Passenger Presence and Injury Severity of Single Vehicle Crashes and Rear-end Crashes with Trucks

Quan YUAN, Shuai JING, Yibing LI

State Key Laboratory of Automotive Safety and Energy, Tsinghua University, Beijing, China E-mail: yuanq@tsinghua.edu.cn

Abstract: Single vehicle crashes and rear-end crashes with trucks are two major types of serious crashes in the roads of China, especially in expressways. In order to identify the influences of passenger presence on the injury severity of these crashes, 200 crash samples from Beijing were used to carry out the statistical analysis and comparative study. Chi-squared test was applied to analyze the significance of the main contributing factors related to the passenger presence in vehicles. The results revealed that driving with passengers had lower mortality than driving solo, especially for the drivers older than 25 years. Two passengers in vehicles appeared to have the lowest mortality in crashes. Male drivers with male passenger(s) had more risk to be involved in a crash than other gender groups. Compared with driving solo, when passengers existing in vehicles, speeding and low visibility increased the likelihood of rear-end crash; younger driver, speeding, suburban area increased the likelihood of single vehicle crash. Speeding was a common significant factor for the two types of crashes, which suggested that drivers with passengers were more liable to drive with over speed. These research findings are hopeful to contribute to crash prevention and injury reduction in future.

Key words: Passenger presence, driver, single vehicle crash, rear-end crash, severity

1 Introduction

China is a developing country with a growing number of vehicles and very high frequency of traffic crashes. Rear-end crashes (REC) and single vehicle crashes (SVC) make up a large proportion of traffic crashes and are usually associated with heavy casualties and property losses. Meanwhile, these two crash types represent main accidents in expressways. In China, the frequency of rear-end crashes is the third highest among various types of vehicle crashes ^[1]. A variety of human, vehicle, road and environmental factors have different impacts on the occurrence of crashes. As an important factor related to traffic safety, passenger presence in vehicles may increase or decrease the risk and severity of crashes. To date, there have been some studies on how the presence of passengers in vehicles affects crashes, which provide insights on the relevant human factors in traffic events.

While a general protective effect of the presence of passengers is found, this is reduced in young drivers, during darkness, in slow traffic and at crossroads, especially when disregarding the right of way and passing a car^[2]. Passengers may also distract drivers in an amount which cannot be compensated for in all situations and by cautious driving.

The presence of two or more passengers, irrespective of the ages of passengers significantly increases the risk of car crash injury among younger drivers^[3].

During the night, driving with a single passenger was associated with approximately half the risk of driver fatal injury relative to driving either solo or with two or more passengers ^[4]. Furthermore, significant differences are likely to exist between night and day. This may be as a result of different passenger effects on driver behavior.

Passenger presence increases crash risk for teenage drivers, especially when the passengers are other teenagers and especially when they are male ^[5]. Teenagers are more susceptible to peer influences than adults. Possible ways to reduce the resulting crash problem include altering the in-vehicle behavior of teenagers or influencing their selection of travel partners. Legal restrictions on passengers with teenage drivers have been found effective in reducing the crash problem.

Distractions were more commonly reported among girls and students attending moderate- to high-income schools ^[6]. Conversation with passengers was the most commonly reported type of distraction. Driving under the influence of alcohol and having had a crash as a driver were both significant predictors of reporting passenger-related distraction.

Speeding substantially increases the likelihood of severe injuries for teenage drivers and their passengers ^[7]. Teenage drivers have an increased likelihood of more severe injuries when distracted by a cell phone or by passengers, than when the source of distraction is an in-vehicle device or inattention. Passengers of teenage drivers are more likely to sustain severe injuries when their driver is distracted by devices or passengers than with a non-distracted or inattentive driver.

Drivers are less likely to be involved in a car collision between two or more cars that result in personal injuries or death when they are accompanied by passengers, regardless of driver or passenger characteristics ^[8].

Strong correlations between passengers and crash characteristics were found to exist ^[9]. Drivers generally have safer driving behavior when they are accompanied by other passengers while more passengers reduce driver's crash potential. Younger driver's crash potential increases with the presence of a younger passenger only. Young drivers with only younger passengers are more likely to be involved in single-vehicle crashes in high-speed and low-volume conditions.

