ORIGINAL ARTICLE DOI: https://doi.org/10.18502/fem.v7i2.12769

Measuring the effect of vehicle safety on road traffic crash severity in Iran: using structural equation modeling

Alireza Zemestani[1], Amir Kavousi[2], Homayoun Sadeghi-Bazargani[3], Hamid Soori[2]*

1. Department of Epidemiology, School of Public Health and Safety, Shahid Beheshti University of Medical Sciences, Tehran. Iran

2. Department of Epidemiology, School of Public Health and Safety, Safety Promotion and Injury Prevention Research Center Shahid Beheshti University of Medical Sciences, Tehran, Iran.

3. Road Traffic Injury Research Center, Tabriz University of Medical Sciences, Tabriz, Iran.

***Corresponding author:** Hamid Soori; **Email:** hsoori@yahoo.com

Published online: 2023-04-25

Abstract: **Objective:** Vehicle safety plays a key role in reducing the number of road traffic deaths and serious injuries. This study aims to investigate the effect of vehicle safety on the severity of traffic crashes in Iran using structural equation modeling (SEM).

Methods: This was a comparative cross-sectional study of all imported vehicles with Aras free trade zone license plate as well as all domestic vehicles (cars produced in Iran) commuting on Tabriz-Jolfa road. The study population included drivers who had accidents on Tabriz-Jolfa road over a period of one year from September 22, 2020 to September 21, 2021 and were injured or their vehicles had been damaged (n=652). Data was collected using set of questionnaires with 10 sections. The effect of independent variables, as exogenous latent variables (human, vehicle, and environmental factors), on a dependent variable, as an endogenous latent variable (crash severity) was measured using SEM. All data were analyzed using Mplus 8.0 software.

Results: In the structure part of the model with foreign vehicles group, the effect sizes of three exogenous variables, i.e., human, environmental, and vehicle factors, on the dependent variables were found to be 0.412, 0.396 and 0.358, respectively. The effect sizes in the model with domestic vehicles were found to be 0.312, 0.702 and 0.820, respectively.

Conclusion: Vehicle factors (variables related to car safety) had a high impact on crash severity in the national license plate and domestically manufactured vehicle group, indicating the necessity of improving vehicle safety.

Keywords: Air Bags; Seat Belts; Structural Equating Modeling; Traffic Accidents

Cite this article as: Zemestani A, Kavousi A, Sadeghi-Bazargani H, Soori H. Measuring the effect of vehicle safety on road traffic crash severity in Iran: using structural equation modeling. Front Emerg Med. 2023;7(2):e17.

1. Introduction

According to the latest report from the world health organization (WHO), published in 2018, more than 1.35 million people annually die due to road traffic crash (RTC) worldwide. RTC is considered the eighth cause of mortality among all age groups in the world and it is also among the major causes of death in countries with low socioeconomic status (1,2). Injuries caused by RTCs lead to the death of children and youth such that it is the first cause of mortality in the age group of 5-29 years (1,3). Iran is among the countries with the highest death rate due to RTCs. According to the WHO estimate, the annual incidence of death due to RTCs is 20.5 cases per 100,000 population in Iran (1).

Low quality of vehicle safety is one of the most important causes of deaths and injuries in RTCs. Improving vehicle safety was among the three important strategies for reducing the number of deaths resulting from RTCs by 50% in Europe from 2010 to 2020 (decade of action) (4,5). Vehicle safety is increasingly critical to accident prevention and plays a key role in reducing the number of deaths and serious injuries due to RTCs (1). Considering the high share of passenger cars in RTCs (6), the government should examine vehicle quality and oblige domestic automobile manufacturers to comply with quality standards of vehicles.

Previous studies have investigated the role of human, environmental, and road factors as well as factors related to vehicle safety and quality on traffic accidents. These studies highlighted the direct and indirect effects of each factor on traffic accidents (7,8).

Severity of injuries and vehicle damage are considered two main indicators of crash severity level. Other factors such as driver's characteristics, road conditions, highway geometry, environmental factors, vehicle type, and roadside objects may also be directly or indirectly associated with crash severity. All of these factors interact in a complex manner, so it is often difficult to distinguish their interrelationships (8).

