ANALYSIS OF TRAFFIC CRASH CHARACTERISTICS AND SAFETY POLICIES

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ABSTRACT

Traffic safety is one of the most important elements in building a harmonious society and improving people's livelihood. Traffic crashes have been increasing with the rapid expansion of the highway networks and vehicle ownership from 1990 to 2003 in China. The Chinese government has developed numerous programs and policies to improve traffic safety, such as Safety Enhancement Engineering (SEE), New Safety Design Concept for Roadway (NSDCR), Road Safety Audit (RSA), Road Safety Management Planning (RSMP), Safety and Expedite Road Engineering (SERE); implementation of these programs and policies has seen a 50 percent decrease in the number of crashes and casualties since 2004. The objective of the paper was to analyze the impact of safety policies on crash characteristics.

The paper analyzed the trend of traffic safety and the changes in crash frequency and severity distributions during the period from 2000 to 2010, and discussed the effect of the safety programs and policies (including SEE, NSDCR, RSA, RSMP and SERE) on crash reduction. Based on the analysis, this paper proposed several recommendations for highway design practitioners, and policy makers to improve traffic safety.

Keywords: Traffic safety, Crash characteristics, Crash distribution, Crash index, Safety policy

INTRODUCTION

Traffic safety is one of the most important elements in building harmonious society and improving the people's livelihood. With the emergence of the golden period in road construction and automobile development in China，serious traffic safety situation began to appear in the early years of the 21st century (Li et al. 2007; Zheng, 2006; Zhong and Sun, 2007). In order to reverse the climbing trend in crash frequency and injuries, the Chinese government has developed a series of safety program and policies to improve traffic safety, such as the Safety Enhancement Engineering (SEE), New Safety Design Concept for Roadway (NSDCR), Road Safety Audit (RSA), Road Safety Management Planning (RSMP), Safety and Expedite Road Engineering (SERE) since early 2004. The success of these policies is obvious as the number of crashes and casualties has reduced by the annual average rate of 10 percent. As a result, the number of crashes and casualties in 2010 fell to about 60 percent of that number in 2004. The objective of the paper was to reveal the change of crash characteristics and the patterns of crashes due to the implementation of road safety programs and policies.

The paper is organized as follows. First, the paper analyzed the trend of traffic safety, and discussed the change in crash frequency and severity distributions, and major crash contributing factors using the crash data from 2000 to 2010. Then an analysis was performed to evaluate the effect of safety programs and policies on crash reduction, including SEE, NSDCR, RSA, RSMP and SERE. Based on the analysis, this paper was concluded with several recommendations for highway design practitioners, and policy makers to improve traffic safety.

COMPARISON OF GENERAL TENDENCY

Traffic Safety Trend

While the rapid development of highway and automobile industry provides mankind a great privilege，traffic crashes bring a great loss of property and danger to human life. The general trends of crash indices (including number of crashes, number of fatalities and number of injuries) has shown a significant growth since 1990’s (according to The China Crash Data Annual Report 1990-2009). The statistical data from Ministry of Public Security show that 65,225 people were killed in traffic crashes in 2010. Since more detailed crash data for 2010 has not been issued yet, the crash data from 1990 to 2009 were used in the paper. As shown in Figure 1, the shape of crash indexes looked like an inverse U shape. The growing speed of crash indexes was slow in

early 1990's, but there was a sharp increase from 1998 to 2002. The crash indexes peaked in 2002, with 562,074 injuries and 109,381fatalites in 773,137 crashes. The fatality rate per 10,000 vehicles was 13.71 in 2002.

The Chinese government began to attach great importance to the traffic safety. A new traffic safety law was passed and became effective in 2004. At the same time the government began to implement traffic safety programs and policies such as SEE, NSDCR, RSA, RSMP, and SERE (Zhang, 2010). As a result, the crash indices had been moving downward significantly from 2003 to 2010; the crash indices decreased at 8 percent (as shown in Table 1). This trend suggests that new traffic safety policies had positive effects on crash reduction (Tang, 2007). The total number of crashes in 2010 dropped nearly 50 percent from 2002. Furthermore, the overall severity of traffic crashes has been decreasing gradually year by year.

