Multipattern Road Traffic Crashes and Injuries: A Case Study of Xi'an City

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Abstract: Many studies focused on the development of crash analysis approaches have resulted in aggregate practices and experiences to quantify the safety effects of human, geometric, traffic and environmental factors on the expected number of deaths, injuries, and/or property damage crashes at specific locations. Traffic crashes on roads are a major cause of road crashes in the metropolitan area of Xi'an. In an attempt to identify causes and consequences, reported traffic crashes for six years in Xi'an were analyzed using a sample of 2038 reports. The main types of information from such reports were extracted, coded, and statistically analyzed. Important results were obtained from frequency analyses as well as multiple contributory factors related to traffic crashes, including crash severity, time and location of occurrence, geometry of the road, AADT and v/c. This paper presents the results of such analyses and provides some recommendations to improve traffic safety and further studies to analyze potential crash locations.

Keywords: traffic accidents; crash features; contributory factor; crash type; v/c

1 Introduction

Worldwide deaths, disabilities, and injuries from road accidents, a major concern all over the world, have reached epidemic proportions. In 2002, more than 1.18 million people died in road crashes, and approximately fifteen million are injured annually (Source: World report on road traffic injury prevention: summary, 2004). In Europe, the sharp increase in accidents related to urban traffic costs more than two billion dollars during recent years. In Britain, around 3,500 people are killed each year and around 33,000 people are injured in road accidents. There were nearly 6,420,000 auto accidents reported to the police in the United States in 2005, and 2.9 million people were injured and 42,636 people killed, in which talking on a cell phone caused nearly 25% of accidents (Source: http://www.griefspeaks.com/id114.html). In New York City, specifically, the review of 2010 traffic accident database found: 1) 269 traffic deaths of all types and a 34 percent increase in auto fatalities; 2) 18 and 152 fatalities from bicycle accidents and pedestrian accidents, respectively (Source: http://www.lawfitz.com/new-york-city-traffic-accident-deaths-rise-slightly-in-2010). Nowadays, China has also witnessed a substantial rise in the number of traffic crashes, injuries and fatalities, especially since 1998 [1, 2].

In response to these issues, various studies have recently examined aspects of motorcycle safety, in combination with available influencing variables and causes information. Typically, researchers employ statistical techniques (i.e., Poisson, negative binomial and regression models, etc.) in these types of studies [3]. Over the past years, numerous investigations have looked at the age and gender of drivers as risk factors, and younger and older drivers are more prone to be involved in a serious accident than median-aged ones [4]. Road geometric type, lightness, weather condition and other environmental factors (e.g., the time of the day, traffic volume, etc.) also play an important role when analyzing the aspects of accident crashes and injuries [5~8].

To provide a broad overview, numerous statistical researches have been conducted in order to understand the relations between influence factors and crash features via types of models [9, 10]. Another class of studies utilize time series techniques for identifying the change of accident counts and accident rates at a given time, analyzing the effects of potential factors on accident occurrence, and developing a statistical model for forecasting future trends of crashes and injuries such as in references [11~13], and so on. Actually, each crash is a unique event that is caused or influenced by combinations of variables that may not even be observable [14]. Furthermore, reaching such conclusions that a set of variables can be identified as the causes of traffic crash is almost impossible.

This study follows an earlier work on the analysis of traffic accidents at intersections [15] and aims to identify the multiple crash features in Xi'an city. Several potential factors including district, human, vehicle, time, traffic volume, environmental and site factors are considered. Statistical analyses of multiple vehicle traffic accidents are conducted using the crash data in Xi'an city over the time of 2004~2009. The corresponding safety improvement measures are suggested so as to enhance the safety performance of road traffic and decrease the probability of crash occurrence in China's metropolitan regions.

