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INTEGRATING BEFORE AND AFTER CRASH FEATURES INTO MEASURING THE EFFECTIVENESS OF INTERSECTION SAFETY IMPROVEMENT PROJECT IN HARBIN

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Abstract. Many studies focused on the analysis of effect factors contributing to the crashes and development of crash prediction models have resulted in aggregate researches to quantify the safety effects of geometric and traffic variables and environmental concerns on the expected outcome of fatal, injury and/or property damage losses at specific locations. Crash insight regarding different locations, however, has rarely been performed. Such investigations are useful for at least two reasons. First, there is a priori need to identify high risk sites with respect to crash. Second, it is generally believed that different crash types (e.g. rear-end, angle etc.) are associated with road geometry, the environment and traffic condition, and as a result justifying the inside causes of such crashes helps with understanding and improving the specific ability to make effective countermeasures. Therefore, the objectives of this paper are to (1) demonstrate that different crash types are associated to intersections in different ways and (2) reveal that the statistics of intersection crashes may lead to greater insights considering crash occurrence and countermeasure effectiveness. This paper first divides crashes into 5 categories or types: pedestrian-involved, rear-end, head-on, angle and sideswipe crash types. Based on 3208 crashes collected on the intersections in the city of Harbin during the period of 1992–2008, distribution, overall count and the occurrence of rate features are estimated resulting in two models. The performed analysis reveals that safety improvement factors such as the presence of a signal light set, a traffic monitoring device and ITS measure have a positive association with intersection crash in different ways, suggesting that different traffic control and management aspects may be helpful in identifying specific countermeasures in the overall safety improvement project.

Keywords: intersection crash, occurrence rate, traffic control, signal light, countermeasures.

1. Introduction

A road intersection is definitely high-risk locations for automobiles and pedestrians. Over the past ten years, the statistics of crashes, fatalities and injuries involving intersections reveal that some 32000 deaths and more than 320000 injuries occur annually on the metropolitan areas in China (Pei, Hu 2004). A recent government report surveyed from four typical cities, including Beijing, Xi'an, Changsha and Qingdao prepared by the National Policy Agency shows that intersection crashes account for more than 30% of all crashes and are more serious in Southeast China (Wang *et al*. 2007). Statistics for Heilongjiang province is average about 400 fatalities and 1500 injuries per year. An intersection is a dangerous spot for bicycle–motor vehicle (BMV) or pedestrian-motor vehicle (PMV) collision because of frequent conflicts between bicycle flow, pedestrian flow and vehicle flow.

These alarming figures and values associated with property losses and especially with losses of life or injuries attracted wide concerns from public agencies to take precautions, to improve the safety design of road bottlenecks (i.e. intersection) and to educate drivers and individuals. Within the same context, an extensive amount of researches has been conducted up-to-date. Even a prompt review of the studies would reveal the major regulations that support crash occurrence. These are: (a) geometric; (b) driver; (c) management-related; (d) environmental influences. Within each factor, several variables can be identified as being the most influential force on the likelihood of crash occurrence, generally by combining several years of data to underline statistical analysis and develop statistical models. Through a multiple of scales and scopes, numerous cross-sectional studies have been conducted so far as to understand the relationships between factors and intersection involved crashes (Pernía *et al.* 2002; Wang *et al.* 2006; Murphy, Hummer 2007; Tay, Rifaat 2007; Liu *et al.* 2008). Another class of studies utilizes time series techniques for identifying whether a change in a policy at a given time had an impact on accident rates, thus analyzing relationships with other predictors by comparing trends in predictors and fatal accidents and developing a statistical model for forecasting future fatality rates such as in research works of Bared *et al.* (2005), Kim *et al.* (2007), Ye *et al.* (2009), Abdel-Aty *et al.* (2009), Mitra (2009), Al-Harthei *et al.* (2010), etc.

Actually, each traffic crash is a unique event that is caused or influenced by combinations of factors that may not be even observable. All of these previous efforts above take a particular type of a crash and try to identify a change in that type of the crash under certain circumstances in the observed models or statistical expressions (Jonsson *et al.* 2007). However, reaching such conclusions that a set of factors can be identified as the causes of a traffic crash is almost impossible. To provide a broad overview, the intersection presents a hazardous environment to drivers, induced by the presence of pedestrians, bicyclists, motorcycles and a sudden disruption of complex traffic flow, et al. Thus, conflicts between vehicular traffic and pedestrian–motorcycle activity are likely to reduce capacity in the intersection and increase crash probability for all involved (Weerasuriya *et al.* 1998). Thus, it is impossible to distinguish the nature of causation in detail, except that assessing the macro-distribution of such crashes in a systemic attribute.