Statistical methods such as the structural equation modeling (SEM) are commonly used to diagnose and analyze the contribution of human, environmental, road, and vehicle factors to the severity of accidents (8). SEM accounts for complex correlations between endogenous variables, i.e., variables that could be determined by other variables, and exogenous variables, i.e., variables that are simultaneously independent (9). SEM is a common and very powerful multivariate analysis technique from the multivariate regression family. To be more precise, SEM is an extension of the general linear model, which enables the researcher to simultaneously test a set of regression equations and examine the correlation between different variables (10,11). This study aims to measure the effect of vehicle safety on the severity of RTCs using SEM in two groups of cars manufactured inside and outside of Iran and comparing the severity of accidents in these two groups.

2. Methods

2.1. Study design

This was a comparative cross-sectional study. Given the large number of foreign-produced vehicles in Aras free trade zone located in East Azerbaijan province in Iran (Appendix figure 1) and their availability for epidemiologic studies, this area was chosen as the study setting. The sample size was calculated using Schreiber's method (rule of thumb) as well as Trout's theory (12,13). Ten samples were selected for each variable. The statistical population was all drivers of imported vehicles with Aras free trade zone license plate as well as all drivers of domestically-produced vehicles commuting on Tabriz-Jolfa road (Appendix figure 2). The study population included drivers who had accidents on Tabriz-Jolfa road (138 Km) over a period between September 22, 2020 and September 21, 2021 and were injured or damaged their vehicles. Vehicles with national license plate, as the representative of domestic vehicles (cars produced in Iran), were compared with those with Aras free trade zone license plate, as the representative of imported vehicles (cars produced in foreign countries, which are mainly produced in Japan, South Korea, France, Germany, and the United States of America).

2.2. Sampling

The samples were selected from the cars that had the accident outcomes and also from the drivers who had the experience of the accident. Accident outcomes, i.e., whether the outcome was injury to drivers or passengers or damage to drivers' vehicles, were extracted from the reports of East Azerbaijan province traffic police (Rahvar police) and insurance companies for the two groups.

Since all accidents on the Tabriz-Jolfa road are covered by three road police stations on the Tabriz-Marand, Marand-Jolfa, and Jolfa-Marand roads, and all accidents on this road are recorded and collected by these three centers, for the domestically produced cars, first, the list of cars that were involved in an accident was taken from these three centers and also insurance companies in Marand and Jolfa cities. Then, using stratified random sampling based on the price category of the cars, samples were selected from the cars involved in the accident. Due to the fact that the number of cars that crashed in the group of foreign cars were limited, all the cars that crashed in this group during the study period, were included in the study.

2.3. Data collection

A set of questionnaires with 10 sections was first prepared to collect the data. This set included two checklists and eight questionnaires. The first section included items about participants' demographic and general characteristics. The second section contained items about the presence or absence of vehicle safety equipment and whether or not they were used as well as some other technical specifications of the vehicle (Appendix table 1). Sections 3 to 10 included the 60-item NEO five-factor inventory (NEO-FFI) questionnaire (14), Manchester driving behavior questionnaire (MDBQ) (15), attention deficit hyperactivity disorder (ADHD) self-report scale (16), Smits's multidimensional fatigue inventory (MFI) (17), Pittsburgh sleep quality index (PSQI) (18), drivers' distraction assessment questionnaire (19), 6-item Iranian socioeconomic status (SES6) questionnaire (20), and self-made vehicle safety knowledge measurement questionnaire (VSKMQ).

After selecting the samples, the vehicle drivers in the recent accident were contacted. After setting the meeting with these drivers, the questionnaires were completed through interviews. The data recorded by East Azerbaijan province traffic police were used to collect information on traffic violations or driving behavior. Moreover, the data related to accident outcomes (i.e., whether the outcome was injury to drivers or damage to drivers' vehicles) were extracted from the reports of traffic police for the two groups.

The data related to vehicles' technical specifications were extracted from vehicle manuals or automobile company websites.