2 Data

Xi'an is the capital of the Shaanxi province and one of the oldest cities in China, with more than 3,100 years of history experiencing Zhou, Qin, Han, Sui, and Tang. Since the 1990s, as part of the economic revival of interior China especially for the central and northwest regions, Xi'an has re-emerged as one of the most populous metropolitan areas in inland China, with more than 7 million inhabitants, which has also alarmingly increased the annual traffic crashes and injuries.

The research relies mainly on accident reports archived from General Department of Transportation and its different branches located in different traffic policy teams in Xi'an city. All 2361 crashes within 6 districts, namely Xincheng, Beilin, Yanta, Lianhu, Baqiao and Weiyang, from the year 2004 to 2009 were collected randomly without any specifications or criteria. In this paper, only motor vehicle crashes are considered.

For each sample, a copy of the accident report was obtained to learn more details about the crash, such as the time, location, cause, type of crash, weather, drivers and vehicles. Unfortunately, missing or incomplete data was a common problem in the crash reports (e.g., the condition of road surface, control pattern of intersection, etc.). Thus it is difficult to know exactly how some crashes occurred simply from the accident report [16]. On the other hand, hand-writing is commonly used to record and draw the crash description on spot, and it is sometimes clear enough to identify the crash details.

Therefore, 323 records accounting for 13.68% of the original collection were removed from the crash database due to missing or incomplete information, and this left 2038 samples used for the future research, in which 12.41% proved fatal, 28.16% resulted in serious injuries and the rest in slight injuries.

3 Crash Features

Analyses were performed on the data collected from the General Administration of Transportation in the form of accident reports. The analyses included frequency, cross-classification tabulation, and construction of crash spot maps.

3.1 Temporal-Spatial Patterns

Xi'an is at the top of list of cities with alarmingly high traffic crash fatality rates in China. A summary of crash type statistics for the year 2004~2009 for each district is presented in Table 1. More than 85% of crashes were vehicle collisions/crashes. About 53.8% of the total road traffic accidents occurred in the Yanta district and Beilin district.

Table 1

Number of crashes and injuries by districts

Districts	Crash Type					Injuries			Deaths
	Collision	Running over	Overturning	Drugs	Total	Minor	Major	Total	
Yanta	587	24	32	19	662	70	36	105	38
Beilin	509	12	23	4	548	54	15	68	36
Lianhu	274	15	24	13	326	79	42	121	45
Weiyang	92	21	18	3	134	61	30	91	57
Xincheng	171	14	31	23	239	69	26	95	60
Baqiao	101	11	9	7	128	75	19	94	17
Total	1734	97	137	69	2038	407	167	574	253

Around 318 fatalities occurred in the year 2009 with a decreasing trend. However, the overwhelmingly high proportion of younger drivers involved in traffic crashes has become a serious new concern. Over 60% of the fatalities for 2009 were in the age group of 18-40, though Xi'an had implemented new and stricter penalties under the new national traffic laws in May 2008 in order to minimize traffic crashes. The statistics show that the main cause of crashes is careless driving (e.g., mobile phone use while driving, fatigue, obsessive behavior, etc.) and speeding, which represent about 43% and 26% of the total crashes, respectively. The second main cause of crashes is drunk driving representing about 14%. The rest of the reasons together represent about 17% of total crashes due to facilities, weather and other effects. Therefore, all but a few crashes can be blamed on careless driving, and other factors also play important roles.

Statistics also demonstrate that the safety situation in Xi'an was still serious as shown by the numbers of reported crashes during the years 2004~2009, which are presented in Table 2. The number of crashes increased steadily during the years 2004~2006, and following this period began to decrease. Collisions represented the larger proportion of the total number of crashes. However, the crash rate was still at a high rate. The average number of crashes per day increased from 0.91 in 2004 to 1.06 in 2006 and then decreased to 0.85 in 2009. Crashes involving personal injuries fluctuated between a daily average of 0.15 to 0.4 and, fatal crashes which included at least one death occurred at a daily average of about 0.13, which meant perhaps one life was lost weekly because of road crashes.

