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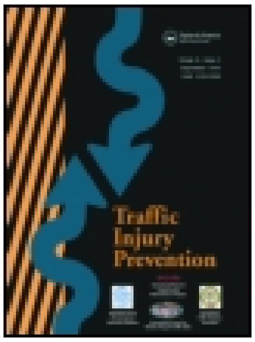

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A Study of Fatal Pedestrian Crashes at Rural Low Volume Road Intersections in Southwest China

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ABSTRACT

Objective: Although intersections correspond to a small proportion of the entire roadway system, they account for a disproportionally high number of fatal pedestrian crashes, especially in rural roads situated in low- and middle-income countries. This paper examines pedestrian safety at rural intersections and suggests applicable accident prevention treatments by providing an in-depth analysis of 28 fatal pedestrian crashes from eight low volume roads in Southwest China.

Methods: The Driving Reliability and Error Analysis Method (DREAM) is a method to support a systematic classification of accident causation information and to facilitate aggregation of that information into patterns of contributing factors. This is the first time DREAM was used to analyze pedestrian-vehicle crashes and provide suggestions for road improvements in China.

Results: The key issues adversely affecting pedestrian safety can be organized in four distinctive thematic categories, namely *deficient intersection safety infrastructure*, *lack of pedestrian safety education*, *inadequate driver training* and *insufficient traffic law enforcement*. Given that

resources for traffic safety investments in rural areas are limited, it is determined that the potential countermeasures should focus on low-cost, easily implementable and long-lasting measures increasing the visibility and predictability of pedestrian movement and reducing speeding and irresponsible driving for drivers and risk-taking behaviors for pedestrians.

Conclusions: Accident prevention treatments are suggested based on their suitability for rural areas in Southwest China. These countermeasures include introducing better access management and traffic calming treatments, providing more opportunities for pedestrian education and enhancing the quality of driver training and traffic law enforcement.

Keywords

pedestrian accidents, rural low volume roads, intersection crashes, DREAM, China and developing countries

Introduction

There are 1.24 million road traffic deaths worldwide and 92% of them occur in low- and middle-income countries (WHO, 2013). Pedestrians are particularly vulnerable to road traffic accidents; pedestrian deaths represent 22% of all the road traffic deaths (WHO, 2013) with over half of them occurring in medium- and low-income countries (Naci et al., 2009). In China, which is the focal point of this research, the highest proportion of road traffic deaths among road user types is pedestrians, at 24.96% (RIOH, 2011).

To improve pedestrian safety in low- and middle-income countries, more attention should be given to rural intersections. Intersections represent the most dangerous road sections for pedestrians; this is where vehicles and pedestrians' paths meet. For example, although intersections represent only a miniature percentage of surface road mileage, 21% of all pedestrians are killed at U.S. intersections (FHWA, 2009). Moreover, pedestrians are more likely to die from a pedestrian crash in rural areas than in urban areas (Mueller et al., 1988; Zhang et al., 2014) because of higher driving speeds, fewer pedestrian facilities, longer emergency response time and further distance to crash locations and disregard of traffic control devices by road users (Hall et al., 2004; Gonzalez et al., 2007; FHWA, 2009; Zegeer and Bushell, 2012). This rural-to-urban accident fatality balance is representative of the Chinese context; standardized rates of road traffic fatalities in China increased by 131% in rural areas and by 31% in cities between 2002-2002 and 2011--2012 (Wang and Chan, 2016).

While much research has examined intersection safety problems at urban intersections, there is limited literature for rural intersections. Pietrucha and Opiela (1993) believed that little consideration is given to the needs of pedestrians on suburban and rural roads, and called for increased attention to access control in guidelines for highway designers. Treatments that are safety-effective on urban streets may not be appropriate for rural roads due to the different road traffic environments (Hall et al., 2003) and typically different capacities in investing and innovating; resources usually are scarcer in rural areas.

Most of the few existing studies directly referring to rural pedestrian crashes are American (e.g. Mueller et al., 1988; Hall et al., 2004). The transport context of rural areas in low- and middle-income countries is quite different from that in developed countries though. Therefore, probably the characteristics and causal patterns of fatal pedestrian accidents in low- and middle-income countries differ too (Wang et al., 2013). These differences will influence the performance of countermeasures that may be effective in another context but may not work for China or for another developing country.