2.4. Data analysis

In order to control the confounder variables, the vehicles were matched in terms of traffic on Jolfa-Tabriz road by selecting the vehicles that traveled on the road at least twice during the previous year. The respondents who did not answer some questions or the questioner missed asking them some of the questions were contacted again and the missing or unanswered items were completed. To avoid bias, especially information bias, the same questionnaire was used for all participants in the study. The time and place of the interview was left to the choice of the participants. After collecting the data, the completed questionnaires were coded and the final analysis was performed based on the given codes.

Based on the literature review and previous evidence, the studied variables were divided into three categories, namely human, environmental, and vehicle (car) factors. The variables of injury and vehicle damage were entered into the model as the accident severity assessment index (Table 1). Finally, the effect of independent variables on dependent variables was investigated and the effect of the three mentioned factors on crash severity (vehicle damage and injuries) was measured using SEM. T-test and chi-squared test were used for univariate analysis. All data were analyzed using Mplus 8.0 (21) and SPSS.22 software.

2.5. Structural equation modeling

SEM is a statistical technique that can process endogenous and exogenous variables to identify causal relationships between latent or observed variables. This technique manages endogenous and exogenous variables, simultaneously (7,22,23). SEM analysis allows us to investigate complex relationships between independent and dependent variables and integrate factor analysis (measurement model) and structural relationships (structural model) into a coherent model. The possibility of testing theories of relationships between variables is among the main advantages of using SEM. This method also enables the researcher to analyze the data by estimating the measurement error (23,24).

2.6. Model development

In our study, there were 53 observed variables, which were classified into 3 exogenous variables and one endogenous latent variable based on the literature review. Crash severity was considered as an endogenous latent variable, which was measured under the influence of latent (exogenous) variables of human, vehicle and environmental factors. Table 1 in the appendix presents the observed variables constituting latent variables and data of the measured variables. The final model, consisting of one endogenous and three exogenous variables, was developed for foreign and domestic vehicles, separately (Figures 1,2), as well as combination of both groups (Appendix figure 3). Each factor was measured by the observed variables, the validity of which was affected by the random measurement error. All the observed variables were regressed on their respective factors. Finally, four latent factors were found to be correlated, i.e., three latent structures of human, environmental and vehicle factors could affect the latent variable of crash severity.

It should be noted that tire, windshield, anti-lock braking system (ABS), hazard, directional and brake lights, electronic braking system (EBS), and emergency braking assistant (EBA) in foreign vehicles group and traffic role, energy absorbing steering, electronic stability control (ESC), intelligent speed adaptation (ISA), and active rollover protection (ARP) in the domestic vehicles group were removed from their model due to their lack of dispersion within the respective group.

2.7. Model assessment

The following indices or conventional fitting criteria were used to assess the SEM model: Chi-squared statistic (X^2), root mean squared residual (RMSR), root mean squared error of approximation (RMSEA), goodness of fit index (GFI), adjusted goodness of fit index (AGFI), comparative fit index (CFI), normed fit index (NFI), and non-normed fit index (NNFI) or Tucker-Lewis index (TLI). In large samples and real data, the Chi-squared statistic is often significant even when the model fits properly. Therefore, in the SEM models with large sample sizes and real data, Chi-squared as well as other fitting indices are used to assess the model fitting. If GFI, AGFI, CFI, NFI and NNFI values are greater than 0.9, and RMSEA and RMSR values are less than 0.05, the model fit is appropriate and acceptable (7,25).

3. Results

Out of the 700 questionnaires that were distributed, 652 were completed and analyzed (400 questionnaires related to domestic vehicles and 252 related to foreign vehicles). Forty-eight questionnaires that had several incomplete and missing information were excluded from the study. The latent construct, description of variables, and descriptive analysis for the variables are given in the appendix tables 1-3.

Sixty-one percent and 39% of the participants were drivers of domestic and foreign vehicles, respectively. The results indicated that the mean number of violations or infringement and accidents among drivers of foreign vehicles was more than drivers of domestic vehicles (P=0.000). The mean age of domestic and foreign vehicles involved in accidents was 7.75 and 5.27 years, respectively (P=0.000). About 98% of the drivers were male in both groups (P=0.385). Approximately 30% of the accidents in both groups occurred during the official weekend in Iran, Thursday and Friday (P=0.449).

