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An incident database for improving metro safety: The case of shanghai

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ABSTRACT

Large cities depend heavily on their metro systems to reduce traffic congestion, which is particularly the case with Shanghai, the largest and most developed city in China. For the purposes of enhancing the possibility in quantitative risk assessment and promoting the safety management level in Shanghai metro, an adaptable metro operation incident database (MOID) is therefore presented for containing details of all incidents that have occurred in metro operation. Taking compatibility and simplicity into consideration, Microsoft Access 2010 software is used for the comprehensive and thorough design of the MOID. Based on MOID, statistical characteristics of incident, such as types, causes, time, and severity, are discovered and 24 accident precursors are identified in Shanghai metro. The processes are demonstrated to show how the MOID can be used to identify trends in the incidents that have occurred and to anticipate and prevent future accidents. In order to promote the application of MOID, an organizational structure is proposed from the four aspects of supervision, research, implementation, and manufacturer. This research would be conducive to safety risk analysis in identifying relevant precursors in safety management and assessing safety level as a qualitative tool.

1. Introduction

Increasing numbers of people in China live in cities and the size of cities is expanding rapidly with the growth in urbanization. Taken together with the massive increase to over 250 million motor cars (Edelman, 2009), this has resulted in a major traffic congestion problem and associated atmospheric pollution. The metro is the most effective means of solving this problem in major cities. According to recent statistics, metro network systems are expanding at a rate of 30–50 km per year in such big cities as Beijing, Shanghai and Guangzhou. Additionally, up to December 31, 2014, 36 cities in China had been approved to construct metro system, and 22 cities had already been operating metro. As a result of this extensive and rapid development, metros are entering a new era of operations in China and with an increased need for more sophisticated operating systems.

Of particular concern is the serious consequences of metro accidents, such as the Baku metro accident in the Azerbaijan Republic (in 1995, more than 340 casualties) and Daegu, Korea (in 2003, more than 189 casualties), making their management and prevention a very important issue. Crucially though, most metro accidents can be predicted and prevented by the proper utilization of existing knowledge (Wang and Fang, 2014). From a safety science perspective, this takes the form of a figurative iceberg of which serious accidents are the tip (Yang et al., 2012). As shown in Fig. 1, this points to a broadening base of serious accidents, non-serious accidents and near misses. Preventing accidents, therefore, involves focusing on the lower levels, or precursors, and paying more attention to near misses.

Near misses have been studied in many fields, such as aviation, petrochemical and medicine. These studies show that the frequency of accidents can be reduced through effective near miss management (Van der Schaaf, 1992; Jones et al., 1999; Cambraia et al., 2010; Zhou et al., 2011a). The direct comparison between accidents and near misses is shown in Table 1. This can be analyzed from the perspectives of frequency, loss and recovery.

For such an analysis to be carried out in practice involves the collection of data in the form of 'incident' cases, comprising both accidents and near misses. In safety research, accident case analysis has been extensively applied in such fields as nuclear engineering (Choi et al., 2008), construction engineering (Goh and Chua, 2010), medical engineering (Andersen et al., 2010) and chemical engineering (Tauseef et al., 2011). Despite being well known that quantitative risk assessment in metro operation safety cannot be practiced effectively without adequate information of previous

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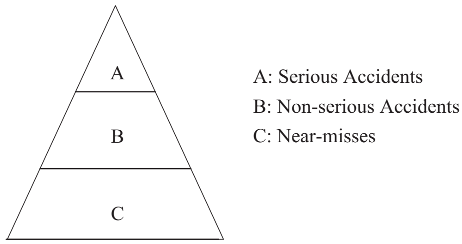

Fig. 1. Incident pyramid.

Table 1
The difference between accidents and near misses.

Incident type	Frequency	Loss	Recover
Accident	Low	Obvious properties or casualties	Difficult to return to be normal operation
Near-miss	High	Almost no loss	Easy to return to be normal operation

incidents (Shin et al., 2009), there are no professional metro operations incident databases in existence in any metro operation company in China. The purpose of this paper, therefore, is to develop such a database and demonstrate its use in a city such as Shanghai.

The paper is organized as follows. Following the literature review in Section 2, Section 3 describes the metro operation incident database (MOID). Its use is then demonstrated by collecting and analyzing Shanghai metro incident data from different viewpoints in Section 4. Section 5 offer some suggestions for its use in improving safety management. Conclusions and suggestions concerning possible implementation issues and future study are provided in the final Section 6.