Thus, there is a significant research gap in the literature that this article addresses by studying pedestrian fatalities at intersections on rural low volume roads (LVRs) in Southwest China. More specifically, the paper proposes ways for enhancing pedestrian accident prevention by: initiating an in-depth data investigation of fatal pedestrian intersection crashes on rural LVRs, identifying the major characteristics and contributing causes for them, and discussing relevant viable safety countermeasures for reducing the incidence of these crashes. While the data analyzed refer to Southwest China, these results and recommendations may be generalizable (although the paper's emphasis is on quality rather than quantity) for the context of other low- and middle-income regions with similar geopolitical, socio-economic and transport provision characteristics.

Methodology

Data Collection

Altogether 896 fatality documents for accidents occurring in rural LVRs in Southwest China between 2005 and 2010 were collected. Information about the study area is provided in Table 1 and the Appendix (see Figure A1). Seventy-seven of these fatalities refer to intersection accidents; 28 involved pedestrian fatalities, which is the focus of this study. The eight rural LVRs are all paved, undivided two-lane roads. The data were retrieved from the local police accident reports (one per accident). All the documents included information about the site-specific conditions, medical examiner reports, driver licensing files, vehicle registration files, vehicle examiner reports, and interviews with the involved parties and witnesses. This data collection enabled the authors to identify the factors contributing to pedestrian fatal crashes (hereafter described as contributing factors).

Data Analysis Methods

The Driving Reliability and Error Analysis Method (DREAM) was adopted to examine the crash-contributing factors for each accident. DREAM is more accurate than descriptive or regression analysis in identifying and categorizing the contributing factors of a crash at rural intersections and the causal relationships between these factors (Ljung, 2002). In Europe, more than 1,000 crashes have been analyzed by DREAM (Wallén Warner et al., 2008a) while 90 car-to-pedestrian incidents from Japan were analyzed by a modified version of DREAM (Habibovic et al., 2013). This is the first time DREAM was used to analyze pedestrian-vehicle crashes and provide suggestions for road improvements in China. The Appendix provides more information about DREAM.

The first step of the analysis identified areas of commonality between the crashes. Next, the contributing factors and causation patterns were studied through DREAM for each driver in each case, resulting in one causation chart per involved driver. Then the individual causation charts were aggregated into several charts based on vehicle trajectory and type. Each aggregated causation chart visualizes the frequency of contributing factors and causation links between factors (Wallén Warner et al., 2008a).

Results

An Overview of the Pedestrian Crash Characteristics

The general characteristics of the examined crashes are presented in Table 2, categorized in four major crash characteristic groups referring to road traffic environment, vehicle, pedestrian and driver. A more detailed presentation of these characteristics can be found in the Appendix (see Table A1).

Road traffic environment

Seventy-five percent of the pedestrians were killed at T-intersections. Also, 96% of the intersections were in residential areas, all were uncontrolled, 82% had no pedestrian facilities and none had overhead illumination. Fifty percent of the crashes occurred at night or under low-light conditions, which is consistent with other studies on rural traffic accidents (Hall et al., 2004; Zegeer and Bushel, 2012).

Vehicle

All the collisions analyzed involved a single vehicle. Sixty-one percent of all vehicles exceeded the speed limit at the crash time. Small passenger cars, motorcycles and light trucks were the three types of vehicles most frequently involved in these accidents. Seventy-nine percent of

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crashes involved straight crossing vehicles, which is not consistent with the findings of FHWA (2009) suggesting that crashes with pedestrians occur more often with turning vehicles than with straight-through traffic.

Pedestrian

Eighty-nine percent of the pedestrians were killed when they were crossing the road. Fifty-six percent of the pedestrians that died were aged either younger than 15 or 65 and over. Crash data consistently shows that children and older adults are more often involved in fatal pedestrian crashes (WHO, 2008; FHWA, 2009; Souleyrette et al., 2010). None of the pedestrians involved in the fatal crashes was found to be drinking. This is not in line with the results of Hall et al. (2004) reporting that 32.8% of the pedestrians that died on rural roads had consumed alcohol.

