An Investigation on Crash Worthiness of Different Vehicle Brands: A Case Study of Rollover Crashes

Hessam Arefkhani[1], Ali Tavakoli Kashani[2]

Received: 19.06.2017 Accepted: 23.12.2017

Abstract

This study aimed at indexing crash worthiness capability of 20 most frequently used car brands in Iran. Since rollover crashes are one of the most important crash types due to their high impact on crash severity, they were chosen as the case study of the current research. In this regard, the data of 42,118 rollover crashes of urban and rural roads of Iran which occurred from 2009 to 2012 was used. Binomial Logistic Regression Model was applied in order to define crash worthiness index based on the driver's injury status. Although the results revealed that Proton and Hyundai/Light truck had the best performances in rollover crashes, no special trend was found regarding to crash worthiness capability of foreign and Iranian brands. The results of motorcycle rollover crashes were also included for model validation.

Keywords: Rollover crashes, crash worthiness, binomial logistic regression model, vehicle brand, Iranian car brands.

Corresponding author E-mail: alitavakoli@iust.ac.ir
[1] M.Sc. Grad., School of Civil Engineering, Iran University of Science and Technology, Tehran, Iran
[2] Assistant Professor, School of Civil Engineering, Iran University of Science and Technology, Tehran, Iran

1. Introduction and Literature Review

One of the most important types of single vehicle crashes regarding to injury severity risk, is rollover crashes. While rollover crashes make up a small proportion of crashes, they are the reason of a great proportion of crash deaths [Digges and Malliaris, 1998; Liu and Xia, 2015; Naing et al. 2008].

Many factors, which generally fall into three categories of human, vehicle, and road, can affect injury status of an occupant (including driver) in a rollover crash. For instance, fastening seat belt, driver personality (which are the subsets of human factor), secondary safety features of the vehicle, vehicle type, car brand (which are the subsets of vehicle factor), crash type, and road condition (which are the subsets of road factor). There are studies about each one of the affecting factors. For example, in their studies Liu and Xia (2015); Mirzaee Tayeghani et al. (2017); Tavakoli Kashani and Besharati (2016), examined the effect of various human and roadway factors, Helai Huang et al. (2011); H. Huang et al. (2016); H. Huang et al. (2011); Keall and Newstead (2008); Malliaris and Digges (1999); Tavakoli Kashani and Arefkhani (2017b), studied the effects of vehicle type, and Helai Huang et al. (2014); H. Huang et al. (2016); Newstead, et al. (2004); Newstead, et al. (2004); Tavakoli Kashani and Arefkhani (2017a); Fotovati, et al. (2011), investigated the effects of car brand on the injury status of occupants in different crash types [Liu and Xia, 2015; Mirzaee Tayeghani et al. 2017; Tavakoli Kashani and Besharati, 2016; Helai Huang et al. 2011; H. Huang et al. 2016; H. Huang et al. 2011; Keall and Newstead, 2008; Malliaris and Digges, 1999; Tavakoli Kashani and Arefkhani, 2017b; Helai Huang et al. 2014; H. Huang et al. 2016; Newstead, et al. 2004; Newstead, et al. 2004; Tavakoli Kashani and Arefkhani, 2017a; Fotovati, et al. 2011].

In further detail, Fotovati et al. (2011), has conducted a study on evaluating crash severity in rollover crashes in rural roads of Iran. They meant to compare between national and international car brands. They first introduced an index called hazard index (HI) for the estimation of how a car is hazardous in a crash; and then, calculated the mentioned above index for each car brand. In the next stage, the authors tried to find the best statistical distribution which best described the calculated HI for all brands. They finally found out that Orlang distribution is the best. Consequently, they could compare the HI of different brands. The results showed that international brands are better than national brands in case of rollover accidents [Fotovati et al. 2011].