During the past ten years, urban traffic safety, especially for intersection locations, has also drawn the heated attentions around Harbin. A variety of quantitative intersection involved injuries and fatalities over the period of 10 years are analyzed. Detailed comparisons show that intersections have exceptionally higher rates of collisions and crashes that occurred during peak hours in winter, especially rear-end collisions induced by a slippery pavement (Pei, Hu 2004). Therefore, urban intersections are sure to be the problematic locations in Harbin. However, research has been rarely conducted to investigate how such locations have been involved and are presently performed so as to estimate the magnitude of the problem and to find remedies for typical locations. Even though it has been realized by some officials that these sites, particularly unsignalized intersections, are prone to crash, there is no scientific basis for this belief.

Several studies have dealt with the intersection safety problem in Harbin, and lead to an agreement that this problem is so serious that strict and comprehensive measures are needed. According to the forever investigation, it has indicated that intersection caused accidents in Harbin are common to all intersections inside the city and in fringe areas linking either an expressway and arterials or residential and commercial areas. In addition, some minor roads or branches are easily neglected. ARSEI (America Road Safety Engineering Institute) considers that the average crash rate can be reduced by 15% after the collection of signal control. In other words, signal control of an urban road is an efficient measure to reduce the road traffic accident rate. However, safety inspective is not always taken into the consideration of traffic control, including signal light set and capacity management during the past decades.

The Sustainable Livelihoods Access and Safety (SLAS) project, sponsored by the Transportation Management Department of Harbin has been implemented since October 2005. Team comprising members from colleges, research institutes, companies and government departments as well as independent consultants based in the local region have been engaged in the study of how to improve safety performance within road intersections allocating 2 million RMB for safety facilities. Upon such a basis, this study aims at investigating accidents that have occurred at such sites with an emphasis on road intersections. By exploring the recorded crash data (the only source of accident data provided by specific governmental department), this study attempts to mine the features of intersection involved crashes and answer several traffic safety questions related to the safety improvement project in Harbin. The paper is organized as follows: data on crash resources are introduced following the general introduction and literature review then analyzing crash features. The article ends with conclusions and final remarks.

2. Data

Harbin, the capital of Heilongjiang Province, lies in the northeast of China mainland (Fig. 1), and its longer winter continues about 7 months in a year with snowfall. Such geographic location and cold weather lead to more traffic crashes in ice and snow involved witnesses.

To analyze the occurrence of traffic crashes at the intersections in Harbin, a total of 161 intersections covering more than 55% of intersections are presented in Table 1. Data on the accidents during the period from 1992 to 2008 making a total of 3936 crash records and observations are used in the following analysis. In this paper, only motor vehicle involved crashes are considered.

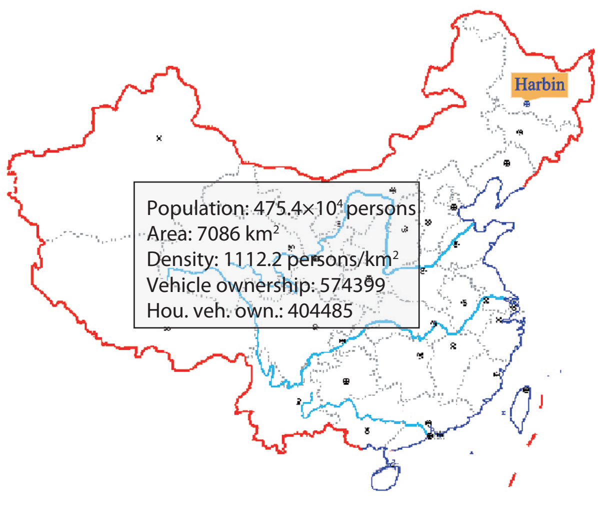

Fig. 1. The position of Harbin city in China mainland (Hou. veh. own. = household vehicle ownership)

Table 1. The classification and composition of plain intersections

Intersection type	Three-legged[1]	Four-legged[2]	Five-legged	Roundabout
Count	68	85	3	5
Percentage	40.7	55.6	1.4	2.3

Regular intersection = intersection whose linking angle ranges 70~110°;
In-regular intersection = intersection whose linking angle is more than 110° or less than 70°;
[1] The number of regular and in-regular intersections is 46 and 22;
[2] The number of regular and in-regular intersections is 71 and 14.

Unfortunately, missing or incomplete data were a common problem in reports on the accidents. Generally, the police officers should take responsibility for usually recorded information, such as the time, location, cause and type of an accident. However, such messages and other important details (e.g. traffic signal and road surface conditions) were not filled in because of individual reasons or spot un-identification. Considering practice in accidents occurring in China, the name of the road is written along with the type of a location (intersection or a road section) and thus it is difficult to know exactly where the accident occurred simply from the location described in the accident report. On the other hand, hand writing is commonly used to record and draw the crash message, and therefore such drawing of an accident provides little help in figuring out more details about the location characteristics and the accident itself.