Driver

All drivers were adults aged 19 to 50. In contrast, an American study on rural vehicle crashes, found that younger drivers aged 15 to 19 were involved in 34.3% of all crashes (Avenoso and Beckmann, 2005). Only in one crash, the driver was reported drinking.

In-Depth Causal Mechanism

Different vehicle types and trajectories have different crash patterns (Wallén Warner et al., 2008a). There were two vehicle trajectories in all 28 crashes, straight crossing and left turning. The authors categorized vehicles into two types: motorcycles and automobiles (including passenger cars and all kinds of trucks). Because all motorcycles were going straight through the intersection, three crash patterns were analyzed: motorcycle straight crossing, automobile left turning and automobile straight crossing. The three aggregated causation charts are shown in Figures 1--3.

In the figures, the letter and number combinations written at the start of each box are identification codes of the contributing factors in DREAM. The total number of times a contributing factor occurs is represented by the number in brackets within each box. For visual guidance when looking for patterns, the factor frequency numbers are also indicated through box border thickness. For links between boxes, the number of times a link occurs is represented by the number on the connecting arrows and the thickness of the arrows. The Appendix provides further information for the interpretation of the charts.

Motorcycle straight crossing crashes

Seven pedestrians were hit by straight crossing motorcycles when they were crossing the road. In Figure 1, almost all the drivers were coded with *A1.3 Timing: no action*, indicating that the drivers did not make any attempt to slow down or stop as they approached the intersection. The most common immediate contributing factor was *C2 Misjudgement of situation* due to *M2 Inadequate transmission from road environment* and *B1 Missed observation*. The ultimate contributing factors referring to more than half of the drivers were *Q1 Inadequate information design*, *N4 Inadequate training* and *J1 Reduced visibility*.

Automobile left turning crashes

There were six crashes that occurred when the automobiles were turning left. Figure 2 shows that half of the drivers were coded as A2.1 *Speed: too high*, indicating that although the drivers noticed the intersection or the pedestrians, they remained at a high speed. The most common immediate contributing factor was *C2 Misjudgement of situation* due to *L1 Insufficient guidance* and *F5 Overestimation of skills*. The ultimate contributing factors involving more than half of the drivers were *Q1 Inadequate information design*, *Q2 Inadequate road design*, *M1 Inadequate transmission from other road users* and *F6 Insufficient skills/knowledge*.

Automobile straight crossing crashes

There were 15 crashes that occurred when the automobiles were going straight. Figure 3 shows that more than half of the drivers were coded as A2.1 *Speed: too high*, indicating that although the drivers noticed the intersection or the pedestrians, they remained at a high speed. The most common immediate contributing factor was *C2 Misjudgement of situation* due to *M2 Inadequate transmission from road environment* and *B1 Missed observation*. The ultimate contributing factors that occurred for more than half of the drivers were *Q1 Inadequate information design*, *M1 Inadequate transmission from other road users* and *F4 Habitually stretching rules and recommendations*.

Discussion

There are four major issues for pedestrian safety at intersections on rural LVRs in Southwest China, namely *deficient intersection safety design and facility provision, lack of pedestrian safety education, inadequate driver trainin*g and *insufficient traffic law enforcement*. Effective countermeasures are recommended for each of these issues in the following sections, after reviewing numerous relevant accident prevention studies and the Chinese road and traffic design guidelines. Due to limited resource allocation in these areas, the recommended countermeasures had to be low-cost, easily implementable, long-lasting and low-maintenance, and to fit the demographical and transportation profile of the rural areas in Southwest China.

Deficient Rural Intersection Safety Design for Pedestrians and Countermeasures

Most of the pedestrians were hit by straight-going vehicles when they were crossing T-intersections in residential areas (see Figure 4). In China, there is no access management framework for rural roads. When rural highways go through villages and towns, branch roads and even house doors form many T-intersections or accesses (Zhou, 2008), which greatly increase the chances of conflict between pedestrians and vehicles. Although safety issues at these T-intersections are common in China, there are still no road design standards to resolve them. So a primary countermeasure would be revising the highway design standards. Some engineering access management methods, such as insulating fences and walls, are already applied on some highways to prevent pedestrians from crossing roads randomly. However, the number and distance of fence openings should be designed more systematically and according to pedestrian crossing needs.

