffic dispatcher, even in the highest grade of automation – GOA4 (unattended train operation) (MODURBAN project group, 2008). That is to say, although the automated system prevented the emergencies caused by dispatcher's error behaviors effectively, the human error behaviors during emergencies cannot be ignored. In emergencies caused by passenger behaviors, equipment failure, or other social disaster, system may lose a part of automated safety protection function. Then, error behaviors of the traffic dispatcher are more likely to lead to a grave consequence. Tragic examples include the 2003 Daegu metro fire and the 2011 Shanghai metro collision, which are characterized by error behaviors of the traffic dispatcher. In the Daegu metro fire, the traffic dispatcher is failed to stop the second train to enter the fire and an additional loss of more than 70 lives occurs. The collision of Shanghai metro with 271 injured

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could have been completely avoided, if the traffic dispatcher found the position of all trains in the fault area before restarting the operation.

Despite of these, compared to other industries such as aviation and nuclear power, error behaviors of the traffic dispatcher in emergency have previously received limited attention. The development of appropriate prevention or mitigation strategies needs to identify these error behaviors that frequently result in the occurrence of accidents first (Baysari et al., 2008). But at present there is no structured method available for assisting safety officers in investigating and classifying human error behaviors within the metro emergencies, which can be easily associated with specific tasks and related system functions. The purpose of this article is to present a structured error behavior analysis method for traffic dispatcher that addresses these needs.

To date, no published research has examined the traffic dispatcher's specific error behaviors associated with metro emergency, but there are some researches available in other relevant domains of the railway control system and the air traffic control (ATC) system for reference.

Vanderhaegen (1999) presented a human unreliability analysis method for railway control system based on a causal human–machine unreliability model proposed by Telle et al. (1996), which contains three frequently occurrence error types: an acquisition related error, a problem solving related error and an action related error.

The technique for the retrospective and predictive analysis of cognitive errors (TRACEr) was developed for ATC system (Shorrock and Kirwan, 2002) on the basis of the expanded information processing model (Edwin and Laurie, 1984) and each task error was analyzed to four levels of detail: external error modes (EEM), cognitive domains (CD), internal error modes (IEM) and psychological error mechanisms (PEM). TRACEr was also used in the 'Human Error in Air Traffic Management' project by Eurocontrol, ultimately resulting in HERA-JANUS (Isaac et al., 2003).

The human factors analysis and classification system (HFACS) and its derivatives have been widely used in the railway control system and the ATC system. The original HFACS was developed by analyzing an extensive set of aviation accident report, and comprised four taxonomies: unsafe acts, preconditions for unsafe acts, unsafe supervision and organizational influences (Shappell and Wiegmann, 2000). Among them, unsafe acts were identified as decision errors, skill-based errors, perceptual errors, routine and exceptional violations. Following its development, HFACS was reportedly successfully applied to investigate accidents in the ATC and the railway system. For example, Anthony carried out an in-depth analysis of the ATC-related accident reports between 1985 and 1997 maintained by the NTSB and revealed that skill-based error behaviors (attention failures and memory lapses) were the most common type of error behavior committed by ATC personnel (Anthony et al., 2001). Daramola conducted a content analysis of the accident reports during 1985–2008 in Nigeria's air transport industry using the HFACS, and the results showed that skill based errors is the most frequently human error type.(Daramola, 2014). The U.S. Federal Aviation Administration (FAA) used HFACS to examine ATC operational error behaviors, and most ATC operational error behaviors were classified as decision errors and skill-based errors (Scarborough et al., 2005). HFACS was also successfully applied to rail (HFACS-RR) by U.S. Federal Railway Administration (Reinach and Viale, 2006) and was developed as a software tool named HEIST to help the railway industry consider human error issues at all levels of the system, including the railway traffic dispatching system (Reinach et al., 2007).

The Contributing Factors Framework (CFF) provided by Rail Safety Regulators' Panel is a tool developed for the collection and codification of data regarding rail accidents and incidents (Panel, 2011). Read et al. analyzed 96 Australian accidents and incidents occurring between 1999 and 2008 by using CFF, and found that task demand factors were significantly more often associated with skill-based errors, knowledge and training deficiencies significantly associated with mistakes (Read et al., 2012).

Besides, Kontogiannis et al. propose a framework of cognitive strategies in error detection in air traffic control, which contained two detection mechanisms of the situation assessment and the planning stages of performance (Kontogiannis and Malakis, 2009). Kim et al. developed a computer-aided system for analyzing human error in railway operations based on the Human Error Analysis and Reduction (HEAR) for use in Korean railway industry (Kim et al., 2010).

Whilst great headway has been made in the rail control and the air traffic control area, the available techniques may have, in fact, had less real use in metro traffic dispatching system considering the differences arising from the system. As mentioned above, error behavior analysis methods are always based on the theoretical human error behavior classification models which are closely related to the system and task characteristics. According to Johnson (1999), until these practical problems are addressed, increasingly esoteric models of human and organizational failure will be of little practical benefit. Furthermore, a more detailed error behavior classification is required for the special use of accident investigation. This article represents our attempt to analysis the types of error behavior that metro traffic dispatchers currently make during emergencies in China, and develops a structured error behavior analysis method. In conclusion to this article, the proposed method could potentially be used to either prevent these error behaviors from being made or mitigate their consequences.

2. Human error behavior classification models

The use of formal human error classification models is widespread throughout most complex safety critical systems. Various classification models of human error behavior have been proposed based on different theoretical foundations. For example, the classification model based on the observable false behaviors, such as Swain's error of commission and omission classification (Swain and Guttman, 1983), and the behavior classification of the predictive human analysis method (PHEA) (Baber and Stanton, 1996); the classification model based on the theory of schema, such as Norman's error categorization (Norman, 1981); the classification models based on the decision-making theory, such as Rouse's concept model of operating procedure error (Rouse and Rouse, 1983); the classification model based on information processing theory, such as Rasmussen's skill-based, rule-based, and knowledge-based behaviors (Rasmussen, 1983), Wickens' error behavior classification (Wickens, 1992), Reason's unsafe acts model and the Generic Error Modeling System (GEMS) (Reason, 1990).

The majority of traffic dispatcher emergency management tasks are generally seen as cognitive, meaning a high reliance on mental processes. These cognitive skills include detection and selection of appropriate fault information, diagnosis and identification of fault type, prompt decision making, rapid spoken communication, etc. Since most of these tasks cannot be observed directly, the human information processing theory is suitable for conducting the traffic dispatcher error behavior analysis. Some of the more prominent and influential frameworks in this theory are the traditional human information processing model (Wickens, 1992), the skills-rules-knowledge model (Rasmussen, 1983), and the model of unsafe acts (Reason, 1990).

An important notion behind the skills-rules-knowledge model is that human behavior can be controlled at different levels of conscious control which depends on the degree of familiarity with the