Therefore, 728 records accounting for 18.50% among original collections are removed from the crash database for their missing or incomplete message, whereas the remaining 3208 samples are selected for future analysis and modelling, in which 13.49% are fatal, 26.09% – resulted in serious injuries and the rest in slight injuries. For each observation, in addition, a copy of an accident report is obtained to learn more details about the crash causes. These include channelization measures and intersection geometrics. Regulatory control measures such as the existence of signal control types provided by a surveillance camera were obtained from the visited site or recorded file.

3. Crash Analysis and Performance Evaluation

Crash distribution characteristics are analyzed, including a count of the number, crash type, crash severity and time distribution (month, week and hours in a day).

3.1. Crash Distribution by Facilities, Severity and Time

The main types of crashes at intersections include 5 types:

- *pedestrian-involved collision*: pedestrian-motor vehicle collision (PMV);
- *rear-end collision*: a single vehicle bumps into the tail of another one driving in the same direction (in our case, multiple rear-end collisions are not considered);
- *head-on collision*: two vehicles collide face to face while driving in the opposite directions;
- *angle collision*: a vehicle runs into another perpendicularly;
- *side wipe*: a vehicle scraps another one driving in an adjacent lane in the same or an opposite direction.

Then, 3028 samples are divided into 5 types (Table 2) and crash data of each type fall into two groups: crashes from signal controlled intersections and those from un-signal controlled intersections. The suggested statistics reveals that the right-angle crashes cover as much as 51.68% among all crash records for 5 types of crash. The second position is side wipe accounting for 16.24%. In response to intersection types, four-legged intersection involved crashes witness about 56.89%. According to the control pattern at intersections, the crash proportions of crash record for signal and un-signal in-

Table 2. A composition of accidents on each kind of links and intersections

Intersection		*PIC*		*REC*		*HOC*		*AC*		*SW*		Total
Type	Count	I_SC	I_USC	I_SC	I_USC	I_SC	I_USC	I_SC	I_USC	I_SC	I_USC	
Three legged	68	11	38	31	77	26	75	97	213	21	53	642
Four legged	85	29	67	74	149	87	196	163	806	69	185	1825
Five legged	3	3	8	11	27	8	16	36	108	17	61	295
Roundout	5	5	9	13	35	11	23	57	178	35	80	446
Total	161	48	122	129	288	132	310	353	1305	142	379	3208

PIC – pedestrian involved collision; *REC* – rear-end collision; *HOC* – head-on collision; *AC* – angle collision; *SW* – side wipes;
I_SC –signal controlled intersection; I_USC – un-signal controlled intersection

tersections make 25.06% and 74.94% respectively and easily reach that signal control has a significant influence on the safety performance of intersections, especially for those with irregular patterns.

In this research, crash severity is classified into three categories: high, medium or low. In our case, high crash refers to serious injuries requiring hospital care and fatalities; medium crash includes those with minor injuries not requiring hospital care; low crash is mainly defined as leading to no physical injuries.

Fig. 2 presents crash counts considering severity. It can be easily noticed that fatality crashes cover less than 4.5% among all crash records. However, 91.5% of such level crashes have occurred at unsignal-controlled intersections. For the overall samples, approximately 89.1% of the occurrences of intersection related crashes are due to the absence of signal control and traffic monitoring devices at intersections. For a typical road in Harbin,

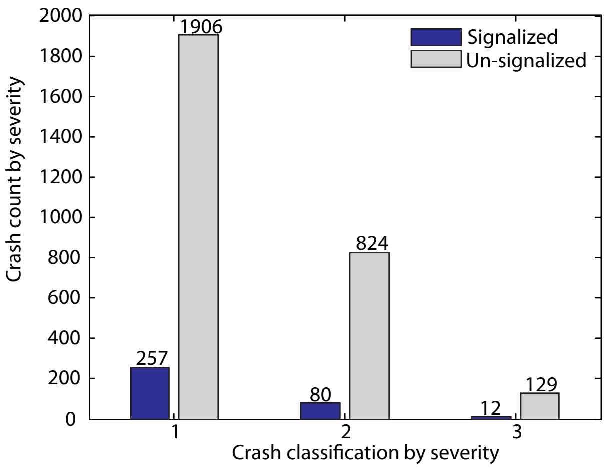

Fig. 2. Counting intersection crashes by severity in Harbin during the period from 1992 to 2008: 1 – low level crash; 2 – medium level crash; 3 – high level crash

nearly 50 crashes involving about 120 fatalities and injuries were witnessed each year on Hongqi Str., an arterial linking three main districts (Xiangfang, Nangang and Daowai), before 1998. However, the safety performance of this nearly 12 km road has been improved significantly and approximately 60 crashes, fatalities and injuries have been decreased carrying out this safety improvement project.

