New systems-based method to conduct analysis of road traffic accidents

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\section*{A B S T R A C T}

Road safety has become a major public issue in China. This study collected a total of 396 road traffic accident cases that occurred in 28 provinces from 1985 to 2014 in China. The type of vehicles involved in the accidents includes cargo vehicles (126), passenger vehicles (253), dangerous chemicals transport vehicles (128), and cars (9). A new systems approach that integrates the causal categories framework based on the human factor analysis and classification system (HFACS) and the contributory factor interactions model (CFIM) was applied to conduct analysis of road traffic accidents to determine whether systems approaches should be used during road accident analysis efforts. The analysis of results leads to the following conclusions. (i) According to the causal categories framework based on HFACS, the frequency of “unsafe behaviours” is highest at the category level; the frequency of “violations” is the highest at the subcategory level. “Overloading/over crowding,” “speeding,” “failed to provide supervision,” and “fatigue driving” should receive attention at the special indicator level. (ii) The new systems-based method that integrated the HFACS and the CFIM, which highlights the interactions between all levels of the causal categories, is a suitable method to analyse road traffic accidents. (iii) All latent categories, including “outside factors,” “organizational influences,” “unsafe supervision,” and “preconditions for unsafe behaviours,” can affect “unsafe behaviours”; “outside factors,” “organizational influences,” “unsafe supervision,” and “preconditions for unsafe behaviours” can influence each other. These interactions have not been quantitatively examined in previous studies. The findings of this study also demonstrate that the OR is a suitable technique to quantitatively examine the interactions among contributory factors.

\section*{1. Introduction}

Over the past several decades, China’s economy has experienced sustained and rapid growth, which greatly changed the transportation modes in China (Huang, Wang, & Hu, 2016); the number of motorized vehicles is increasing (Zhang, Tsimhoni, Sivak, & Flannagan, 2010). By the end of 2016, 146 million individuals owned motorized vehicles in China (Traffic Management Bureau of the Public Security Ministry, 2017). The cost of the rapid increase in motorization is high as road traffic accidents resulted in increased casualties and property losses (Zhang et al., 2010). According to China Statistical...
Yearbook (2015) (NBSC, 2015), a total of 136,386 road traffic accidents occurred, which caused 42,847 fatalities, 141,718 injuries, and direct economic loss valued at 938.37 million yuan in 2014 in China, with 18.8 rate per 100,000 population (WHO, 2015). Significant reductions in death and injury have been made in the past ten years in China; however, persistent problems remain and injury and fatality rates are serious. Road safety has become a major public issue, which concerns governments, policy-makers, the transport industry, health practitioners, researchers, and the public (Chen, 2014; Development & Research Center of State Council, 2007; Mao & Yu, 2002; Zhang et al., 2010).

Understanding the various factors that cause road traffic accidents is crucial (Theofilatos & Yannis, 2014; Wang, Quddus, & Ison, 2013). Empirical research has identified a large number of factors, which are usually related to drivers, vehicles, roads, and the environment (Hughes, Newstead, Anund, Shu, & Farkmmer, 2015; Larsson, Dekker, Tingvall, Wegman, & Hagenzieker, 2010; Salmon & Lenné, 2015; Wang et al., 2013; WHO, 2004), are statistically associated with road accident occurrence (Elvik, 2006). According to Sabey and Taylor (1980), road-user factors were the sole or contributory factors in approximately 95% of all road accidents. For drivers, their behaviors, such as overloading/overcrowding, speeding, fatigue driving, and drink driving might affect road safety (Arnold et al., 1997; Brodie, Lyndal, & Elias, 2009; Chang & Manzerling, 1999; Cui & Ma, 2010; Fleiter & Watson, 2016; Geng, 2013; Newnam & Goode, 2015; Salmon, Read, & Stevens, 2016; Washington et al., 1999). For example, speeding-related deaths accounted for 14.4% of the total number of road traffic accident deaths in 2006 in China, which was the highest among traffic violations (Yu, 2009). In the USA, approximately 29% of fatal crashes were associated with speeding (IIHS, 2013). The accidents caused by fatigue driving accounted for approximately 20% of the total number of traffic accidents and approximately 40% of major traffic accidents in China (Mao, Yu, & Zhang, 2009). Environmental conditions, such as weather and road, could affect road safety (Andrey & Yagar, 1993; Caliendo, Guida, & Parisi, 2007; Chang & Chen, 2005; Ma, Liu, & Zheng, 2007).