Recently, Huang et al. (2016), have investigated the correlation between vehicle type (different brands), occupant injury and vehicle damage. In order to reach the specified goal, they used a Bayesian bivariate hierarchical ordered logistic model. They compared different car brands by defining two indices: Occupant Protectiveness (OP) and Vehicle Protectiveness (VP). The results showed that Cadillac, Volvo and Lexus are the best and Kia and Saturn are the worst brands regarding to OP and VP [Huang et al. 2016].

As in Table 1, rollover collisions constitute only 4.5 percent of Iran crashes, but they are responsible for approximately 31 percent of drivers' deaths. Thus, studying rollover crashes are of a main concern in Iran. Only a handful of studies dealt with rollover vehicle crashes of Iranian fleet; and among them a number of studies concentrated on rollover crashes and car brands crashworthiness indices simultaneously.

Using the data of Table 1, Table 2 is obtained. In this table crash severity risk defines as the number of dead drivers plus the number of injured drivers over the number of uninjured drivers multiple 100 for each crash type. Clearly, it shows how many drivers are killed or injured for 100 uninjured divers. Considering the fact that rollover crashes are among the crash types with the highest injury severity risk as well as the purpose of this study, merely rollover crashes were included and the relation between different car brands crashworthiness capabilities and driver Injury Status (IS) was investigated. In this regard, crashworthiness index (CWI) for 20 of the most frequently used car brands in Iran was calculated. Then all the brands were compared to a reference brand by their CWI to find out.

Table 1. Descriptive statistics of different crash types

Crash type	No. of dead drivers (% of total dead)	No. of injured drivers (% of total injured)	No. of uninjured drivers (% of total uninjured)	Total (%of total)
Firing	1 (0.03%)	7 (0.01%)	130 (0.02%)	138 (0.02%)
Collision with parked vehicles	8 (0.22%)	252 (0.23%)	1985 (0.25%)	2245 (0.24%)
Multi-vehicle collision	130 (3.64%)	2791 (2.55%)	65587 (8.15%)	68508 (7.47%)
Collision with fixed objects	295 (8.26%)	4217 (3.85%)	39214 (4.88%)	43726 (4.77%)
Motorcycle-vehicle collision	884 (24.74%)	73664 (67.28%)	110020 (13.68%)	184568 (20.12%)
Two-vehicle collision	879 (24.60%)	16049 (14.46%)	535396 (66.57%)	552324 (60.21%)
Animal-vehicle collision	23 (0.64%)	203 (0.19%)	3614 (0.45%)	3840 (0.42%)
Occupant ejection	1 (0.03)	11 (0.01%)	343 (0.04%)	355 (0.04%)
Multi-collision	39 (1.09%)	1174 (1.07%)	7309 (0.91%)	8522 (0.93%)
Run-off road collision	191 (5.35%)	1629 (1.49%)	10185 (1.27%)	12005 (1.31%)
Rollover collision	1122 (31.40%)	9493 (8.67%)	30532 (3.80%)	41147 (4.49%)
Total	3573	109490	804315	917378

Table 2. Crash severity risk for crash types

Crash type	Crash severity risk
Firing	6.2
Collision with parked vehicles	13.1
Multi-vehicle collision	4.5
Collision with fixed objects	11.5
Motorcycle-vehicle collision	67.8
Two-vehicle collision	3.2
Animal-vehicle collision	6.3
Occupant ejection	3.5
Multi-collision	16.6
Run-off road collision	17.9
Rollover collision	34.8
All types of crashes	14.1

whether or not there are any meaningful differences between their crashworthiness capabilities.

On one hand, the literature review reveals that the study of rollover crashes is still an open and continuing issue; and on the other hand, the importance of perusing the rollover crashes in Iran was shown. There is one extra motivation for conducting this research. During the last thirty years, Iran government pursues a policy in the field of car manufacturing industry; that is the limitation of car importation. As a result of this policy, share of Iranian brands or brands which are manufactured inside the country (including passenger cars, buses, trucks and pick-ups) raised to about 80 percent in Iran traffic flow. Due to this fact and the critical conditions of road traffic safety as well, a major controversy has been ensued between Iranian experts, mainly comparing domestic brands with foreign ones.