Also, more than 80% of the intersections examined lack pedestrian facilities; *Q1 Inadequate information design* is one of the ultimate contributing factors to almost all crashes. Only a few intersections have pedestrian crosswalks, speed limit signs, stop signs, warning signs or signs indicating the entrance to a residential area. Earlier studies suggest that a systematic use of stop signs and markings could have alerted drivers to expect pedestrian activity (Polus, 1985, Preusser et al., 1998; Persaud et al.; 1997; Retting et al. 2003). More pedestrian crossings could also raise drivers' awareness especially if flashing beacon signs are installed to make them more visible to traffic as suggested by Turner et al. (2006). However, the effectiveness of these facilities is somewhat questionable due to their random setting positions. In the Chinese *Specification for Layout of Highway Traffic Signs and Markings* (RIOH, 2009), the setting positions of warning signs and crosswalk markings have not been clarified for the intersections of LVRs examined by the present study or any low-speed road segments where design speed is less than 70km/h. Therefore, this work highlights the need to implement these signs and markings and to regulate specific position requirements for all the road traffic signage in rural highways.

Speed affects both the severity of a crash, the risk of being involved in a crash and pedestrian fatality risk (Aarts and Van Schagen, 2006; Rosen et al., 2011), so controlling vehicle speeds is of critical importance. Since half of the automobile drivers remained at a high speed even though they noticed the intersection or the pedestrians the authors highlight the need for engineering countermeasures that can slow down vehicles. Speed bumps are commonly used in low-speed roads in China (Liu et al., 2011) because of their low cost and easy installation. The effects of speed bumps on reducing vehicle speeds were quite significant (Huang et al., 2011). However, there is only one standard referring to rubber speed bumps' size and quality requirements in China and no standards about their layout and setting positions. Roundabouts could also be effective in forcing drivers to reduce speed during the approach, entry and movement within the roundabout in both urban and rural environments (Ourston and Bared, 1995; Isebrands, 2009; Xia and Shi, 2013).

Raised crosswalks and elevated crossings is another applicable safety measure. Recent studies (Cherry et al. 2012; Chen, 2013) proposed that these can best enhance the safety of pedestrians however there is evidence that these are not adequately utilized in many Chinese settings (Tao et al., 2010). Designating senior/school zones and constructing safety facilities to protect pedestrians from potential traffic accidents within these zones is according to Jung et al. (2016) a way to reduce accidents related to pedestrian age. Since darkness increases the fatality in a pedestrian–vehicle crash (Aziz et al., 2013; Zhang et al., 2014), the provision of street lighting, may improve intersection safety.

More experimental studies are needed on the safety effectiveness of these engineering mechanisms. Also a more supportive regulatory framework should complement their use. These mechanisms though may not be enough *per se*; they may make the risk of accident lower but provide no safety in themselves (Johansson, 2009).

Inadequate Pedestrian Safety Education and Countermeasures

M1 Inadequate transmission from other road users was another ultimate contributing factor in the crashes examined, indicating that the pedestrians did not convey their crossing intentions sufficiently to the drivers. In most cases, pedestrians crossed the roads without looking first for any impending vehicles, which is in line with a recent observation-based Chinese study (Zhuang and Wu, 2011). Pedestrians lacking road safety responsibility is a universal problem (Ponnaluri and Nagar, 2010; Mwakalonge et al., 2015). Road traffic education is a cost-effective and sustainable method, which can fundamentally change people's attitudes to pedestrian safety and behaviour when crossing an intersection. Targeting insufficient pedestrian education in rural areas, unconventional ways of "simpler" road traffic safety education should be introduced, such as the use of loudspeakers from village radio stations to daily broadcast road traffic safety programs, with an emphasis on safe intersection crossing behavior, in fixed times and making village cadres to take some responsibilities of publicizing traffic safety information.