Certainly, traffic crash varies with a significant range within different hour, day, month or year and location, climate, traffic infrastructure and culture would affect crashes. Therefore, it is reasonable to consider the timely distribution of crashes, namely statistic characteristic during different time. Table 3 presents the monthly distribution of crashes before and after such a safety improvement project on the basis of crash data from four arterials in Harbin (Xinyang Rd., Nanzhi Rd., West Dazhi Str., and Nantong Str.). The records of three years also indicate that more crashes occurred in winter days and a big percentage of crashes were reduced launching this safety improvement project in a certain urban road.

From the overall aspect, Eq. (1) and Table 4 give us weekly and hourly distributions of intersection related crashes in Harbin. Distribution percentages have experienced little changes over the period of ten years (1995–2005), though the overall crash counts have witnessed a significant decline. By the comparison displayed in Table 4, we can see that the hourly features of crashes on the highway and in the urban area are quite different. For urban intersection, time periods from 6:00 to 8:00 and from 16:00 to 18:00 are two peaks of crash occurrence as this is the time when the majority of people go to work and back home when congested traffic can easily induce side wipes or rear-end collisions. However, time from 12:00 to 14:00 is a critical period for taxi and bus drivers. For truck drivers, long time driving at night often causes fatigue and a loss of patience. Thus, more rear-end

Table 3. Monthly distributions of intersection involved crashes on four typical arterials

Month	1	2	3	4	5	6	7	8	9	10	11	12	Total	Max[2]	Min[2]	Mean[2]	Std.[2]
Crashes[1] in 1995	22	19	16	18	10	8	9	13	9	18	17	14	173	22	8	14.42	9.24
Crashes[1] in 1998	16	13	11	9	6	7	10	8	9	11	13	14	127	16	6	10.58	12.24
Crashes[1] in 2005	10	9	10	7	2	4	6	5	4	6	8	11	82	11	2	6.83	15.06

[1] Crashes count involving injuries of less than 2 persons or deaths of less than 1 person;
[2] These statistical values are all in response to the monthly count of crashes.

Table 4. A percentage comparison of hourly distributions of crashes on the highway and intersection

Hour	0–2	2–4	4–6	6–8	8–10	10–12	12–14	14–16	16–18	18–20	20–22	22–24
National[1]	4.6	24.2	21.4	6.6	3.8	8.5	5.3	5.1	5.2	4.9	3.7	6.7
Highway[2]	10.2	11.3	19.4	15.3	5.2	4.5	7.1	6.4	8.2	4.3	2.7	5.4
Intersection[3]	10.3	6.7	9.2	10.9	5.6	5.2	11.6	6.3	10.7	5.4	7.9	10.2

[1] National highway crash data; Source: National Highway Traffic Accident Report in 2005–2008;
2 Highway crash data (Hashuang, Hada, Hamu, and Hahei); Source: Heilongjiang Traffic Accident Report in 2005–2008;
[3] Intersection crash data in Harbin in 2005–2008.

and opposite collisions occur between 22:00 and 24:00 and from midnight to 2:00, and therefore more attention should be paid to the limit of driving time.

$$WD = \begin{bmatrix} \text{Week day} \\ \text{Crash count} \end{bmatrix} = \begin{bmatrix} \text{Sun.} & \text{Mon.} & \text{Tue.} & \text{Wen.} & \text{Thu.} & \text{Fri.} & \text{Sat.} \\ 11.53 & 14.32 & 15.71 & 15.38 & 14.69 & 14.95 & 13.42 \end{bmatrix},$$

where: *WD* – weekly distribution of crashes in percentage, %.

Considering the above results, one can see that Tuesday and Wednesday are risky days when more crashes occur. In fact, the Department of Transportation in Harbin have suggested a trend and made great effort to reduce the number of crashes in the whole city since 1998. The result of statistic crashes is declining compared with the past two years, including 1996 and 1997. In addition, universities and training agents provided some programs to make the youth and drivers use safe tires, realize the great hazard of driving drunk and avoid over speed and fatigue driving. Some modern devices are performed effectively to make a forward alarm to driving behaviours under higher risk action.