Table 2
Statistics of traffic crashes over the year 2004-2009

Year	2004	2005	2006	2007	2008	2009
Total number of crashes	332	346	387	345	317	311
Collision crashes	270	284	324	291	262	259
Crash of overrun/overturning/drugs/others	62	61	64	54	55	52
Total injuries	113	73	102	146	86	54
Minor injuries	76	48	68	107	60	38
Major injuries	37	25	34	39	26	16
Fatal crashes	41	41	37	39	46	49
Average no. of crashes per day	0.91	0.95	1.06	0.95	0.87	0.85
Average no. of injuries per day	0.31	0.20	0.28	0.40	0.24	0.15
Average no. of fatalities per day	0.11	0.11	0.10	0.11	0.13	0.13

3.2 Frequency in Age and Weather

Frequency analysis was performed for the following variables: time, day, weather, road surface condition, crash type, crash location, number of lanes, road type, car movement, crash type (general crash, rear end side collision), and severity.

Table 3 presents the injuries and deaths involved in crashes. Clearly, the number of male persons related to crashes was about three times of that of females and about a half of the injuries and deaths were drivers, which also confirmed the importance of educating the safe driving program. Moreover, the percentage of motorcyclists was up to 15.79%, an alarming number among all the injuries and deaths. It was also noticed that 70.77% of injuries and deaths involved persons aging 25~60, especially those between 31~40, a group with higher driving risk. However, we found that the crash involvement rate of younger and older drivers was significant higher than that of medium aged ones.

Table 3
Injury and death categories involved in crashes

Persons	Male	Female	Driver	Passenger	Pedestrian	Motorcycler	Bicycler
Percent/%	74.86	25.14	46.17	13.43	13.45	15.79	11.16
Age	< 16	16-24	25-30	31-40	41-50	51-60	> 61
Percent/%	9.34	11.54	15.93	18.89	19.24	16.71	8.35

Table 4 shows the effects of weather and brightness on crash occurrence. Obviously, the weather has a significant effect on crash occurrence and more than two third of observations occurred on bad weather days including cloudy, rainy, foggy, snowy, and heavily windy ones. Brightness also affects the frequency of crashes through affecting driving behavior of drivers, and we can see that as high as 17.94% of crashes during darkness, with street lamps.

Table 4
Crash distribution by weather and bright effect

Weather	Sunny	Cloudy	Rainy	Foggy	Snowy	Heavy windy
Percent/%	31.73	13.79	17.38	11.17	17.48	8.45
Brightness	Dawn	Daylight	Twilight	Dark with street lamp	Dark without street lamp	Entrance and exit to urban tunnel
Percent/%	1.33	63.74	6.15	17.94	9.97	0.87

3.3 Location Specification

Crash distributions according to road type are shown in Table 5. It can be noticed that 33.46% of crashes were in arterial roads. Cumulative percentage shows that 45.09% of crashes occurred on expressways and arterials. This is because of high speeds and high traffic volumes on these two types of roads, and more frequent entrances and exits on such type of roads also contributed to the occurrence of crashes. The second highest incidence rate was in the sub-arterials category, with 19.72% of crashes occurring on them, due partially to the lack of effective safety facilities. Significantly, unsignalized intersection is a typical black spot prone to traffic crashes.

Table 5
Crash distribution by road type and crash location

Road Type	**Percent/%**	**Position**	**Percent/%**
Expressway	11.63	Roundabout	2.49
Arterial	33.46	Bridge	0.65
Sub-arterial	19.72	Tunnel	0.87
Branch and minor roads	10.12	Unsignalized intersection	12.43
Residential Street	2.36	Signalized intersection	6.27

Table 6 shows the cross tabulation of crash types and districts. It can be noticed from the results that car collision which had the highest percentage of crash occurrence had its highest percentage of 21.8% in Beilin district. This may be attributed to the high traffic volume and low speeds in these districts. The other types are noticed to have their highest percentage of occurrence in Weiyang and Baqiao. Unfortunately, truck-involved crashes made up a large percentage in the crash reports, and this is particularly true for outlying or peripheral areas [17]. Roadside barriers, light poles, even trees and other stationary objects sometimes are prone to cause serious secondary collisions and severe injuries.