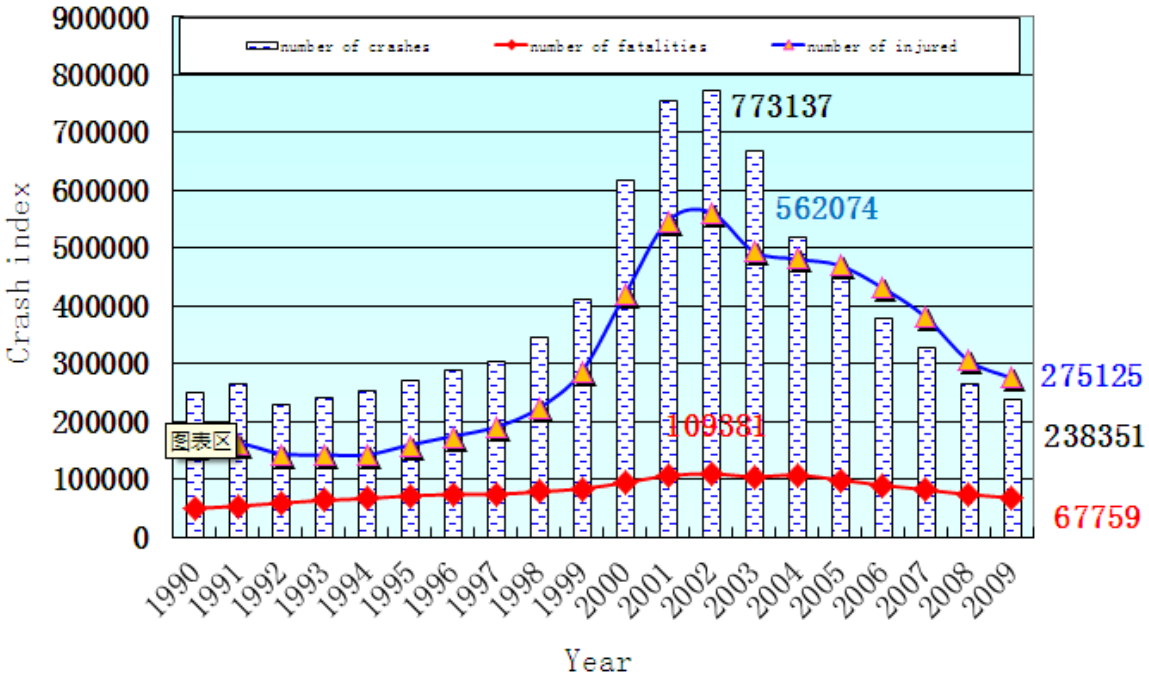

Figure 1 The trend of crash indices from 1990 to 2007

Table 1 The trend of crash indices

Year	Number of crashes	*Percentage of change in crashes	Fatalities	*Percentage of change in fatalities	Number ofinjuries	*Percentage of change in injuries	Mortality rate per 10,000 vehicles MV	*Percentage of change MV	Mortality rate per 100,000 population MV
1990	250297	--	49271	--	155072	--	33.38	--	4.31
1991	264817	5.80%	53292	8.16%	162019	4.48%	32.15	-3.68%	4.6
1992	228278	-13.80%	58729	10.20%	144264	-10.96%	30.19	-6.10%	5
1993	242343	6.16%	63508	8.14%	142251	-1.40%	27.24	-9.77%	5.36
1994	253537	4.62%	66362	4.49%	142251	0.00%	24.26	-10.94%	5.54

1995	271843	7.22%	71494	7.73%	159308	11.99%	22.48	-7.34%	5.9
1996	287685	5.83%	73655	3.02%	174447	9.50%	20.41	-9.21%	6.02
1997	304217	5.75%	73861	0.28%	190128	8.99%	17.5	-14.26%	5.97
1998	346129	13.78%	78067	5.69%	222721	17.14%	17.3	-1.14%	6.25
1999	412860	19.28%	83529	7.00%	286080	28.45%	15.45	-10.69%	6.82
2000	616971	49.44%	93853	12.36%	418721	46.37%	15.6	0.97%	7.27
2001	754919	22.36%	105930	12.87%	546485	30.51%	15.46	-0.90%	8.51
2002	773137	2.41%	109381	3.26%	562074	2.85%	13.71	-11.32%	8.79
2003	667507	-13.66%	104372	-4.58%	494174	-12.08%	10.81	-21.15%	8.08
2004	517889	-22.41%	107077	2.59%	480864	-2.69%	9.93	-8.14%	8.24
2005	450254	-13.06%	98738	-7.79%	469911	-2.28%	7.57	-23.77%	7.6
2006	378781	-15.87%	89455	-9.40%	431139	-8.25%	6.16	-18.63%	6.84
2007	327209	-13.62%	81649	-8.73%	380442	-11.76%	5.11	-17.05%	6.21
2008	265204	-18.95%	73484	-10.00%	304919	-19.85%	4.33	-15.26%	5.56
2009	238351	-10.13%	67759	-7.79%	275125	-9.77%	3.63	-16.17%	5.1
2010			65225	-3.74%			3.2	-11.85%	