3.2. Crash Count Considering Intersection Type

Generally, traffic crash has direct relation with automobiles. Various previous researches have indicated that the collocation of traffic monitoring and signal control pattern are helpful to manage traffic flow within intersections, which helps in reducing the irregular degree of traffic flow as well as the occurrence of crashes (Das *et al.* 2009; Harrison 2005). Despite that automobile ownership increased from 106 thousand in 1998 and 132 thousand in 2003 to 194 thousand in 2008, crashes on the expressway and arterials experienced an increase and reduction from 315 to 509 and 296 for these three years of typical research. The number of the injured reduced from 458 in the peak of the year 2003 to 271 in 2008, as shown in Fig. 3.

Exploring the inside causes, the number of traffic monitoring or signal controlled intersections increased from 97 and 173 to 282 along all urban expressways and arterials over the period from 1992 to 2008, and all these traffic safety improvement measures have partially contributed to the enhancement of overall safety performance as daily traffic bottlenecks. For example, East Dazhi Rd (Hongbo Roundout – Nantong Str.) has 8 big intersections that witnessed more than 36 fatal crashes every year before 2003 and the total annual count has been reduced as much as by 60% since these intersections have been installed with traffic monitoring videos in that year.

By contrast, Fig. 4 presents a tendency to the occurrence of accidents for intersections within minor and branch roads in the same three typical years.

The examined situation indicates that the frequency of accidents does not have a distinct change in these periods, though confronting a relatively big increase in 2003, which is partially due to few control measures added to minor roads and branches. With a rapid increase of private vehicles, more crashes have occurred, especially pedestrian–vehicle crashes.

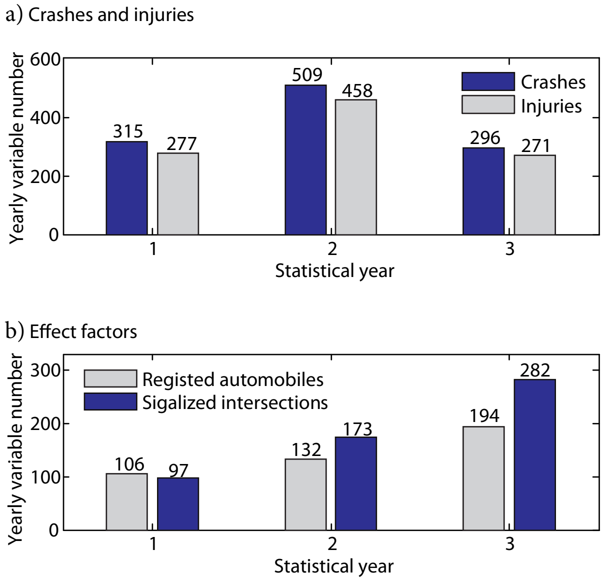

Fig. 3. Crashes on expressways and arterials in typical years: 1 – in 1998; 2 – in 2003; 3 – in 2008

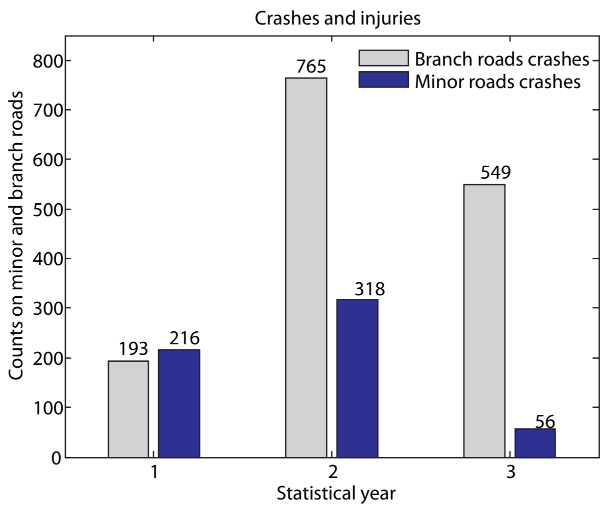

Fig. 4. Crashes on minor and branch roads in typical years: 1 – in 1998; 2 – in 2003; 3 – in 2008

3.3. Crash Rate

The intersection is the area that has big traffic density in the urban road system where most traffic conflicts occur. Signal control is an efficient means of reducing intersection accident rate, can separate conflict traffic-flow by time and eliminate or reduce (in two phases, at signal control intersection, the conflict between the left turn and straight-going always exists) the number of conflict points at the intersection; thus the possibility of intersection accident becomes not that strong. In this research, the average crash rate for intersection i can be then defined as the average crash times (ACT) per 100 million entering vehicles (100MEV) and obtained as:

$$ACR_i = \frac{RCC_i}{365 N_{\text{inter}} N_{\text{year}} Q_i} \times 10^8, \quad (1)$$

where: ACR_i – the average crash rate per 100MEV at intersection i, ACT/100MEV; RCC_i – statistical crashes at intersection i; Q_i – the average daily volume at intersection i, pcu/day.