Some experts argue that domestic brands are the main cause of low-level traffic safety in Iran, while the others believe that there are no meaningful differences between safety capabilities of foreign and domestic brands.
"*Are there any meaningful differences between crashworthiness capability of different vehicle brands in case of a rollover crash?*". With respect to previous paragraphs, the overall objective of this paper is to answer the before mentioned question considering the most prevalently brands of Iranian fleet.
Rest of the paper is organized as follows: section 2 is about crash data preparation and a brief explanation of the methodology. In section 3 results and discussions are presented and finally in section 4 the conclusion of the study is provided.

2. Methodology

2.1 Crash Data

In order to achieve the defining goal of this study, historical crash records of all urban and rural roads of Iran during 2009 through 2012, which contains 1,360,415 crash and 2,407,196 driver records (including all types of crashes), was used. The data were collected from Iran Traffic Police crash database. After cleaning the database, the intended dataset organized with the following considerations:

- Only rollover crashes were included.
- The database was exactly reviewed and only 20 most frequently used vehicle brands (different types of each vehicle brand may be available) plus motorcycles were kept.
- The focus is on the *driver* IS as the seating position of the driver is fixed compare to other vehicle passengers.
- Forasmuch as there are significant differences in injury severity level of females and males in traffic crashes [Ulfarsson and Mannering, 2004], gender of the driver was included in the model as a control variable.
- Area type variable (i.e. rural or urban) as a surrogate factor for the variation of vehicles' mean speeds in rural and urban roads was included in the model. The area type variable is considered as another control variable.

Finally, data filtering yields to a 42,118 crash and driver record dataset.
In Table 3 percentages of vehicle brands and motorcycle in the study dataset as well as the place of manufacturing for each brand have been brought. Peugeot 405, Pride and Peykan (passenger cars and pick-ups) constitute almost 60 % of the dataset brands.
Since the number of Motorcycles w not ignorable, they were also included in the model to see their performances in rollover crashes.

2.2 Model Development

The driver's injury status[1] was considered as a dichotomous dependent variable in this study (code 0= Not Injured and code 1= Injured/Dead); and a Binomial Logistic Regression Model (BLRM) was employed. As a result of data shortage, the authors decided to combine driver's death and injury severity levels and consider them as one level. For some brands, number of dead drivers were too low and this could lead to very low significant levels for those special brands.
Logistic regression is a mathematical modeling approach that can be used to describe the relationship between several independent variables to a dichotomous dependent variable [Gail et al. 2007; Gujarati, 2014].

Using BLRM a relationship between driver's injury status and different brands crashworthiness indices is established.
Logistic function is

$$f(z) = \frac{1}{1+e^{-z}} \quad (1)$$

Table 3. percentages of vehicle brands and motorcycle in the study dataset

Brands	No. of each brand in the crash dataset	% of each brand in the crash dataset	Manufactured in
Peugeot 405[a]	9378	22.27%	Iran[b]
Pride (as reference group)	8905	21.14%	Iran
Peykan/Pick-up truck	3356	7.97%	Iran
Peykan	3305	7.85%	Iran
Mercedes-Benz/Bus, Truck, Minibus	3298	7.83%	Germany
Samand	3066	7.28%	Iran
Motorcycle (different brands)	2786	6.61%	-
Zamiad/Pick-up, Light Truck	2575	6.11%	Iran
Peugeot 206	1219	2.89%	Iran
Renault	982	2.33%	France
Mazda/Pick-up truck	564	1.34%	Japan
Toyota/Pick-up truck	481	1.14%	Japan
Citroen	384	0.91%	France
Hyundai/Light truck	287	0.68%	South Korea
Toyota	256	0.61%	Japan
Nissan	206	0.49%	Japan
Hyundai	167	0.40%	South Korea
Rio	150	0.36%	Iran
Renault/Truck	136	0.32%	France
Sepand	129	0.31%	Iran
Daewoo	127	0.30%	South Korea
Mazda	97	0.23%	Japan
MVM	87	0.21%	China
Mercedes-Benz	51	0.12%	Germany
Kia	40	0.09%	South Korea
Suzuki	31	0.07%	Japan
Proton	28	0.07%	Malaysia
BMW	27	0.06%	Germany
Total	42118	100.00%	

a. By default, passenger car type of the brand unless otherwise stated.