*Note: The percentage of change is defined as the value of statistical year divided by corresponding value of last year.

Although the general trend of crashes has been going down in China, Table 2 shows the mortality rate per 10,000 vehicles was 3.2 in 2010, which was slightly higher than that of developed countries like US, Japan, Germany. The mortality rate per 10,000 vehicles ranged from 0.8 to 2 in developed countries, which was about one third to half of that number in China in 2010.

Table 2 The mortality rate per 10,000 vehicles from 2002 to 2008

Country\Year	2002	2003	2004	2005	2006	2007	2008
Germany	1.28	1.23	1.08	0.98	0.93	0.89	0.81
Spain	2.13	2.10	1.80	1.60	1.44	1.33	1.00
France	2.16	1.68	1.59	1.43	1.25	1.22	1.13
Italy	1.60	1.43	1.30	1.35	1.31	1.21	1.18
Holland	1.18	1.23	0.95	0.87	0.84	0.79	0.75
U.K.	1.15	1.10	1.02	0.99	0.95	0.92	0.74
U.S	1.91	1.86	1.80	1.77	1.70	1.61	1.46
Japan	1.08	0.99	0.94	0.87	0.80	0.63	0.65
Korea	4.60	4.40	3.90	3.40	3.20	3.10	2.93
China	13.71	10.81	9.93	7.57	6.16	5.11	4.33

In addition, the mortality rate per 100,000 population showed a convex parabolic curve from 1990 to 2009 (as shown in Figure 2). Table 3 indicated the average annual growth rate was 6.47 percent from 1990 to 2002 and the mortality rate per 100,000 population reached 8.79, which

was twice of that number in 1990. The average annual decrease rate was 6.6 percent and the mortality rate per 100,000 population dropped to 5.1 in 2010.

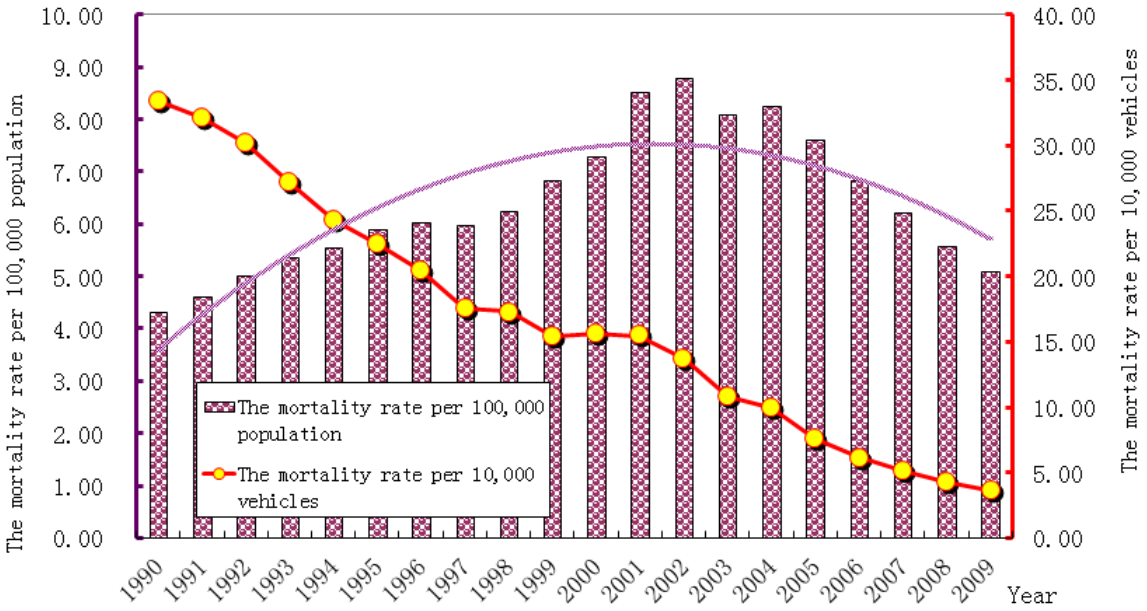

Figure 2 The tendencies of the mortality rate per 10,000 vehicles and the mortality rate per 100,000 population from 2000 to 2009