With reference to Eq. (1), we have calculated that the *ACR* value of arterials is 8.12 ACT/100MEV. Table 5 gives the average crash rate for each kind of at – grade intersections, which indicates that conditions for complex driving are prone to bring more automobiles involved into crashes with higher probability.

However, the impact of signal light and traffic monitoring devices on road safety is territorial, not limited to the intersection and can spread to the adjacent road segments and intersections. Therefore, it is necessary to combine segment characteristics together while discussing intersection involved crash features.

Statistical practice proves that the road segment accident rate has a negative relation to the signalized degree and a positive proportion to traffic volume (Keller *et al.* 2006). Suppose that a geometric intersection satisfies a common design requirement, then the crash rate is also defined as the average crash times (ACT) per 100MEV, expressed by Eq. (2):

$$CR_{ij} = \frac{k_i}{\rho_i} \times \frac{RCC_{ij}}{365 N_{\text{inter}} N_{\text{year}} Q_{ij}} \times 10^8, \quad (2)$$

where: CR_{ij} – crash rate per 100MEV for segment i in road j, ACT/100MEV; RCC_{ij} – a crash record of segment i in road j; Q_{ij} – the average daily volume of segment i in road j, pcu/day, Q_{ij} = sum ($AADT_{ij} l_{ij} / L_j$), l_{ij} – the length of segment i in road j and L_j is the total length of road j including segment i; ρ_j – a signalized level of road j, $\rho_j = N_j / L_j$, N_j – the total number of signal control intersections within road j; k_i – a parameter to be estimated for road I determined by road type and facility equipment level.

It should be noted that a crash sample surveyed from Harbin has indicated that k of Harbin ranges within 10÷13 for the segments without a medial divider or 8÷10 for those with a medial divider (Pei, Hu 2004).

Eq. (2) is mainly suitable for the expressway and arterial. For the branches, it may lose its power because of pedestrian violation. Xianfeng Rd. is the major arterial in Harbin linking Nangang District and Daowai District. Thus, the crash rate is analyzed according to the signal control pattern, as shown in Table 6 presenting that the crash rate at signalized intersections is lower than that at non-signalized ones in 300%.

Table 7 gives the determined crash rates of four typical arterials in Harbin (West Dazhi Rd., Xuefu Rd., Xinyang Rd., and Nanzhi Rd.). Clearly, a decreasing percentage of the crash rate of Nanzhi Rd. satisfies (6.61–2.03) / 6.61 × 100% = 69.29%. Safety performances of other three roads have also been significantly increased.

In 2004, Harbin added 'Fast-Track' system, a suit of a compute real control signal system combining SCATS signal control system and Autoscope Video Detect System. These four signalized intersections received obvious changes in the intersection crash rate and severity degree reduction. No people died and the injured crash of kind A (the most serious type) reduced from 4.51 ACT/100MEV in 1992 to 0.59ACT/100MEV in 2005.

Table 5. The average accident rates by at-grade intersection types

Intersection type	Three legged_R	Three legged_IR	Four legged_R	Four legged_IR	Five legged & roundabout
ACR(ACT/100MEV)	3.6	4.9	5.4	7.1	10.8

Three legged _ R = three legged intersection with regular pattern;
Three legged_IR = three legged intersection with in-regular pattern.

Table 6. Intersection crash rate at Wenchang Rd.

Intersection type		AADT	Crashes	Crash rate
		1000pcu	Total	ACT/100MEV
Unsignalized	5	42	78	5.99
Signalized	8	68	43	1.27

Table 7. Typical roads and statistical crash parameters

Road	Medial divider	Length	Signalized level	AADT	Crash rate (before / after)		k
		km	number/km	1000pcu	ACT/100MEV		
West Dazhi	N	3.10	3.1	35	9.73	4.31	10.9
Xuefu	N	4.80	2.3	28	7.11	3.29	11.8
Xinyang	N	1.63	3.5	37	10.49	4.76	10.7
Nanzhi	N	4.72	1.7	26	6.61	2.03	13.2

4. Proposed Counter Measures

Some counter measures are suggested for improving Harbin's safety project at the next step, ranging from pedestrian safety, high level traffic management and speed limit etc.

4.1. Consideration for Pedestrian Safety

Through the records on crashes over the period from 1992 to 2008, we find that about 12% of all crashes were related to pedestrians and as much as 35% of crash fatalities were involved in BMV collisions. Therefore, pedestrian safety should be paid more attention in the future plans. However, just as in Beijing, Harbin also confronts the same problem: pedestrians are not willing to obey traffic rules and almost all drivers also do not make the way for crossing pedestrians, which have caused more conflicts around pedestrian crowd locations (i.e. railway station, shopping mall, hospital, etc.).