b. According to the Iranian culture and industrial atmosphere of Iran industries, considering some models of a special international brand as a separate brand is logical. Obviously for other international brands, those models that exist in Iran's fleet are of a concern.

If one sets $z = \alpha + \beta_1 X_1 + \beta_2 X_2 + ... + \beta_k X_k$ (X: independent variable, k: index of independent variable) then

$$f(z) = \frac{1}{1+e^{-(\alpha+\sum \beta_i X_i)}} \tag{2}$$

Since the outcome of a logistic function is something between 0 and 1, it could be written as

$$P(result = 1 | X_1, X_2, ..., X_k) = \frac{1}{1+e^{-(\alpha+\sum \beta_i X_i)}} \tag{3}$$

Or

$$P(X) = \frac{1}{1+e^{-(\alpha+\sum\beta_i X_i)}} \quad (4)$$

Where X is a shortcut notation for the collection of variables X_1 through X_k.

Logit transformation, denoted as $logit\, P(X)$ is

$$logit\, P(X) = \ln[\frac{P(X)}{1-P(X)}] \quad . \quad (5)$$

Using some algebra, $logit\, P(X)$ will look like

$$logit\, P(X) = \alpha + \sum \beta_i X_i \quad (6)$$

where $P(X) = \frac{1}{1+e^{-(\alpha+\sum\beta_i X_i)}}$.

It is worth noting that $\frac{P(X)}{1-P(X)}$ = odds of X (the probability of happening over the probability of not happening for X), therefor $logit\, P(X)$ is the *log odds* of X. In a logistic regression model α is the background log odds and β_i shows the change in log odds of its corresponding variable, X_i.

If someone considers a special level of a multilevel independent variable as a reference group, and code it as 0, then all β 's of different levels of that special independent variable represent purely the log odds of their own levels compared to the reference category. Another important topic is that each independent variable contributes to the model by a product form.

For example, suppose that driver age between 25 and 45, and urban crashes are set as reference categories of driver age and area type independent variables, respectively. Then $\beta_{rural} = -0.228$ would mean that the odds of a diver being killed or injured in a rural crash is almost $e^{-0.228} = 0.80$ times of the same crash happens in an urban area. The same is for $\beta_{under 25} = 0.202$; again it means that the odds of an under-25 age driver to be killed or injured in a crash is about $e^{0.202} = 1.22$ times of the same driver to be killed or injured with an age between 25 and 45, keeping all other effective factors fixed. If one wants to check the effects of these two variables on the dependent variable simultaneously, as mentioned before, it would be $e^{-0.228} \times e^{0.202} = 0.80 \times 1.22 = 0.98$ meaning that the odds of an under-25 age driver being killed or injured in a rural crash is nearly 0.98 times of (or approximately the same as) a driver with the age of 25 to 45 being killed or injured in an urban crash, keeping other effective factors constant. For more information please refer to [Gail et al. 2007; Gujarati, 2014].

In summary, in the current study there are four independent variables: vehicle brand, area type, age and gender of driver and one dichotomous dependent variable; that is driver's IS.

2.2.1 Control Variables

Obviously, driver's injury status depends not only to the characteristics of the vehicle, but also to some other factors such as driver's age, driver's gender, speed of the vehicle at the crash moment and so on. Thus, to better identify the effect of vehicle characteristics on driver's IS, other external factors have to be controlled. Considered control variables of this study are summarized in **Error! Reference source not found.**.

2.2.2 Crashworthiness Index

In order to index crashworthiness, the driver's IS for each brand is considered. If the driver of the vehicle is killed or injured, the dependent variable will be set as 1; otherwise it would be 0.