Koppel et al. (2011) used a naturalistic, observational approach to examine if children in vehicles are a significant source of driving distraction ^[10]. Video recordings were analyzed for 92 driving journeys undertaken by 12 families including 25 children and 19 drivers. The results suggest that drivers need to be educated about the potential crash and injury risks associated with both child occupant-related and non-child occupant-related activities while driving their vehicle.

In China, few studies examined the influence of passengers in vehicles on the frequency and severity of crashes. The big data of traffic accidents in China lack of information related to passengers in vehicles involved in crashes. This paper tries to employ crash data to explore the situations of passengers in typical accidents. Using 200 serious rear-end crashes and single vehicle crashes in Beijing, the analysis aimed to identify the factors that are related to the presence of passengers for the two main types of crashes. The results indicated how the passenger factors impact on the injury severity of crashes and provided useful insight for the severity reduction of traffic crashes.

2 Methods

2.1 Crash data

The crash data were extracted from the real-world crash cases analyzed by the Crash Reconstruction Lab of Tsinghua University for the Bureau of Beijing Traffic Security Administration. From 2011 to 2013, about 2000 serious crash cases were investigated, which accounted for about 20% in the total serious crashes occurred in Beijing area. And from these 2000 cases, a random sample of 100 serious rear-end crashes and 100 single vehicle crashes with required information was selected for this research. The Single vehicle crashes (SVC) mainly refer to the collisions between vehicles and road facilities (e.g. trees, poles, barriers, guardrails). All the vehicles involved in SVC were passenger vehicles. Every rear-end crash case contained two vehicles and all the front vehicles are trucks. All types of vehicles are more likely to be involved with serious injury, when in a collision with a large truck. Therefore, this research focus on rear-end crashes involving trucks. Fig. 1, Fig. 2 and Fig. 3 show the characteristic and proportion of selected crash types in this study, which account for about 10% in the total crashes. The main data were obtained from the police records on the crashes, and researchers' detections on the vehicles involved in crashes.



Figure 1 Diagram showing selected characteristics of crash types



Figure 3 Offset crash

2.2 Candidate variables

The in-depth data of crashes included the information of time, driver, passenger, vehicle, road and environment, and was described by 19 variables for each crash (Table 1). The severity levels for occupants involving in crashes were defined as: not injured, injured and fatal.

Туре	Variables	Categories
Time	Time of day	Day(7:00-19:00), night
	Day of week	Weekday, weekend
Drivers	Residence	Beijing (local), other province/city
	Age	\leq 25 years, >25 years
	Gender	Male, female
	Injury	Fatal, injured, not injured
Passengers	Presence	Yes, no
-	Age	\leq 25 years, >25 years
	Gender	Male, female
	Injury	Fatal, injured, not injured
Vehicles	Vehicle type	Commercial vehicle, passenger vehicle
	Crash position	Full frontal crash, offset crash
	Speed	Speeding, not speeding (from crash report)
Environment	Weather	Good (Clear), adverse (cloudy, rain, snow, haze, others)
	Visibility	Day, night(lighting or not)
	Area	Urban, suburban
Road	Road surface	Dry, wet
	Line type	Straight, crossing/exit/entrance
	Road type	Express way, others
	Lanes in the same direction	<3 lanes, ≥ 3 lanes

Table 1. List of main variables related to crashes

2.3 Statistical methods

Based on the crash data, the characteristics of the crashes and the correlation between these factors and injury severity of crashes were examined under the consideration of how many passengers there were in vehicles. The descriptive statistics was carried out to find the relationship between the number, gender and age of passengers in vehicle and the frequency and injury severity of crashes.

Chi-square test can examine the deviation between the observed value and theoretical value, and small chi-square indicates the high consistency. In this paper, chi-square test was used to find out significant variables related to the status of passenger presence in vehicles.

3 Results

3.1 Descriptive statistics

Overall, Table 2 shows that the frequency of driving solo (without other passengers) was much lower than that of driving with passenger(s), 73 vs. 127. On the other hand, the mortality of driving solo exceeded that of driving with passengers, 56% vs. 32%.