We found that children (aged 0--14) and older people (aged 65 or older) made up of more than half of the pedestrian deaths; the two age groups are more likely than any other to be involved in pedestrian fatal crashes globally (Duperrex et al., 2002; Prato et al., 2012). Due to a rapidly changing demographic structure, China is facing an even bigger challenge since the population of both children and seniors is predicted to dramatically increase (Zhang and Lin, 2015). For most of the children in schools, road traffic education is an occasional activity. Hence, schools need a complete and systematic traffic education plan. Also creating a culture of parental awareness for the issues referring to children crossing behavior could be a key for accident prevention something also suggested by Tapiro et al. (2016). For the senior people, interactive education and material that meets older people's special (and perhaps more complex as Nikitas et al. (2011) and Sochor and Nikitas (2016) suggested) requirements could be more effective. For instance, hazard perception tests can be employed (Rosenbloom et al., 2015), but the method may be high-cost unless professional educator services are provided on a volunteering basis. Also the adoption of pedestrian gestures informing drivers of pedestrian's intent to cross (Zhuang and Wu, 2014) and the implementation of special materials that reflect light well to the canes of elderly pedestrians and the bags of teenagers and children (Zhuang and Wu, 2011) will make easier for drivers to detect them.

Inadequate Driver Training and Countermeasures

Lack of driving skills and unawareness of traffic safety regulations was a main problem for automobile and motorcycle drivers. More specifically, for left turning automobile drivers, one of the major ultimate contributing factors was *F6 Insufficient skills/knowledge*, while for motorcyclists, was *N4 Inadequate training*. In China, people get training and apply for the driving examination through driving schools. The main reason that a driver may be lacking the necessary driving skills and safety awareness is that many driving schools cut the training time

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short and only teach a limited range of basic driving lessons. According to a survey conducted in one of the provinces examined by the present study, 73% of the drivers had less than six months of training time before getting their license (Chen, 2008). Even worse, some of the driving schools help people cheat in the examinations or sell driving licenses. Moreover, in rural areas, a certain amount of illegal driving schools exist attracting people because of their policy to charge cheaper training fees (Chen, 2008; Gao et al., 2008). Therefore, enhancing the supervision on driving schools in rural areas is critical. Inadequate training for motorcycles refers to driving without a license or without wearing a helmet which is in line with recent statistics (RIOH, 2011). Promoting license holding and helmet wearing with specially designed campaigns and penalising offenders could therefore help.

Insufficient Traffic Law Enforcement and Countermeasures

Besides pedestrian and driver education, strict traffic law enforcement can be an effective method to stop illegal behavior (Rosebloom, 2006; Zhang et al., 2006). The high proportion of speeding and driving without a license that the present study reports implies weak traffic law enforcement. At present, this is a common problem for rural areas in China. A main reason for this is the limited police resources available (Jia et al., 2016). For example, it is not rare that as few as three or four local traffic policemen supervise as many as four or five towns in the region of the study, which may have 0.3 million population in total. There are several ways to address the problem of police resources shortage. First, the number of traffic policemen in rural areas needs to be increased sufficiently. Second, traffic wardens can be hired to help enforce the traffic law. Third, rural public organizations can be encouraged to play bigger roles in road traffic safety policing. Forth, camera enforcement can be adopted to replace physical patrolling for the most accident-prone intersections.

The Study's Limitations

The number of the fatal crashes examined was restricted to 28, which is small compared to the number of accidents associated with pedestrian deaths occurring in China. However, collecting accident reports of this detailed nature through police agencies in China is a task of significant difficulty, since these reports are not accessible to researchers as easily as they could be in Europe or North America. However, working on an in-depth analysis with this amount of pedestrian fatal crashes, where quality considerations are prioritized over quantitative ones, is not unusual. These numbers are in line with those of other studies (e.g. Ljung Aust et al., 2012; Chen and Zeng, 2010). Our DREAM-based analysis, provides, despite the small sample, a systematic mechanism for understanding the main reasons behind the occurrence of accidents happening in an area where no such research has ever been conducted.