Table 3 The mortality rate per 100,000 population from 2002 to 2008

Country\Year	2002	2003	2004	2005	2006	2007	2008
Germany	8.30	8.00	7.10	6.50	6.20	6.00	5.40
Spain	13.10	13.00	11.20	10.50	9.40	8.60	6.80
France	12.90	10.10	9.20	8.90	7.50	7.30	6.70
Italy	11.80	10.60	9.70	9.37	9.60		8.10
Holland	6.10	6.30	4.90	4.60	4.50	4.30	4.10
U.K.	6.00	6.20	5.60	5.60	5.50	5.00	4.30
U.S	14.93	14.74	14.59	14.66	14.24	13.61	12.25
Japan	6.53	6.04	5.76	5.38	5.00	4.50	4.04
Korea	15.20	15.00	13.60	13.20	13.00	12.72	12.11
China	8.79	8.08	8.24	7.60	6.84	6.21	5.56

CHANGE CHARACTERISTIC AND POLICY

Since the crash rate remains at a higher level, the government has developed and implemented several national traffic safety programs and policies which contributed to the reduction in crash rates. RSA, and NSDCR were adopted for freeway, TSEP was for Grade highways, and RSMP, and SERE were applied to urban roadways. Besides these national policies, local government entities have initiated some traffic safety campaigns, but these campaigns by local governments

have received limited effects. Table 4 shows crash distributions by different types of roads and national safety policies.

Table 4 Crash distributions by types of roads and safety policies

YEAR	2004		2005		2007		2009		Safety policies
Road type	Fatalities	Percentage share	Fatalities	Percentage share	Fatalities	Percentage share	Fatalities	Percentage share	
Freeway	6,235	5.82%	6,407	6.49%	6,030	7.40%	6,028	8.90%	RSA,NSDCR
Class IV and Above Highways	73,850	68.97%	70,282	71.18%	54,241	66.58%	42,843	63.23%	TSEP
Urban streets	26,992	25.21%	22,049	22.33%	21,198	26.02%	18,888	27.88%	RSMP,SERE

Freeway

Freeway is a two-way multi-lane highway facility with full control of access and interchanges, and with central strip and median barrier, and with lateral barrier, and with speed limits ranging from 80 km/h to 120km/h. NSDCR and RSA were introduced to identify design deficiencies for freeways. The Chinese freeway mileage reached 34,000 centerline kilometers in 2004. Roadway designers sometimes paid little attention to the actual travel demand and just followed the design standards with little consideration of actual conditions. This situation resulted in a few common design deficiencies as shown below:

The difference between design speed and operating speed are about 20 to 40km/h, which means some alignment geometric designs may be disadvantageous to safe driving.

Some guide signs at freeway ramp entrances may confuse drivers who are unacquainted with the freeway, and this situation may mislead drivers making errors in judgment and driving.

Some roadside barriers on roads in mountainous areas are not designed strong enough to contain and protect run-off-road vehicles.

The number of monitoring facilities is not adequate detecting and disseminating bad weather conditions in time.

Traffic violations such as overloading, speeding, driving with fatigue are not uncommon.

NSDCR is focus on improving safety by emphasizing safety concepts in newly designed freeway (Meng, et al 2008; Zhong et al, 2006). These concepts include: forgiving design, selecting routes to avoid areas which commonly see inclement weather conditions, designing mild curves, providing clear zones, improving traffic management such as installation of dynamic message signs and auto-enforcement system. NSDCR is useful to eliminate deficiencies in design phase (Mao, et al 2007; Rune, 2004).