	Passenger number in vehicles																	
	0		0 1		2			3			4		>4					
	F	Ι	Ν	F	Ι	Ν	F	Ι	Ν	F	Ι	Ν	F	Ι	Ν	F	Ι	Ν
REC	17	16	3	11	30	5	1	7	1	1	2	0	0	1	0	2	1	2
SVC	24	11	2	15	15	2	2	7	3	2	3	0	5	5	1	2	1	0
Total	41	27	5	26	45	7	3	14	4	3	5	0	5	6	1	4	2	2

Table 2. Driver's injury severity vs. passenger number

Note: F=fatal; I=injured; N=not injured

Fig. 4 shows the Mortality by passenger number for total 200 cases. It can be seen that the mortality is reduced with the increase of passenger number; it gets the lowest point at 2 passenger number and then inversely turns to increase gradually. Therefore two passengers in vehicle present the best situation.



Figure 4. Mortality by passenger number for 200 cases

Table 3 illustrates the driver's injury severity when compared driving solo with driving with passenger(s). For the total cases when crashes occurred, the mortality of driving solo was higher than that of driving with passengers. For the REC, the mortality of driving solo was about twice of driving with passengers (47.2% vs. 23.4%). And for the SVC, the difference of mortality was about 1.6 times higher.

Table 4 shows the different gender of passengers in vehicles, which was divided into 9 different gender groups. For the two types of crashes, solo driving of male driver accounted for 35% and ranked first. Male driver with male passengers accounted for 27% and 33% respectively, which ranked second. Male drivers with male passengers had more proportions than male drivers with female passengers or mixed gender passengers, especially for the SVC.

	Driving solo						Driving with passenger(s)			
	F	Ι	Ν	Total	Mortality	F	Ι	Ν	Total	Mortality
REC	17	16	3	36	47.2%	15	41	8	64	23.4%
SVC	24	11	2	37	64.9%	26	31	6	63	41.3%
Total	41	27	5	73	56.2%	41	72	14	127	32.3%

Table 3. Driver's injury severity compared driving solo with driving with passenger(s)

Gender group type	REC N (%)	SVC N (%)	Total
Male driver/ no passenger	35	35	70
Male driver/ male passenger(s)	27	33	60
Male driver/ female passenger(s)	18	10	28
Male driver/ mixed gender	8	14	22
Male driver/unknown passenger(s)	9	4	13
Female driver/ male passenger(s)	1	1	2
Female driver/ mixed passenger(s)	0	1	1
Female driver/ no passenger	1	2	3
Female driver/ unknown passenger(s)	1	0	1
Total	100	100	200

Table 4. Occupants' gender group by two types of crashes

Table 5. Male driver and passengers with different gender vs. injury severity in fatal crashes

		Rear crash		Single crash		Total
	Fatal (%)	Injured	Fatal (%)	Injured	Fatal (%)	Injured
Male driver/male passenger(s)	17 (63)	10	14	18	31	28
Male driver/female passenger(s)	14 (74)	4	4	6	18	10
Male driver/mixed gender	6 (75)	2	6	8	12	10
Male driver/no passenger	16 (46)	19	23	12	39	31
Total	53	35	47	44	100	79

Table 5 presents the driver's injury severity with different gender group of passengers for male drivers in fatal crashes. Totally, driving solo ranked first and male driver-male passengers appeared second. The two types of crashes had quite different results. Solo driving of male driver accounted for 33% for REC and 49% for SVC. From this result, it can be concluded that driving solo is apt to involve in single vehicle crash. Male driver with male passengers had a larger share than the group involving mixed gender.