2. Literature review

2.1. Definitions

There has been some substantive theoretical development of the concepts involved in safety management and notable criteria have been introduced. For example, Cavalieri and Ghislandi (2010) have developed a widely accepted classification method based on set theory. This model enables the identification of events as errors, incidents, operational interruptions, accidents or near misses. They also explicate relationships and differences between incidents, accidents and near misses.

Three main definitions exist in the literature: Labelle (2000) define an incident as an event that does not affect the completion of an activity; Cavalieri and Ghislandi (2010) define an accident as an unplanned incident that causes injury to persons and/or harm to property, the environment or a third party; Zhou et al. (2009) define a near-miss as an incident that does not develop into an accident. In this paper, a serious accident is defined according to metro operation safety evaluation standards (Ministry of Construction P. R. China, 2007) as having caused serious consequences, such as fatalities, serious injuries, or interrupted operations for at least 60 min. An accident that just causes minor injuries or interrupts operations for less than 60 min is identified as a non-serious accident.

2.2. Current state of safety management in metro operations

Safety management in metro operations has a significant impact on society in many aspects, such as social and economic development. Due to the rapid development of metro construction in China, more and more metro lines have been put into n service, and many cities have entered a new era of networking operation. In general, the development of metro network size and its capacity will increase the difficulty of metro safety management.

In metro operations, organizations try to identify the risks of potential accidents and many studies have been conducted of their safety management. Kyriakidis et al. (2012) proposed a safety maturity model to address behavioral and attitudinal culture, technical and methodological elements, and actual achievements in accordance with safety outcomes. Yan et al. (2012), for example, use Data Envelopment Analysis (DEA) to assess the risk of being crushed by crowds and trampling accidents according to the risk characteristics involved. Tsukahara et al. (2011) also study large-scale fire emergency evacuations in metro stations, which is a significant factor in minimizing damage and avoiding loss of life in an emergency, while Zhang and Hu (2014) present a multi-objective maintenance model of cost effectiveness, aiming to optimize the maintenance strategy of metro vehicles, as the maintenance level of all kinds of equipment is a crucial factor in reducing failure frequency. Lu et al. (2013), on the other hand, analyze safety risk in metro operations using Case-Based Reasoning (CBR), including case representation and retrieval, noting that the precision by which the similarity of the input and stored cases can be determined has a big impact on the result. Zhang et al. (2011) investigate metro topological characteristics with network theory to assess the extent to which a metro network is robust against random and malicious attacks, independent of differences among metro stations and passenger flows.

Most previous studies are therefore concerned with the cause and propagation of accidents, topological analysis, and emergencies. In contrast, this paper is mainly focused on risk identification, precursor analysis, and equipment maintenance in the safety management of metro operations.

2.3. Incident management

Various models and methods have been adopted in studying incident management. Jain and Mclean focus on simulation-based training systems, which have a significant impact on incident management (Jain and McLean, 2005). McLennan et al. (2006) study the decision-making processes relating to the Incident Management Team (IMT), with findings that are a useful in creating, training, managing and providing decision support for IMTs. Runciman et al. (2006) develop an integrated framework for establishing an information and incident management system based on a universal patient safety classification. Travaglia et al. (2009) evaluate an existing electronic incident management system and identify specific problems that need to be targeted for ongoing modifications. A dynamic agent-based model of flood incident management processes has been developed to improve policy analysis and other practical aspects (Dawson et al., 2011), and Liu et al. (2013) present a generalized diversion control model for freeway incident management that can optimize detour rates and arterial signal timing.

These studies mainly focus on the how to deal with safety incidents. However, the use of incident analysis is also very important as it provides a valuable means of improving safety management by learning from past safety-related incidents. The incident databases involved are also very useful tools for managing large amounts of raw data. Such databases have been developed for various applications. The European Commission Joint Research Centre (Institute for Energy) and Det Norske Veritas (DNV), for example, have established an international hydrogen incident and accident database (HIAD) (Kirchsteiger et al., 2007); the U.S. Center for Chemical Process Safety (CCPS) has developed an incident database (Sepeda, 2006); a Danish patient safety database had been devel-