In the structure part of the model with foreign vehicles (model 1), the effect sizes of three exogenous variables, i.e., human, environmental, and vehicle factors, on the dependent variable were 0.412, 0.396, and 0.358, respectively. The effect sizes in the model with domestic vehicles (model 2) were 0.312, 0.702, and 0.820, respectively. This suggests that human and vehicle factors in foreign and domestic vehicles groups were the most significant factors affecting the severity of the crash, respectively (Table 1). Figures 1 and 2 show the effect coefficients of the factors as well as the components of the factors on the severity of the crashes. In these figures, all the coefficients are standardized parameters. The numbers on the arrows and those in parentheses indicate the estimated coefficients and t-value, respectively. In the component part of the factors, the numbers inside the parentheses represent the estimated coefficients. Accordingly, any increase in exogenous variables was accompanied by the possibility of an increase in the endogenous variable (crash severity).

The model measurement sections showed that the latent variable of crash severity in domestic vehicles was somewhat influenced by vehicle damage (0.118), while this coefficient was very low in foreign vehicles (0.005). The variable that provides information about drivers' injuries had a strong and negative effect (-0.674) on accident severity in foreign vehicles, while this coefficient was very low in domestic vehicles (0.010).

Table 1 Model Parameter Estimation of latent Variables

			SEM estimate								
			Foreign vehicles			Domestic vehicles			Total vehicles		
Parameter	**Path direction**	**Latent variable**	**Parameter estimate**	**S.E**	**CR**	**Parameter estimate**	**S.E**	**CR**	**Parameter estimate**	**S.E**	**CR**
Sex	⟵	Human	0.352	0.010	35.20*	0.349	0.007	49.85*	0.420	0.005	84.00*
Age	⟵	Human	0.164	0.445	0.36	-0.262	0.533	-0.49	0.023	0.369	0.06
Infring	⟵	Human	0.025	0.088	0.28	-0.004	0.072	-0.05	0.294	0.059	4.98*
Acnumber	⟵	Human	-0.114	0.056	-2.03*	0.300	0.036	8.33*	0.163	0.031	5.25*
Speed	⟵	Human	0.077	1.376	0.05	0.064	1.170	0.05	0.149	0.893	0.16
Exprnce	⟵	Human	0.781	0.256	3.05*	-0.365	0.405	-0.90	-0.249	0.279	-0.89
License	⟵	Human	0.613	0.339	1.80	-0.417	0.419	-0.99	-0.215	0.292	-0.73
Negscore	⟵	Human	-0.109	0.052	-2.09*	-0.044	0.403	-0.10	-0.099	0.033	-3.00*
Alcohol	⟵	Human	0.123	0.011	11.18*	0.054	0.012	4.50*	0.070	0.008	8.75*
Druguse	⟵	Human	0.027	0.009	3.00*	0.269	0.012	22.41*	0.292	0.008	36.50*
Marital	⟵	Human	-0.267	0.043	-6.20*	-0.132	0.032	-4.12*	-0.228	0.026	-8.76*
Role	⟵	Human	-0.119	0.009	-13.2*	—	—	—	-0.101	0.003	-33.6*
Tripnumb	⟵	Human	-0.174	0.414	-0.42	-0.018	0.142	-0.12	-0.142	0.193	-0.73
Distance	⟵	Human	0.019	1.469	0.01	0.400	1.194	0.33	-0.542	0.932	-0.58
Ownrship	⟵	Human	-0.182	0.018	-10.1*	0.194	0.027	7.18*	-0.904	0.018	-50.2*