3. Results and Discussion

For indexing crashworthiness of vehicle brands in rollover crashes, a BLRM was run. The results of model running have been shown in the following subsections.

Table 4. Description of control variables

Control variables	Description	Descriptive statistic
Area type	Urban=0 (reference)	Urban:14.2%
	Rural=1	Rural:85.8%
Driver gender	Female=0 (reference)	Female:4.5%
	Male=1	Male:95.5%
Driver age	<19=1	<19:1%
	19-25=4	19-25:14.1
	25-45=0 (reference)	25-45:65.1%
	45-65=2	45-65:18.5%
	>65=3	>65:1.3%

3.1 Crashworthiness of Passenger Car Brands

In **Error! Reference source not found.**, 20 of the most frequently used passenger car brads in Iran sorted according to their performance in rollover crashes.

Base on this table, 12 out of 20 passenger car brands are not significant at 95% level of confidence (significant levels which are in bold) and can be omitted. This could be due to small sample size of these brands.

As can be seen Proton, Samand, and Peugeot 206 are three top passenger car brands, respectively; which means that they have the best performances in rollover crashes rather than the other brands. On the other hand, Sepand, Daewoo, and Peykan are the worst brands, respectively. The odds ratio of Proton as the best brand is almost 0.24 while the odds ratio of Samand as the best Iranian brand is about 0.63. It means that the odds of a Samand driver to be killed or injured in a rollover crash is $\frac{0.63}{0.24} = 2.64$ times of a Proton driver and $1-0.63=0.37$ times or 37% lower than a Pride driver. Having this mind, only three passenger car brands have poorer performances than Pride (i.e., odds ratios of greater than 1). For example, comparing Sepand and Pride car brands, the odds of a Sepand driver being died in a crash could be 1.52 times more than a Pride driver.

3.2 Crashworthiness of Bus, Minibus, Truck, Light truck and Pick-up Brands

Table **6** shows the results of non-passenger car performances in rollover crashes. From this table, it is clear that only one brand is not significant at 95% level of confidence; that is Renault/Truck.

The first place goes to Hyundai/Light truck, surprisingly with an odds ratio of 0.38. With a glance at the table, it will be clear that five of seven non-passenger car brands have better performances than Pride in rollover crashes. Only Peykan/Pick-up truck and Toyota/Pick-up truck have poorer performances than Pride with odds ratios of 1.41 and 1.91, respectively.

3.3 Control Variables

Analysis results of control variables are summarized in

Table **7**. Based on this table, all control variables except driver age 45-65, are significant at 95% level of confidence. Interpretation of these results is the same as previous tables. Male drivers are less prone to death or injury than female drivers in case of a rollover crash. The most dangerous and the safest driving age recognized as under 19 and 25-45, respectively. Considering all types of crashes, driving ages of under 19 and 45-65 were known to be the most dangerous and the safest driving ages according to Table 8; as was seen, under 19 drivers are by far the most dangerous age groups for both rollover and all crash types. It is worth mentioning that driving with the age under 19 is illegal in Iran.