Table 6. Driver's age vs. injury severity Note: F=fatal; I=injured; N=not injured

			Driving solo			Drivin	g with pas		
		F	Ι	N	Mortality	F	Ι	Ν	Mortality
	≤25 years	2	5	0	29%	7	5	1	54%
REC	>25 years	15	11	3	52%	8	36	7	16%
	Subtotal	17	16	3	47%	15	41	8	23%
	≤25 years	4	1	1	67%	9	12	2	39%
SVC	>25 years	20	10	1	65%	17	19	4	43%
	Subtotal	24	11	2	65%	26	31	6	41%
	≤25 years	6	6	1	46%	16	17	3	44%
Total	>25 years	35	21	4	58%	25	55	11	27%
	Total	41	27	5	56%	41	72	14	32%

Table 6 shows the different injury severity with different driver's age and number of passengers in vehicles. In REC, for the younger driver (\leq 25 years), driving with passengers had higher mortality than driving solo (54% vs. 29%). However, for the older driver (>25 years), the contrary situation appeared; driving with passengers possessed of lower mortality than driving solo (16% vs. 52%). In SVC, whether younger or older drivers, driving solo resulted in higher mortality than driving with passengers and the differences are close. Totally, for younger drivers, these two situations of passenger presence had similar mortality (46% vs. 44%), while for older drivers, driving solo had higher mortality than driving with passengers (58% vs. 27%).

Fig 5 shows the frequency of total crashes by age and time. It can be seen that in the upper-left of the figure, squares are more than circles, which means crashes involving solo older drivers at night are in the majority. Fig. 6 shows the distribution of fatal crashes by age and time where the numbers of REC (normal triangles) in the upper-left area are more than others. That is to say, older drivers tend to be involved in fatal rear-end crashes when driving solo at night.



Fig. 5 Frequency of total crashes by age vs. time



Fig. 6 Frequency of fatal crashes by age vs. time

3.2 Chi-square test

Based on the data above, descriptive statistics was summarized in Tables 7, 8. Further, Chi-square tests were performed on individual pairs to evaluate the relationship of typical variables with the status of passenger existence. Results

showed that for the REC, vehicle speed, vehicle type, visibility and road surface status were significant factors related to having passenger(s) and no passengers in vehicles. For SVC, driver's age, speeding and crash area were significant factors associated with the passenger carriage situation. For these two types of crashes, speeding was the overlapped significant factor, which revealed that drivers with other passenger(s) were more likely to drive with over speed. However, other variables such as time of day, weather and type of road, were underrepresented in crashes with driving solo or not.

Variables	Categories	Having passenger(s) (%)	No passenger(s) (%)	Chi-squared	p-Value
Time of day	Night (19:00-7:00)	47	25	0.18	0.67
Residence	Other province/city	50	28	0.002	0.97
Drivers' age	Younger driver (<26 years)	13	7	0.01	0.92
Speed	Speeding	42	33	8.33	0.004***
Crash area	Suburban	42	24	0.01	0.92
Crash position	Full frontal	42	19	1.6	0.2
Rear vehicle type	Passenger vehicle	29	18	3.39	0.07**
Weather	Adverse weather	11	8	038	0.54
Visibility	Adverse visibility	27	7	5.31	0.02***
Road line	Crossing/entrance	6	6	1.16	0.28
Road surface	Wet	1	4	4.42	0.04***
Road type	Express way	29	12	1.37	0.24
Day of week	Weekday	51	25	1.33	0.25
Lanes in the same direction	≥3 lanes	31	19	0.17	0.68

Table 7. Data summary of REC

***: statistical significant for 95%, **:statistical significant for 90%

Table 8. Data summary of SVC								
Variables	Categories	Having passenger(s) (%)	No passenger(s) (%)	Chi-squared	p-Value			
Time of day	Night (19:00-7:00)	37	21	0.037	0.847			
Residence	Other province/city	25	11	0.717	0.397			
Drivers' age	Younger driver (<26 years)	24	6	5.31	0.02***			
Speed	Speeding	50	22	4.58	0.03***			
Crash area	Suburban	53	24	4.88	0.027***			
Crash position	Full frontal	29	52	0.26	0.609			
vehicle type	Passenger vehicle	51	32	0.506	0.477			
Weather	Adverse weather	3	11	1.69	0.19			
Visibility	Adverse visibility	20	31	0.22	0.64			
Road line	Crossing/entrance	5	8	0.01	0.907			
Road surface	Wet	10	3	1.24	0.265			
Road type	Express way	6	9	0.07	0.794			
Day of week	Weekday	37	23	0.114	0.735			
Lanes in the same direction	≥3 lanes	8	17	0.3575	0.55			

***: statistical significant for 95%, **:statistical significant for 90%

4 Discussions

The statistical results revealed the characteristics of passengers in these selected crashes, such as gender, age, number, and their corresponding influence on the injury severity of crashes, as well as their relationship with other factors of crashes.