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Table 1. Introduction of the data collection area (National Bureau of Statistics, 2014)

Geographic Characteristics	Total area	65.26 km^2
	Mountainous and hilly area	58.02 km^2
Demographic Characteristics	Total Resident Population	112 million (year-end)
	Rural Population	60.6 million
	Population Aged 0--14	19.5%*
	Population Aged 65 and Over	9.8%*
Socio-economic Characteristics	Gross Regional Product	3633 billion yuan
	Per Capita Gross Regional Product	32438 yuan/person
	Per Capita Disposable Income Regionwide	14555 yuan
	Per Capita Disposable Income of Rural Households	7589 yuan
Transportation Characteristics	Length of Highways	518.3 thousand km*
	Length of two-lane and one-lane Highways	353.5 thousand km*
	Annual Number of Deaths on Traffic Accidents	3564 persons*

* Data from 2013

Table 2. Descriptive statistics of the 28 fatal pedestrian crashes

VARIABLES			**FREQUENCY**	**PERCENTAGE**
ROAD TRAFFIC ENVIRONMENT	Intersection Type	*T-intersection*	21	75.0%
		Others	7	25.0%
	Pedestrian Facilities	*No facilities*	23	82.1%
		Facilities	5	17.9%
	Light Conditions at Crash Times	*Dark*	14	50.0%
		Daylight	14	50.0%
	Roadway Surface Condition	*Dry*	26	92.9%
		Wet	2	7.1%
VEHICLE	Vehicle Type	*Motorcycle*	7	25.0%
		Car	9	32.1%
		Bus	1	3.6%
		Truck	11	39.3%
	Speed at Crash Times	*Speeding*	17	60.7%
		Not speeding	11	39.3%
PEDESTRIAN	Pedestrian Age	*Age 14 or below*	8	28.6%
		Age 15--64	12	42.8%
		Age 65 and older	8	28.6%