Table 5. Crashworthiness by passenger car brands

Number of vehicles=42118	B	S.E.	Wald	df	Sig.	Exp(B)	95% C.I.for EXP(B)		Rank
							Lower	Upper	
vehicle model (pride (Iran) as reference)			2795.249	27	0.000				
Proton (Malaysia)	-1.437	0.735	3.827	1.000	0.050	0.238	0.056	1.003	1
Suzuki (Japan)	-0.824	0.537	2.357	1.000	**0.125**	0.438	0.153	1.256	2
Mercedes-Benz (Germany)	-0.698	0.408	2.926	1.000	**0.087**	0.498	0.224	1.107	3
Samand (Iran)	-0.467	0.054	74.061	1.000	0.000	0.627	0.563	0.697	4
Kia (South Korea)	-0.457	0.418	1.200	1.000	**0.273**	0.633	0.279	1.435	5
Mazda (Japan)	-0.432	0.269	2.592	1.000	**0.107**	0.649	0.383	1.099	6
Peugeot 206 (Iran)	-0.426	0.079	29.268	1.000	0.000	0.653	0.560	0.762	7
Hyundai (South Korea)	-0.417	0.203	4.208	1.000	0.040	0.659	0.442	0.982	8
Rio (Iran)	-0.234	0.204	1.317	1.000	**0.251**	0.792	0.531	1.180	9
Citroen (France)	-0.212	0.128	2.719	1.000	**0.099**	0.809	0.629	1.041	10
Renault (France)	-0.130	0.081	2.585	1.000	**0.108**	0.878	0.750	1.029	11
Nissan (Japan)	-0.096	0.169	0.321	1.000	**0.571**	0.909	0.652	1.266	12
MVM (China)	-0.095	0.253	0.142	1.000	**0.707**	0.909	0.554	1.493	13
Peugeot 405 (Iran)	-0.063	0.035	3.289	1.000	**0.070**	0.939	0.877	1.005	14
Toyota (Japan)	-0.009	0.148	0.003	1.000	**0.954**	0.992	0.741	1.326	15
Pride (Iran)						1.000			16
Peykan (Iran)	0.168	0.046	13.087	1.000	0.000	1.183	1.080	1.296	17
BMW (Germany)	0.216	0.423	0.260	1.000	**0.610**	1.241	0.541	2.846	18
Daewoo (South Korea)	0.398	0.191	4.364	1.000	0.037	1.489	1.025	2.164	19
Sepand (Iran)	0.417	0.188	4.904	1.000	0.027	1.517	1.049	2.193	20

Table 6. Crashworthiness by vehicle brands (bus, truck, pick-up truck, light truck and minibus)

Number of vehicles=42118	B	S.E.	Wald	df	Sig.	Exp(B)	95% C.I.for EXP(B)		Rank
							Lower	Upper	
vehicle model (pride (Iran) as reference)			2795.249	27	0.000				
Hyundai/Light truck (South Korea)	-0.960	0.195	24.321	1.000	0.000	0.383	0.261	0.561	1
Mercedes-Benz/Truck, Bus, Minibus (Germany)	-0.559	0.055	102.552	1.000	0.000	0.572	0.513	0.637	2
Mazda/Pick-up truck (Japan)	-0.413	0.114	13.067	1.000	0.000	0.662	0.529	0.828	3
Renault/Truck (France)	-0.367	0.227	2.622	1.000	**0.105**	0.693	0.444	1.080	4
Zamiad/ Light Truck, Pick-up truck (Iran)	-0.352	0.057	37.789	1.000	0.000	0.703	0.629	0.787	5
Peykan/Pick-up truck (Iran)	0.342	0.045	57.396	1.000	0.000	1.407	1.288	1.537	6

Toyota/Pick-up truck (Japan)	0.644	0.097	43.672	1.000	0.000	1.905	1.573	2.306	7

3.4 All Together

In order to compare all vehicle brands (including passenger car and non-passenger car brands) together, Table 9 has been created. As it is apparent, the results of motorcycles' crashworthiness have been shown in this table. Considering the fact that motorcycles have the least rider protectiveness compare to other vehicles, the poorest performance regarding to crashworthiness was expected for motorcycles before model running; and this is exactly what has happened. Motorcycles placed at the bottom of the crashworthiness ranking table (odds=10.32). This compatible outcome can verify our model. Based on Table 9 some of the non-passenger car brands (such as Zamiad, Hyundai/Light truck, etc.) have better performances than Pride, a passenger car, in rollover crashes. Although it may seem a little abnormal but can be justified by the driver behavior of these kinds of vehicles, the vehicle's resistance, and lower speed at the crash moment compare to passenger cars. However, this subject needs further research.