An accident causation model plays a fundamental role in the investigation and analysis of accidents (Ouyang, Hong, Yu, & Fei, 2010). Models can assist in establishing rules, checking, evaluation, identifying and assessing causations and communications (Hughes et al., 2015). The systems approach is a long-standing philosophy that first emerged at the beginning of the twentieth century (e.g., Heinrich, 1931), and various systems-based accident models have evolved as flexible and combined analytic approaches, which were used to investigate and analyse accidents in the past two decades (Carroll, 1998; Chauvin, Lardjane, Morel, Clostermann, & Langard, 2013; Dien, Dechy, & Guillaume, 2012; Rasmussen, 1997; Reason, 1990, 1997). Examples of several well-known models are Swiss cheese model (SCM) by Reason (1990) and Reason (1997), Accimap by Rasmussen (1997), system theoretic accident modelling and process model (STAMP) by Leveson (2004), and the functional resonance analysis method (FRAM) by Hollnagel (2012). The systems approach focuses on the notion that safety, and indeed accidents in complex sociotechnical systems are emergent property arising from non-linear interactions among components of the complex sociotechnical systems (Leveson, 2004; Salmon, McClure, & Stanton, 2012; Scott-Parker, Goode, & Salmon, 2015). The adoption of systematic thinking is now widely accepted as an appropriate way to understand and prevent accidents in most safety-critical, complex areas (Scott-Parker et al., 2015), including aviation (e.g., Johnson & Almeida, 2008), hospitals (e.g., Leveson, Samost, Dekker, Finkelstein, & Raman, 2016), mining (e.g., Lenné, Salmon, Liu, & Trotter, 2012), railway (e.g., Ouyang et al., 2010), transportation and storage (e.g., Goode, Salmon, Lenné, & Hillard, 2014), and outdoor activities (e.g., Salmon et al., 2012).

Any realistic example of social and technical factors that engaged in goal-oriented behaviour represents a sociotechnical system (Walker, Stanton, Salmon, & Jenkins, 2009), in this sense, the road transport system could be considered as a sociotechnical system (Salmon et al., 2012). However, systems theory and road safety are seldom mentioned when conducting literature studies (Larsson et al., 2010). The researchers have noted that the traditional methods to road safety have limitations, and systems approaches can overcome some of these limitations (Emmerik van, 2001; Larsson et al., 2010). The most serious flaw in the traditional method may lie in disregarding the interactions among the road environment, the vehicle, and the road-user (Zein & Navin, 2003). Fortunately, contemporary road safety strategies contain elements of systems thinking (OECD, 2008), such as the shared responsibility for promoting road safety (Scott-Parker et al., 2015), and a systems approach to road safety was first proposed in the early 1990s (e.g., Zaidel, 1992). Recently, Goh and Love (2012) used systems dynamics to evaluate traffic safety policy; AcciMap, one popular systems approach, was employed to represent the linkages and dependencies within and across system levels in road freight crashes (Newnam & Goode, 2015). STAMP, another popular systems model, was applied in the analysis of the road transport system in Queensland, Australia (Salmon et al., 2016). Stevens and Salmon (2016) used two systems analysis approaches, AcciMap and cognitive work analysis (CWA), to explore beach driving. The adoption of systems lens enabled exploration of a range of contributory factors and discovered alternate likely avenues of accident causation. Now, more researchers and practitioners believe that the new systems approaches may be a way to achieve new and ambitious road safety targets (Larsson et al., 2010; Read, Salmon, & Lenné, 2013; Salmon & Lenné, 2015; Salmon et al., 2016).

The present study applied causal categories based on human factors analysis and classification system (HFACS) and the contributory factor interactions model (CFIM) to conduct an analysis of road traffic accidents. The study aims to (i) analyse the contributory factors of road traffic accidents using causal categories based on HFACS; (ii) develop a new systems approach that combines the HFACS and CFIM to analyse road traffic accidents and even accidents occurring in other domains; and (iii) quantitatively examine relationships between contributory factors across the overall levels of road traffic systems.
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