Overall, in the cases, the frequency of driving with passengers was much higher than that of driving solo, which is similar to the research findings of Lam et al. [3]. However, the mortality of driving solo exceeded that of driving with passenger. This means that drivers are less likely to be involved in a fatal crash when they are accompanied by other

passengers, which are in common with the research results of Rueda-Domingo et al. [8]. Furthermore, crash data showed that two passengers except drivers in vehicles constitute the safest situation with lowest mortality when crashes happened.

For these two types of crashes, solo driving of male drivers accounted for 35% and ranked the first. Male drivers with male passengers had the proportions of 27% and 33%, respectively. Male drivers and male passengers in vehicles were involved in more crashes than male drivers with female passengers or passengers with mixed gender. In other words, male drivers with male passengers had higher crash risk, which is consistent with the previous research findings[5].

The analysis of these selected two types of crashes revealed quite different results. Male drivers driving solo accounted for 31% for REC and 49% for SVC. From this result, it can be concluded that solo drivers without passengers' company are likely to be involved in single vehicle crashes, which is inconsistent with other similar studies [9]. Passengers' influence on driving safety is quite different with different countries and traffic culture.

Concerning driver's age, in REC, the older driver (>25 years) driving with passengers caused much lower mortality than driving solo (16% vs. 52%), while the younger driver (\leq 25 years) appeared a contrary situation. In SVC, for all drivers, whether younger or older, driving with passengers had lower mortality than driving solo. Totally, for younger drivers (\leq 25 years), these two situations of passenger presence had similar mortality and for older drivers (>25 years), driving solo had higher mortality than driving with passengers. Therefore, in general, it can be seen that driving with passengers are safer than driving solo, especially for the older drivers (>25 years). Although more passengers in vehicles may cause distraction of drivers, we found a different result that more passengers are safer. Perhaps people drive more carefully when they are accompanied by other related passengers (e.g. family members, important colleagues, etc.).

Chi-square tests showed that for REC, a significantly larger proportion of having passenger(s) and no passengers in vehicles were related to speeding, vehicle type, visibility, road surface status. When there were passengers in vehicles, speeding, bad visibility increased the likelihood of rear-end crash. On the other hand, for SVC driver's age, speeding and crash area were significant factors associated with the passenger carriage status. When there were other passengers in vehicles, younger driver (\leq 25 years), speeding, location (suburban area) increased the likelihood of single vehicle crash. Moreover, speeding was a common factor for the two types of crashes, which revealed that drivers with other passengers were more liable to drive with over speed. Younger drivers with younger passengers were more likely to be involved in SVC in high-speed conditions, which is consistent with Lee and Abdel-Aty [9].

In China, there have been some new related policy and law for the passenger presence in vehicles, such as if trainee drivers will drive cars into the expressway, they should be companied by a skilled driver with at least three years driving experience. Like that, the influence of passengers will be further studied and applied in the improvement of traffic safety.

5 Conclusions

To sum up, this paper demonstrated the influences of passenger presence on injury severity based on the related data of 200 serious rear-end crashes and single vehicle crashes in Beijing, China. The results of research suggest some analytic conclusions as follows.

In general, for the selected crash cases, driving with passengers are safer than driving solo. Two passengers with the driver in vehicles appeared to have the lowest mortality in crashes. For these two crash types, solo drivers are more likely to be involved in single vehicle crashes. Compared with other gender groups, male drivers with male passengers had higher crash risk. And older drivers are likely to be involved in fatal rear-end crashes when driving solo at night.

Compared with driving solo, when there were other occupants in vehicles, speeding and low visibility increased the likelihood of rear-end crash; younger driver, speeding, suburban area increased the likelihood of single vehicle crash. Speeding was a common factor for the two types of crashes. These conclusions may provide useful reference for the research of automotive safety and crash prevention. However, these conclusions are obtained from limited crash samples. In future, more in-depth data analysis and statistics will be carried out, and more insightful results could contribute to the relevant research of traffic safety and injury reduction of occupants.

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