4. Summary and Conclusion

Road crashes are one of the remarkable causes of human death across the world and especially in developing countries such as Iran. Among different types of road crashes, rollover crashes are of a main concern; because while they make up a small proportion of crashes, they are responsible for a main part of road fatalities. Therefore, there is indeed a need to study safety impacts of rollover crashes.

Table 7. Control variables of crashworthiness model

Control variables of CW	B	S.E.	Wald	df	Sig.	Exp(B)	95% C.I.for EXP(B)	
							Lower	Upper
Area type (urban as reference)								
rural collisions	-0.222	0.034	43.708	1	0.000	0.801	0.750	0.855
Sex (Female as reference)								
Male	-0.272	0.054	25.365	1	0.000	0.762	0.685	0.847
Age (between 25 and 45 years old as reference)			65.224	4	0.000			
Under 19	0.836	0.136	37.975	1	0.000	2.307	1.769	3.010
19-25	0.171	0.034	25.642	1	0.000	1.186	1.110	1.267
45-65	0.056	0.031	3.225	1	**0.073**	1.058	0.995	1.125
65 and 65+	0.270	0.100	7.285	1	0.007	1.310	1.077	1.593
Constant	-0.724	0.061	140.605	1	0.000	0.485		

Table 8. Crash severity risk for age groups considering all types of crashes

	Under 19	19-25	25-45	45-65	65 and above
No. of dead drivers	183	675	1888	723	104
No. of injured drivers	11419	30446	52918	12894	1809
No. of uninjured drivers	4287	126332	490245	168412	15013
Total	15889	157453	545051	182029	16926
Crash severity risk	270.6	24.6	11.2	8.1	12.7

Table 9. Ranking of vehicle brands which are significant at 95%

Brands	CWI	Ranks
Proton (Malaysia)	0.238	1
Hyundai/Light truck (South Korea)	0.383	2
Mercedes-Benz/Bus, Truck, Minibus (Germany)	0.572	3
Samand (Iran)	0.627	4
Peugeot 206 (Iran)	0.653	5
Hyundai (South Korea)	0.659	6
Mazda/Pick-up truck (Japan)	0.662	7
Zamiad/Pick-up truck, Light Truck (Iran)	0.703	8
Pride (Iran)	1.000	9
Peykan (Iran)	1.183	10
Peykan/Pick-up truck (Iran)	1.407	11
Daewoo (South Korea)	1.489	12
Sepand (Iran)	1.517	13
Toyota/Pick-up truck (Japan)	1.905	14
Motorcycle (different brands)	10.320	15

In this regard, the relation between driver's Injury Status (IS) and crash-worthiness capability of 20 most prevalently used vehicle brands of Iranian fleet was modeled in the current study using Binomial Logistic Regression Model (BLRM). Next, based on the calculated Crash Worthiness Index (CWI) of each brand, their performances in rollover crashes were comparedThe analysis results revealed that Proton (Malaysia) and Hyundai/Light truck (South Korea) were the best and Toyota/pick-up truck (Japan) and Sepand (Iran) were the worst brands in comparison to Pride (Iran) the reference brand. Among Iranian brands, the first place went to Samand with an odds ratio of 0.63.

The results also showed the fact that there might be similar observed patterns between one special type of crash compared to the whole population as was seen for the injury severity risk of different driving age groups.

The findings can be utilized by consumer advocate authorities and NGOs. They can help the public to better decide when purchasing a car through informing them about the CW capability of each car brand. This can also cause car manufacturers to review their product design to keep their competitive advantages in comparison to other competitors.

5. End Notes

1. In the database only three levels of driver's injury status have been defined: dead, injured and not injured.

6. References

-Digges, K. and Malliaris, A. (1998), "Crashworthiness safety features in rollover crashes (No.982296)", USA: SAE (Society of Automotive Engineers) Technical Paper.

-Fotovati, M., Najaf, P. and Habibian, M.. (2011) "evaluating rollover crash severity of foreign and domestic vehicles in urban and rural roads", presented at 6th national congress of civil engineering, Iran. (In Persian)

-Gail, M., Krickeberg, K., Samet, J., Tsiatis, A. and Wong, W. (2007) "Statistics for biology and health", Berlin: Springer.