DRIVER	Driver Age	*Age 19--30*	11	39.3%
		Age 31--50	17	60.7%

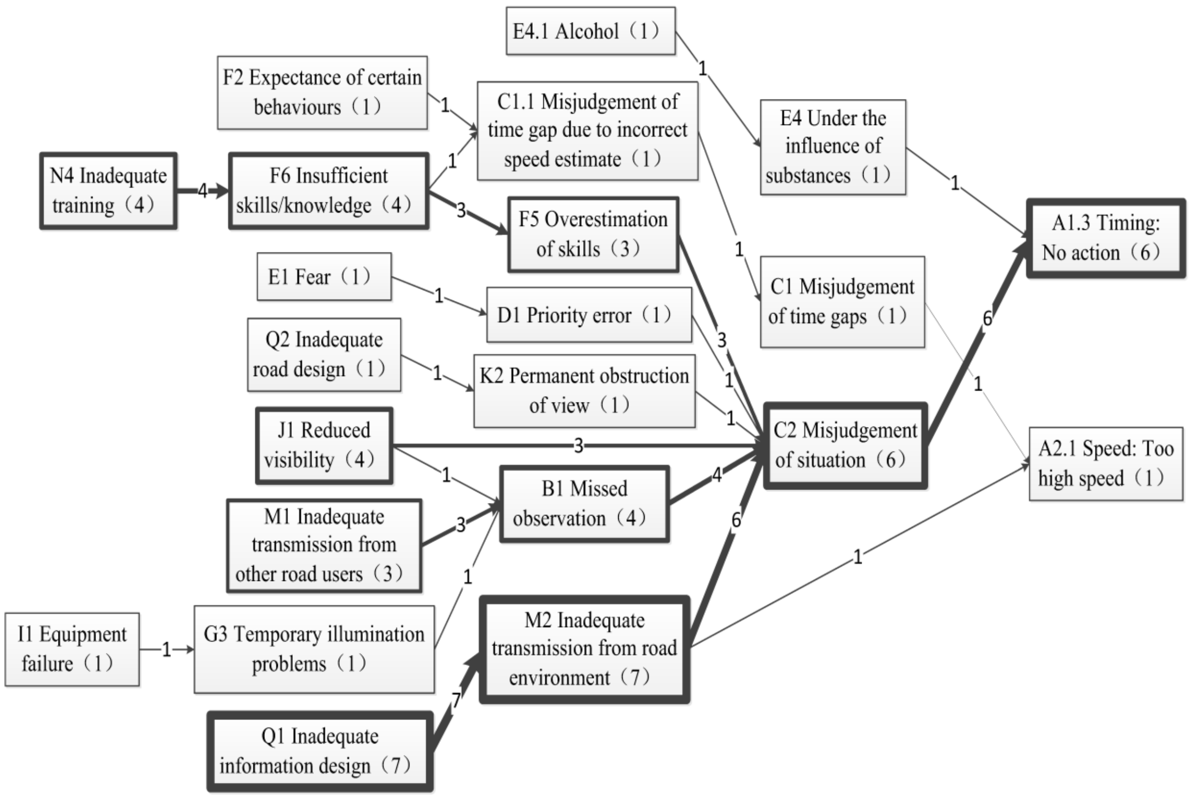

Figure 1. Aggregated causation chart for the motorcycle drivers who were straight crossing

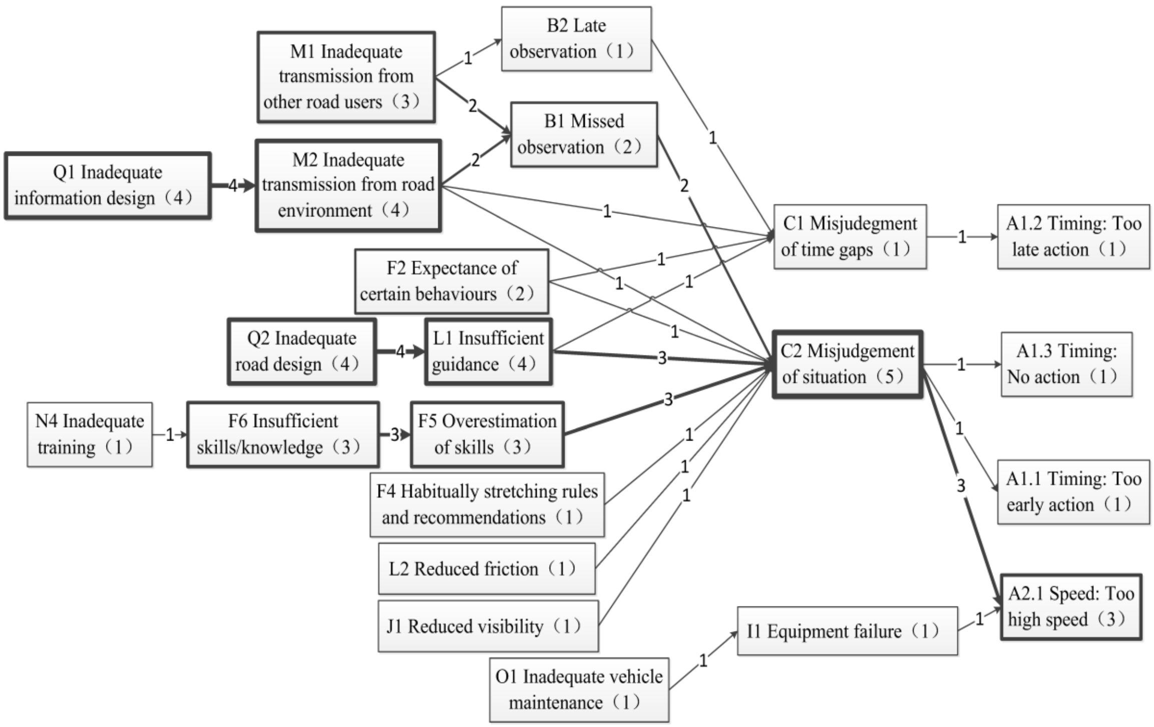

Figure 2. Aggregated causation chart for the automobile drivers who were turning left