NEOFFI	⟵	Human	-0.074	0.799	-0.09	-0.262	0.690	-0.37	-0.049	0.543	-0.09
MDBQ	⟵	Human	0.296	0.698	0.42	0.144	0.605	0.23	0.238	0.504	0.47
ADHD	⟵	Human	0.199	0.404	0.49	0.146	0.381	0.38	0.258	0.289	0.88
MFI	⟵	Human	-0.403	0.375	-1.07	-0.062	0.271	-0.22	-0.355	0.238	-1.49
PSQI	⟵	Human	0.225	0.129	1.74	0.373	0.122	3.05*	0.316	0.093	3.39*
Distract	⟵	Human	0.410	1.174	0.34	0.356	0.804	0.44	0.246	0.754	0.32
SES6	⟵	Human	0.096	0.179	0.53	-0.506	0.103	-4.90*	0.365	0.180	2.02*
Safety	⟵	Human	-0.307	0.629	-0.48	-0.291	0.424	-0.68	-0.647	0.799	-0.80
Time	⟵	Environment	0.236	0.288	0.81	0.118	0.233	0.50	0.127	0.182	0.69
Day	⟵	Environment	-0.121	0.132	-0.91	-0.061	0.102	-0.59	-0.225	0.081	-3.14*
Month	⟵	Environment	0.414	0.219	1.89	0.008	0.148	0.05	0.134	0.122	1.09
Weather	⟵	Environment	-0.441	0.075	-5.88*	0.134	0.057	2.35*	-0.153	0.046	-3.32*
Rodqulty	⟵	Environment	-0.598	0.061	-9.80*	-0.013	0.408	-0.03	-0.287	0.038	-7.55*
Lighting	⟵	Environment	-0.033	0.039	-0.84	0.309	0.309	1.00	0.136	0.028	4.85*
Obstacle	⟵	Environment	0.069	0.159	0.43	0.126	0.114	1.10	0.180	0.093	1.93
Tire	⟵	Vehicle	—	—	—	0.568	0.010	56.8*	0.796	0.006	132.6*
Wiper	⟵	Vehicle	0.184	0.006	30.66*	0.035	0.012	2.91*	0.033	0.008	4.12*
Windshld	⟵	Vehicle	—	—	—	0.044	0.012	3.66*	0.272	0.007	38.85*
Belts	⟵	Vehicle	-0.166	0.036	-4.61*	-0.087	0.025	-3.48*	-0.623	0.021	-29.6*
Carage	⟵	Vehicle	0.109	0.120	0.90	0.229	0.218	1.05	0.414	0.149	2.77*
Length	⟵	Vehicle	-0.107	24.33	-0.004	0.559	17.03	0.03	-0.401	15.26	-0.02
Height	⟵	Vehicle	-0.311	19.06	-0.01	-0.376	2.44	-0.15	-0.531	8.053	-0.06
Width	⟵	Vehicle	0.150	16.92	0.008	0.586	4.51	0.12	0.401	7.828	0.05
Axes	⟵	Vehicle	0.325	17.54	0.018	0.609	6.79	0.08	0.165	8.421	0.01
Steering	⟵	Vehicle	0.551	0.301	1.83	—	—	—	0.672	0.016	42.00*
Hedlight	⟵	Vehicle	-0.126	0.008	-15.7*	-0.122	0.015	-8.13*	-0.270	0.100	-2.70*
Airbag	⟵	Vehicle	-0.952	0.119	-8.00*	-0.284	0.051	-5.56*	-0.909	0.120	-7.57*
ABS	⟵	Vehicle	—	—	—	-0.193	0.044	-4.38*	-0.415	0.029	-14.3*
Hzdlight	⟵	Vehicle	—	—	—	-0.019	0.017	-1.11	-0.279	0.011	-25.3*
Directin	⟵	Vehicle	—	—	—	-0.173	0.014	-12.35*	-0.159	0.008	-19.8*
Brklight	⟵	Vehicle	—	—	—	-.010	0.011	-0.90	-0.209	0.007	-29.8*
EBS	⟵	Vehicle	—	—	—	-0.098	0.048	-2.04*	-0.658	0.038	-17.3*
EBA	⟵	Vehicle	—	—	—	-0.009	0.019	-0.47	-0.950	0.039	-24.3*
ESC	⟵	Vehicle	-0.479	0.058	-8.25*	—	—	—	-0.817	0.035	-23.3*
ISA	⟵	Vehicle	-0.228	0.019	-12.00*	—	—	—	-0.970	0.038	-25.5*
ARP	⟵	Vehicle	-0.624	0.061	-10.22*	—	—	—	-0.563	0.027	-20.8*
Damage	⟵	Severity	0.005	0.031	0.16	0.118	0.035	3.37*	0.177	0.025	7.08*
Injury	⟵	Severity	-0.674	0.048	-14.04*	0.100	0.041	2.43*	0.225	0.031	7.25*
Severity	⟵	Human	0.412	0.033	12.48*	0.312	0.045	6.93*	0.302	0.038	7.94*
Severity	⟵	Environment	0.396	0.051	7.76*	0.702	0.039	18.00*	0.411	0.021	19.57*
Severity	⟵	Car	0.358	0.098	3.65*	0.820	0.021	39.04*	0.513	0.013	39.46*