Table 6
Crash percentage in types on districts

Crash type	Yanta	Beilin	Lianhu	Weiyang	Xincheng	Baqiao
Car collision	18.8	21.8	19	12.5	14.5	13.4
Collision into stationary objects	12.6	12.6	12.1	23.5	19.8	19.4
Collision into pedestrians	14.7	19.5	17.1	13.9	21.7	13.1
Overturning	18.9	15.1	22.5	13.3	11.9	18.3
Falling down	17.3	11.5	16.1	22.9	9.5	22.7
Others	17.7	19.5	13.2	13.9	22.6	13.1

Stationary objects includes light pole, trees, wall and street furniture, etc.

3.4 Potential Causes

As a result of reviewing the crash reports, crashes caused by sudden stop were observed statistically as the most frequent types, responsible for 32.3% of the total records. These usually occurred in traffic congestions where vehicles were moving slowly and traffic was mainly in stop-and-go situations, and drivers usually did not keep enough space between themselves and other vehicles [18]. It also happened when a driver at a relatively high speed was surprised with congestion ahead.

Actually, traffic safety performance function (SPF), has a statistical relationship with congestion on urban freeways and observed safety, measured in the number of crashes over a unit of given time [crashes per kilometer per year (CPKPY)] and it varies with traffic exposure [14, 19], measured in annual average daily traffic (AADT). Six years of data were used to analyze such effects on selected multi-type urban road segments. Figure 1 presents a pattern of total observed CPKPYs as the AADT increases for expressway and arterial segments. It should be pointed out that such a function for branch and minor streets was neglected due to a lack of crash records.

In Figure 1, traffic density at 34,000 AADT is a critical point and can be viewed as a critical density (point A), beyond which notably higher crash rates are observed with AADT changes, and the portion of the left of this critical density can thus be considered as a sub-critical zone, as AADT increasing from 8,000 to 34,000 induces the increase of traffic density by 3.5 times [from 5.7pcu per kilometer per lane to 25.8 pcu/(km·ln)], while traveling speed remains almost the same (62 km/h to 55 km/h). The portion to the right of point B can be viewed as a super-critical zone and the portion between sub-critical and super-critical densities can be viewed as a transitional zone, featuring an increase in CPKPY from 21 to 52, compared with 8-21 from point C to point A. Further examination of SPF reflects that passing an AADT of 34,000, the number of crashes increases at a much faster rate with an increase in AADT.

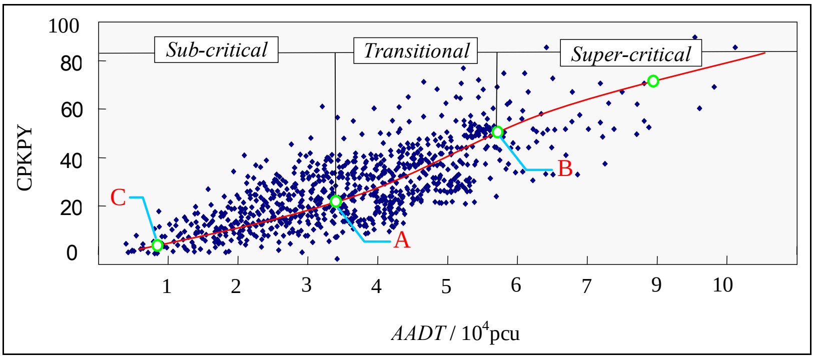

Figure 1

Statistical changes in segment crashes with AADT

A: critical density, with v = 55 km/h and ρ = 25.8 pcu/(km·ln); B: super-critical density, with v < 45km/h and ρ > 52.8 pcu/(km·ln); C: v = 62 km/h and ρ = 5.7 pcu/(km·ln)

In actuality, the crash rate changes with traffic volume, and SPF reflects how these changes take place. Lower rates within equal SPF mean higher safety rather than higher rates. However, numerous research reports have shown that predictive models that use traffic volume as the only explanatory variable may not adequately characterize the crash process on freeway segments [19, 20]. Functional forms that incorporate density and *v*/*c* ratio offer a richer description of crashes occurring on these facilities locating in a rural or urban environment [21].