RSA is viewed as a proactive, low-cost approach to improve safety (Alfonso, 2001). The Ministry of Transport (MOT) in China released the Guidelines for Safety Audit of Highway (JTG/T B05-2004) in 2004 and recommended that RSA should be conducted at various phases such as project planning, preliminary design, final design, and operation phase. RSA is used to check whether there is a deficiency in newly built and operating freeways by using auditors' experiences and qualitative or quantitative appraising approaches. A report of RSA would make useful suggestions to improve the design consistency, coordinate between design speed and operating speed, and make efficient use of roadside safety facilities.

NSDCR has been employed in more than 80 percent newly built freeway projects with more than 25,000 centerline kilometers in the last 6 years. RSA has used in nearly 30 percent newly built freeway projects, with more than 10,000 centerline kilometers and existing 5,000 kilometer operating freeways in the last 6 years.

From During the period 2005 to through 2010, all crash indices remained at low growth rate even though the freeway mileage and vehicle ownership have been increasing significantly. Table 5 showed the crash rate, fatality rate and injury rate per 100 kilometers of freeways in 2004 were 71, 18, 44, respectively, while these numbers dropped to 14, 9 and 9, respectively in 2009. Provided that the freeway mileage and vehicle ownership had not changed since 2004, it the number of crashes had dropped more than a half. Statistics showed that drivers' operating errors and illegal maneuvers had reduced drastically; traffic crashes caused by failure to keep safe distance, speeding and overloading had reduced by 50, 30 and 70 percent, respectively.

Table 5 Crash indices of freeway from 1994 to 2009

	Number of crashes		Number of deaths		Number of injuries		Mileage
Year	Number	%of total	Number	%of total	Number	%of total	(km)
1994	2877	1.14%	539	0.81%	4457	0.78%	1603
1995	4590	1.69%	616	0.86%	1600	1.00%	2141
1996	6797	2.40%	864	1.20%	2215	1.30%	3422
1997	9035	3.00%	1182	1.60%	3190	1.70%	4771
1998	10574	3.05%	1487	1.91%	4034	1.81%	8733
1999	12634	3.06%	1687	2.02%	4921	1.72%	11605
2000	16916	2.74%	2162	2.30%	6442	1.54%	16314
2001	24565	3.25%	3147	2.97%	9978	1.83%	19437
2002	29611	3.83%	3927	3.59%	12253	2.18%	25130
2003	36257	5.43%	5269	5.05%	14867	3.01%	29745
2004	24466	4.72%	6235	5.82%	15213	3.16%	34288
2005	18168	4.04%	6407	6.49%	15618	3.34%	41005
2006	14432	3.81%	6647	7.43%	17116	3.97%	45339
2007	12364	3.78%	6030	7.39%	14628	3.85%	53913
2008	10848	4.09%	6042	8.22%	13768	4.52%	60302
2009	9147	3.84%	6028	8.90%	12780	4.65%	65056

Class IV and Above Highways

Class IV and above highways are two-way two-lane highway usually located in rural areas without control of access, with design speeds lower than 70km/h. TSEP is used to improve traffic safety for these types of highways. The mileage of Class IV and above highways was 1,870,000 kilometer in 2004, which carried majority of roadway traffic in China. Most Class IV and above highways are two-lane highways and has been in operation for more than 10 years. But with increasing traffic volume and emerging heavy-duty trucks, safety deficiencies had been more obvious because of limited investment and relative low design criteria in early construction phase. According to the data of MOT, there were 170,000 crash-prone road segments on the national highway system in 2004. The following deficiencies were often found in crash-prone road segments:

The design parameters based on low design speed cannot provide safety for high-speed vehicles. Some two-lane highways were designed at 40 km/h or below while most drivers are used to driving at more than 70km/h. Speeding on horizontal and vertical curves may not ensure enough sight distance or vehicle stability (Zhong et al, 2008).

Lack of signs, markings, warning devices are not unusual.

Vehicles falling off cliff are common because of lack of roadside barriers on curves and bridges.

Illegal overtaking, usually causes serious head-on collisions and sideswipe collisions (Walmman et al 2001; Zhong et al, 2009). Figure 3 shows the distribution of crashes by type.

Mixed traffic and roadside pedestrian disturbance are often occurred in the suburban areas, and pedestrians and motorcycles usually involved in crashes.

Unfavorable alignment designs such as long downhill segment, and sharp curves may contribute to some crashes.