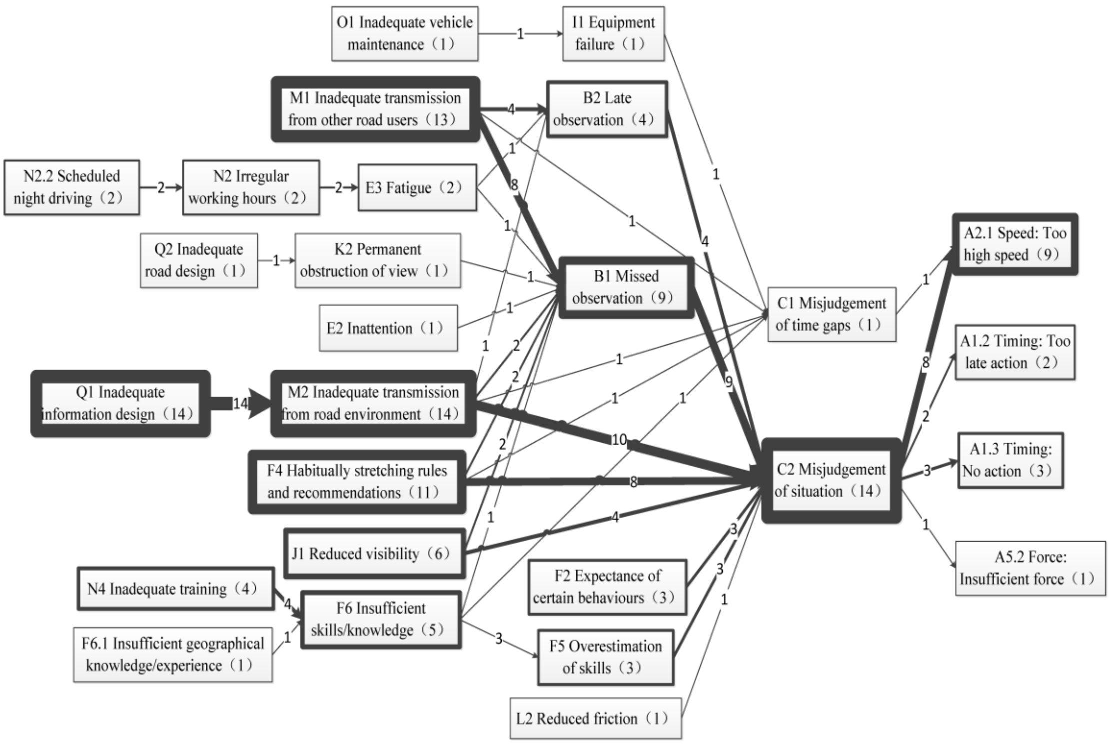

Figure 3. Aggregated causation chart for the automobile drivers who were straight crossing

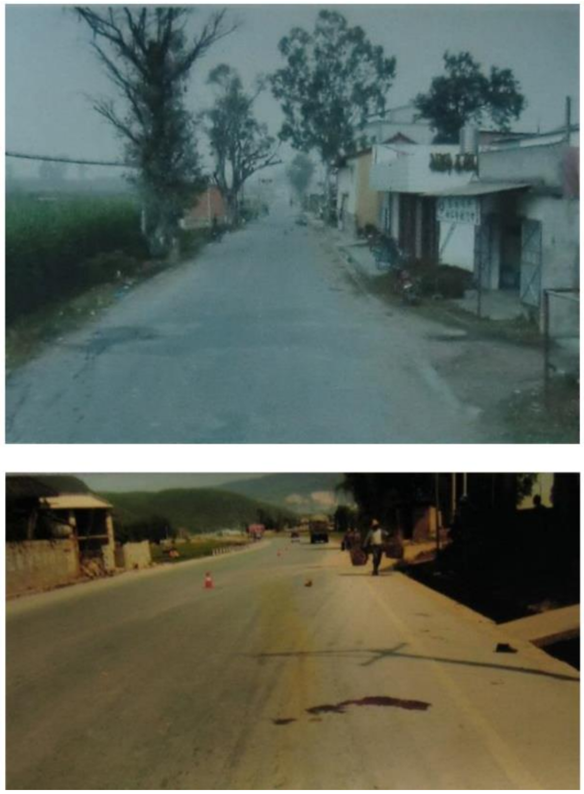

Figure 4. Typical rural T-intersections in residential areas

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