A colourful crossing marker is strongly suggested for minor and branch intersections without traffic signals performing as an alarm for passing drivers. In addition, more concerns should also be placed on the volunteers such as students, the old and people with disabilities (Skyving *et al.* 2009), etc. To be more precise, it is not a must and only a suggestion that we should setup the signal light for passerby safety consideration. Automobile and passerby flow can adopt the average daily peak hour's volume.

4.2. More Effective Traffic Management

A big intersection should take canalization processing.

Road Safety Engineering Institute in America considers that the case of the intersection have set signal control; if adding left turn canalization facility, the accident rate will be reduced by 15% and the intersection with a big area should also setup a safety island for pedestrian crossing, especially for the old (Oxley *et al.* 2006). Traffic congestion within the ramp of the expressway also easily makes side wipes and rear-end collision (Cunto, Saccomanno 2009), as shown in Fig. 5, and therefore effective building measures should be utilized.

The signal light has a stronger significance than other traffic signs, including adjusting traffic order and improving safety conditions, except for capacity improvement (Isebrands 2009). However, we must change the concept that signal control is the only measure to improve intersection capacity and considering safety, the only factor while setting signal control due to the fact that it is still not a uniform standard in China.

Relative setting requirements could be referred to statistics on accidents. If there are 5 or more crashes with injuries, we should refer to the signal control pattern (Burchett, Maze 2006). Considering the defect of 'stop', the sign of 'concession' has an indistinctive effect; thus, we could cut down the number of traffic crashes as more as in 60%. It is not enough that only signal lights are set at road intersections, and road segments with enough crossing demand should also be cared. Moreover, the signal plan should be reasonable as the unreasonable one can significantly decrease drivers' driving performance, thus causing a traffic accident (Obeng, Burkey 2008). Improvements may reduce the accident rate by 10%. Some experiments prove that the advancement of signal timing and canalization at the same time reduces the accident rate by 35% (Pei, Hu 2004).

ITS technique developed in 1990, including the real time signal control system, line-control system, surveillance system, intelligent collision warming system etc., can observably improve intersection safety and reduce the severity degree in a wide-range (Laberge *et al.* 2006; Chang *et al.* 2009). In Beijing, ITS technique has already been introduced into traffic management since 2002, including traffic monitoring and control for road intersections and received a good overall effect during the Beijing 2008 Olympic Games.

4.3. Speed Limit

High speed approaching to the intersection always means more likelihood to be involved into a fatal crash (Obeng, Burkey 2008). When conducting a survey on speed distribution on the expressway in Guangzhou (Fig. 6), it

a) b)

Fig.5. Congestion on the expressway ramp between Sitong Bridge and Suzhou Bridge in Beijing: a – conflicts with a bus-car at a weaving section; b – conflicts with entering and existing vehicles (source: Prof. H.-J. Huang's presentation: 'Urban traffic problems and escape issue')

was found that the average automobile speed was about 56 km/h with approximate reductions in 3km/h and 10 km/h during peak hours and entering and existing processes respectively. In Harbin, accordingly, the average speed is about 61 km/h and reduction percentages for three concerns are nearly equal to those obtained in Guangzhou.

Therefore, a higher driving speed is a potential factor contributing to intersection crashes, especially in hilly areas (Wang *et al.* 2007), and therefore speed limit is necessary for reducing crashes not only at unsignalized intersections but also at signalized ones. Compared with commonly used speed limit (Fig. 7a), Fig. 7b provides us a good measure to reduce approach speed by the sight error. Restricting intersection visibility could also receive perfect feedback on decreasing automobile speed before entering intersection (Charlton 2003).