-Gujarati, D. (2014) "Econometrics by example", Great Britain: Palgrave Macmillan.

-Huang, H., Abdel-Aty, M. and Siddiqui, C. (2011) "Developing crash worthiness index and crash aggressivity index", Paper presented at the Reston, VA: ASCE Proceedings of the First International Conference on Transportation Information and Safety, June 30.

-Huang, H., Hu, S. and Abdel-Aty, M. (2014) "Indexing crash worthiness and crash aggressivity by major car brands", Safety Science, Vol. 62, pp. 339-347.

-Huang, H., Li, C. and Zeng, Q. (2016) "Crash protectiveness to occupant injury and vehicle damage: An investigation on major car brands", Accident Analysis and Prevention, Vol. 86, pp. 129-136.

-Huang, H., Siddiqui, C. and Abdel-Aty, M. (2011) "Indexing crash worthiness and crash aggressivity by vehicle type", Accident Analysis and Prevention, Vol. 43, No. 4, pp. 1364-1370.

-Keall, M. D. and Newstead, S. (2008) "Are SUVs dangerous vehicles?", Accident Analysis and Prevention, Vol. 40, No. 3, pp. 954-963.

-Liu, X. and Xia, J. (2015) "Locally analysing the risk factors for fatal single vehicle crashes hot spots in Western Australia", International Journal of Crashworthiness, Vol. 20, No. 6, pp. 524-534.

-Malliaris, C. and Digges, K. H. (1999) "Crash exposure and crashworthiness of sport utility vehicles (No. 1999-01-0063)", USA: SAE (Society of Automotive Engineers) Technical Paper.

-Mirzaee Tayeghani, M., Saffarzadeh, M. and Asadamraji, M. (2017) "Modeling driver’s hazard perception using driver's personality characteristics", International Journal of Transportation Engineering, Vol. 5, No. 2, pp. 167-182.

-Naing, C. L., Hill, J., Thomson, R., Fagerlind, H., Kelkka, M., Klootwijk, C., Dupre, G.and Bisson, O. (2008) "Single-vehicle collisions in Europe: analysis using real-world and crash-test data", International Journal of Crashworthiness, Vol. 13, No. 2, pp. 219-229.

-Newstead, S. V., Cameron, M. H., and Le Chau, M. (2004) "Vehicle crashworthiness and aggressivity ratings and crashworthiness by year of vehicle manufacture: Victoria and NSW crashes during 1987-2002, Queensland, Western Australia and New Zealand crashes during 1991-2002 (No. 222)", Monash University, Accident Research Centre Reports.

-Newstead, S., Delaney, A., Watson, L. and Cameron, M. (2004) "A model for considering the'total safety'of the light passenger vehicle fleet (No.228)", Monash University, Accident Research Centre Reports.

-Tavakoli Kashani, A. and Arefkhani, H. (2017a) "Indexing crash worthiness, crash aggressivity and total secondary safety for major car brands: A case study of Iran", International Journal of Civil Engineering. doi: 10.1007/s40999-017-0226-3

-Tavakoli Kashani, A. and Arefkhani, H. (2017b) "Indexing crashworthiness for major vehicle brands in rollover crashes: a case study of Iran", Safety Science Monitor, Vol. 20, No. 1, pp. 1-13.

-Tavakoli Kashani, A. and Besharati, M. M. (2016) "An Analysis of Vehicle Occupants’ Injury Severity in Crashes Occurred On Rural Freeways and Multilane Highways in Iran", International Journal of Transportation Engineering, Vol. 4, No. 2, pp. 137-146.

-Ulfarsson, G. F. and Mannering, F. L. (2004) "Differences in male and female injury severities in sport-utility vehicle, minivan, pickup and passenger car accidents", Accident Analysis and Prevention, Vol. 36, No. 2, pp. 135-147.