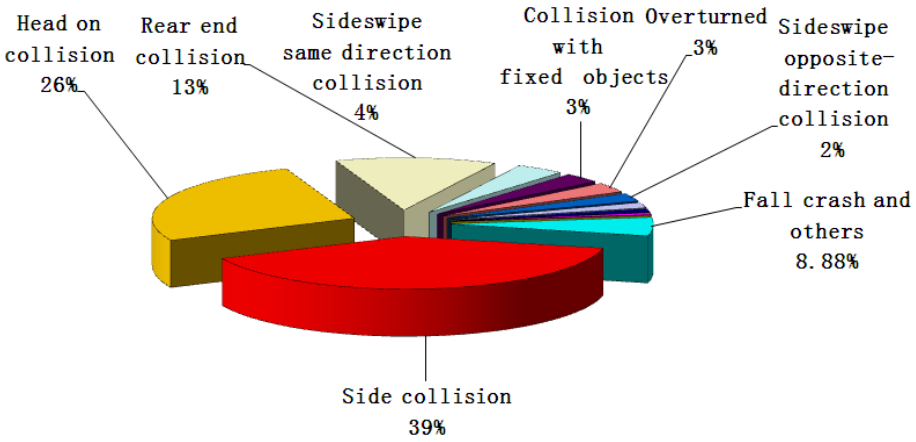

Figure 3 The distribution of crashes by type (2005 - 2009)

MOT initiated and sponsored a nationwide TSEP campaign in 2004. The objective of TSEP was to improve safety performance by rehabilitating dangerous segments on the national highway system and eliminating crash-prone spots in the next few years. MOT issued the Guidelines for TSEP in 2004 and 2010. Integrative countermeasures to sharp curve segments, steep segments, segments with limited sight distance, hazardous roadside segments are provided in the guideline. According to the statistics, the crash mortality rate on TSEP segments reduced by about 7.3 percent after implementation. Especially, the number of vehicles falling of cliff that caused more than 10 deaths in a crash on mountain highway has dropped by 18.1 - 38.8 percent annually during the period 2005 to 2008 (Zhang, 2007). At present, TSEP has been successfully implemented on 134,000 kilometers of highway and treated 424,000 potential hazardous locations, which cost about 15 billion Yuan RMB (about 2.4 billion US dollars) in the last 6 years. It is obvious that TSEP has played an important role in reducing and preventing serious crashes.

City roads

City roads include urban expressways and streets. The New Road Traffic Safety Law has become effective in China since May 1, 2004. To improve road safety both national and local governments are required to make Road Safety Management Planning (RSMP). The goal of RSMP is to integrate safety management into the transportation planning process and routine management. RSMP is one of the most important components of Strategic Plan for Improving Road Safety (SPIRS). RSMP requires cooperation, collaboration and integration of the planning processes of several agencies including traffic police administration, highway administration, municipal administration, etc. RSMP includes traffic management policy planning, road safety system planning, road safety information system planning, road safety campaigns and education planning. RSMP is required to prepare and update periodically. Currently more than 100 cities have launched RSMP and put RSMP into practice since 2004. At the same time, SERE, which initiated by the MPS in the late of 1990s, has been carrying on in order to improve road safety by adding traffic safety and management facilities, optimizing traffic flow, giving priority to buses, getting rid of illegal behaviors and vehicles with poor performance. It has proved that SERE has positive effects since the total number of crashes and casualties kept decreasing, while the number of vehicle went up from 43,286,900 in 2005 to 76,193,100 in 2009. The number of fatalities on city roads was 22,049 in 2005, and this number was further reduced to18,888 in 2009.

CONCLUSIONS

With the government and people attaching importance to traffic safety step by step, traffic crashes have been decreasing gradually in recent years. Since the Chinese government developed and carried out a series of safety programs and policies such as SEE, SERE, RSA and RSMP, the number of crashes has dropped dramatically from 517,889 in 2004 to 238,351 in 2009. The number of fatalities dropped to 65,225 in 2010. Most safety programs and policies have been proved positive and effective in reducing crashes (Zhong and Wei, 2007). The main findings of this study are summarized as follows:

Traffic crashes showed an overall upward trend from 1990 to 2002 and a downward trend from 2004 to 2010 in China. The safety policies (including SEE, NSDCR, RSA, RSMP, and SERE) have significant effects on crash reduction.