Figure 2 shows the relation between crash rates measured in crashes per 100 million vehicle kilometers travelled and *v*/*c* ratio. Obviously, the operation ranging 0.5~0.6 under LOS C meets the lowest level of crash rate and we yield the lowest 45 crashes with respective to moderate *v*/*c* (0.54). Such a V regression mode also shows that free traffic flow usually brings serious rear-end or other types of crashes due to drivers' low vigilance of danger. Furthermore, more congested flow under LOS D or worse improves the likelihood of minor crashes.

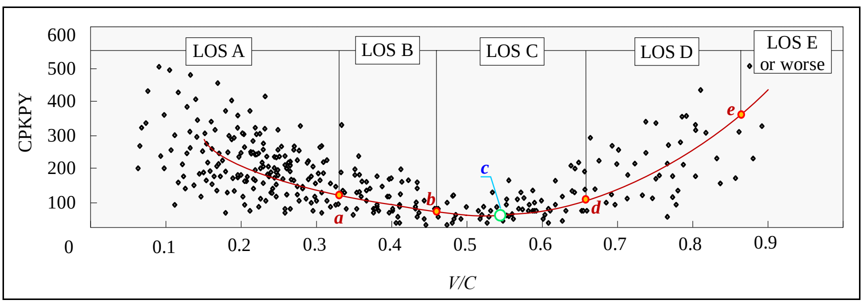

Figure 2

Statistical relation of crash rate and *v*/*c*

a. (0.32, 120); *b*. (0.46, 75); *c*. (0.54, 45); *d*. (0.70, 105); *e*. (0.87, 370)

Nevertheless, separate predictive models for single- and multi-vehicle crashes should be developed rather than one common model for all crash types [22]. Different variables (i.e., type of roads, barriers, etc.), for example, all have varying effects on the occurrence of crashes and statistical rates. Individual analysis may help find potential causes and effective measures to deal with the particular locations or long term safety improvement programs.

Conclusions

The presented study is designed to be a first step towards analyzing traffic crashes in Xi'an city. Crash features related to time, position, type of roads and type of crashes, etc., and exposure effects involving AADT and *v*/*c* analyses provide many important types of information that are required by engineers and decision-makers to improve safety for the driving public in this western metropolis of China. Such analyses must be performed regularly (annually) for long-term traffic safety environment consideration [15].

During the review process of crash reports, some recommendations were suggested. Road geometry in Xi'an should be checked on the national level and improvements should be made at many locations that are not up to standards, for example improving sight distances at intersections and roundabouts; checking the appropriateness of (and redesign if necessary) the acceleration and deceleration lanes to and from arterials and sub-arterials [23], etc. Moreover, it is also recommended to use traffic signals or warning signs before entering the intersections and to provide enough pedestrian crossings and overpasses, especially at heavy traffic intersections and commercial regions [24, 25]. Sufficient traffic safety education is also necessary not only for drivers but also for voluntary participants (i.e., pedestrians, bicyclists, et al). For scientific research demand, crash messages need to be more accurately identified in order to construct more accurate crash database using available GPS technology [26, 27].

Acknowledgement

This research is supported by the China Postdoctoral Science Foundation (No. 2011M501434). Here the helps from our industry partner, Xi'an General Traffic Policy Teams, the editors of Acta Polytechnica Hungarica, anonymous reviewers and authors of cited papers are gratefully acknowledged. We would like to thank, in particular, Prof. K. M. Chen from Chang'an University, for suggesting this research problem and the valuable advice he has given.

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