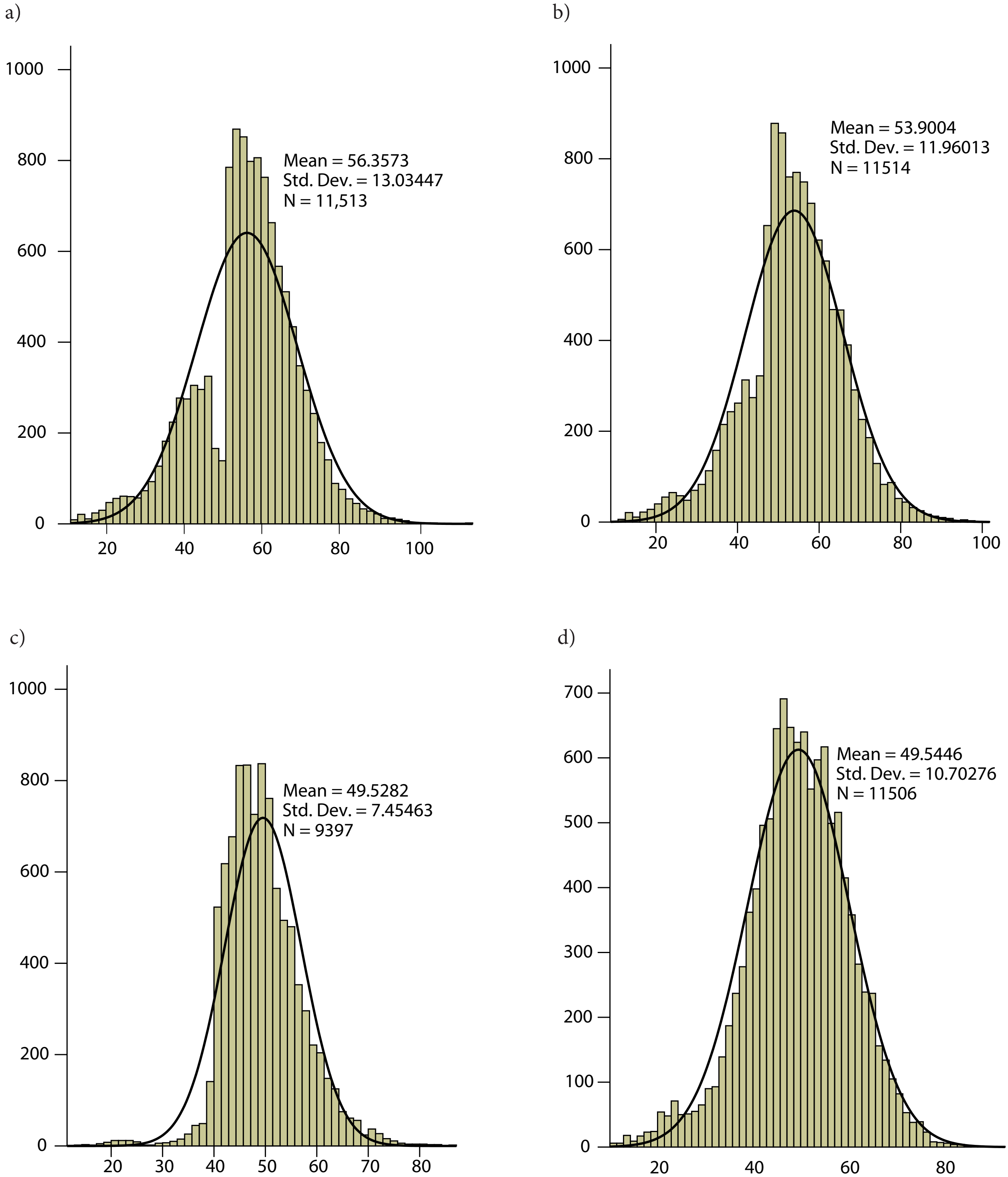

Fig.6. Speed distribution on the expressway in Guangzhou: a – the average speed on the segment; b – the average speed on the segment during peak hours; c – the average entering speed at the ramp; d – the average existing speed at the ramp (Xu 2006)

a)

b)

Fig. 7. Speed limit for reducing approach speed: a – a common used mark board of speed limit; b – speed facility by sight error

5. Conclusions

Intersections are often forced to work in a multi-tasking environment where the encountered situations are usually quite different from those faced in original expectation in nature. Many previous researches regarded analyzing contributable factors (e. g. geometric, traffic variables and environmental concerns) of crashes and the construction of crash foresting models. However, the previous studies on crashes always lead to greater insights considering crash occurrence and measure effectiveness for such a bottleneck and black spot in the road network. Accordingly, this coldest metropolitan (Harbin) in China has carried out a traffic safety improvement project since 2003, aiming at improving the total safety level through constructing new and updating present facilities, especially at intersection locations.

The presented research assumes that the overall safety performance of the intersection could be quantified by sufficient crash observations associated with a traffic management pattern in a negative manner, providing some useful counter measures along traffic management. Signal control is an effective means of improving the traffic order of urban road and reducing the traffic crash rate, but the set and use of light-controlled crossing is often paid less attention. With 3208 intersection crashes in Harbin during the period of 1992–2008, it indicates that signal control and traffic monitoring could efficiently reduce the percentage of intersection crash occurrence, if compared with the non-signalized ones, and the average reduction ratio can achieve to as much as 40% through the estimation and comparison in a half experience equation. Following these considerations, the paper has concluded that we should consider safety standards as important as capacity standards while setting signal control at intersections. Finally, the paper summarizes future countermeasures in Harbin as the next step, including canalizing intersections, improving a signal plan, applying an intelligent transportation system etc., so as to provide multiple strategic, heuristic and sustainable perspectives for traffic management organizations in the fields of drafting planning, setting priorities, generating financial resources and allocating funds.

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