Class IV and above highways[1] share 70 percent of that total number of crashes, while expressways or freeways account for only 6.5 percent of the total. The ratio between the number of crashes on rural highways and city streets is 3:1, which almost has remained unchanged since 2005. But the total number of crashes and casualties has dropped drastically in the last six years.

The paper is sponsored by State Traffic Safety Action Plan (No.2009BAG13A02). With implementation of those safety programs and policies, most crash prone locations have been studied, treated, and experienced a significant drop in crash occurrence. But China is still facing serious challenges in traffic. Experiences have shown a necessity of collaborative efforts among various transportation and transportation related government agencies. These programs and policies should still be valid and implemented to improve traffic safety in the future. It is also suggested that the entire society should make great efforts to take treatments that aim at special characteristics of crashes.

REFERENCES

Alfonso, M. (2001). "Development of a Potential for Safety Improvement Index Austroads", *Road Safety Audit 2nd Edition*. Sydney, New South Wales, Australia.

De, L.P., Sayed, T. (2002). "Development of a Road Safety Risk Index. In Transportation Research Record", *Journal of the Transportation Research Board 1784*. TRB, National Research Council, Washington, D.C., USA.

Hauer, E., F.M. Council and Y. Mo H. (2004). "Safety Models for Urban Four-Lane Undivided Road Segments". *83rd Annual Meeting of the Transportation Research Board (CD-ROM)*. National Research Council.Washington, D.C., USA.

Li, K.B., Li, S.Y., Qian, H.B. (2007). "Study of the Strategy of Improving Road Traffic Safety", *Transportation Science & Technology*, No. 2, 84-86.

Mao, L.Z., Duan, L.R, Mao, E.R. (2007). "International Comparison Analysis on Road Traffic Safety Factors", *Journal of Transportation Systems Engineering and Information Technology*, No.3, 89-92.

Meng, X. (2008). "On Elements of Influencing Road Traffic Safety". *Journal of Liao Ning Police*, Academy No. 4, 104-105.

Ministry of Public Security (2009). *China Crash Data Annual Report 1990-2009.*China.

[1] According to the Chinese Technical Classification of Highways, highways can be classified into the following five classes: Expressway or freeway, Class I, Class II, Class III and Class IV highways.

Rune, E. (2004). "To what extent is there bias-by-selection? Selection for road safety treatment in Norway". *the 83rd Annual Meeting of the Transportation Research Board (CD-ROM),* National Research Council, Washington, D.C., USA.

Tang, H. (2007). "Measures of Road Safety and evaluation", *Public Security*, No.7, 47-53.

Walmman, C.G., Hastrom, H. (2001). " Friction Measurement Methods and the Correlation Between road Friction and Traffic safety" .*A Literature Review. VTI 911A.* Linkoping, Sweden.

Zhang, W. (2007). "Benefits of Road Safety Facilities", *Journal of Chinese People s Public Security University (Science and Technology),* No.2, 54-57.

Zheng A.W. (2006)."Current Situation and Improvement of Road Traffic Safety in China", *Journal of Wuhan Uni. of Sci. & Tech (Natural Science Edition),* Vol. 29, No. 1, 65-69.

Zhong, L.D., Sun, X.D. (2007). "Characteristics of freeway traffic crash in China". *Proceedings of ICTCT Extra-Workshop*. Beijing, Chin.

Zhong, X.M., Wang, H.Z., Sun, X.D. "Study on New Concepts of Highway Safety Design". *85th Transportation Research Board Annual Meeting (CD-ROM),* National Research Council, Washington, D.C., USA.

Zhang, J.J. (2010). "The Blue Book of Road safety in China 2010". *China communications Press*, 66-85.

Zhong, X.M., Wei, Z.H. (2007). "Traffic Safety Situation and Suggestions of Safety Policy for China". *Proceedings of ICTCT Extra-Workshop*. Beijing,China (CD-ROM*).*

Zhong, X.M., Qi, J. (2008). "Setting speed limits for national and provincial highways". *10th International Conference on Application of Advanced Technologies in Tronsportation (AATT2008, in Athens, Greece) (CD-ROM).* Transportation Research Board, National Research Council, Washington, DC, U.S.A.

Zhong, X.M., Chen, X.M, Wei, Z.H. (2009). "Study on the Rules of Crash Distribution Proceedings of 2009". *International Conference of Chinese Transportation Professionals (ICCTP 2009). ASCE*. Haerbin, China.