Table 1 Model Parameter Estimation of latent Variables (continued)

			SEM estimate								
			Foreign vehicles			Domestic vehicles			Total vehicles		
Parameter	**Path direction**	**Latent variable**	**Parameter estimate**	**S.E**	**CR**	**Parameter estimate**	**S.E**	**CR**	**Parameter estimate**	**S.E**	**CR**
			Variance or correlation								
Parameter	**Path direction**	**Latent variable**	**Parameter estimate**	**S.E**	**CR**	**Parameter estimate**	**S.E**	**CR**	**Parameter estimate**	**S.E**	**CR**
Human	⟷	Environment	0.480	0.099	4.84*	0.540	0.052	10.38*	-0.823	0.041	-20.0*
Human	⟷	Vehicle	0.652	0.098	6.65*	0.521	0.061	8.54*	-0.329	0.034	-9.67*
Environment	⟷	Vehicle	0.057	0.036	1.58	-0.182	0.077	-2.36*	0.553	0.045	12.31*

SEM: Structural equation modeling; SE: Standard error; CR: Critical ratio; —— : Incalculable due to the removal of the variable from the model

* Parameter estimates are significantly different from zero. All variables are described in appendix table 1

The critical ratio is a ratio of the parameter estimate to the standard error and on the basis of a probability level of .05, if the critical ratio was found to be more than +1.96 or less than -1.96, the parameter was considered significant.

*One-person study rescuing.

Table 2 SEM models' performance

Fitting index	SEM models			**Criteria of acceptable fit**
	Model 1	**Model 2**	**Model 3**	
Number of variables	45	48	53	——
Chi-squared	139.833	49.689	78.67	Smaller value
Degree of freedom (df)	45	48	53	——
P-value	0.0000	0.0037	0.0014	——
X^2/df	3.107	1.035	1.480	1-5
Root mean square error of approximation (RMSEA)	0.041	0.021	0.034	< 0.05
Standardized root mean square residual (SRMR)	0.024	0.011	0.010	< 0.05
Tucker–Lewis index (TLI)	0.920	0.938	0.965	> 0.9
Comparative fit index (CFI)	0.901	0.941	0.958	> 0.9

SEM: Structural equation modeling; Model 1: Model with foreign vehicles; Model 2: Model with domestic vehicles; Model 3: Model with total vehicles

In model 1, airbag was strongly and negatively correlated with vehicle factor (-0.952), while distance between the two vehicle axles was moderately and positively correlated (0.325), and energy absorbing steering wheel was strongly and positively correlated (0.551) with vehicle factor. Moreover, there was a moderate and negative correlation between vehicle height and electronic stability control (ESC), and vehicle factor (-0.311 and -0.479, respectively). In model 2, variables of tires (0.568), vehicle length (0.559), vehicle width (0.586), and distance between two axles (0.609) were strongly and positively correlated with vehicle factor, while vehicle height was moderately and negatively correlated with vehicle factor (-0.376).

The results of the latent variables of human and environmental factors are given in the tables and figures of the main text and the appendix.

3.1. Model fitting

In this study the X^2 values were found to be 139.83, 49.68, and 78.67 with 45, 48, and 53 degrees of freedom in the first, second, and third models, respectively (P<0.05). RMSEA and SRMR were less than 0.05 in all three models, indicating good fitting of all three models. Moreover, TLI and CFI were close to 1 in all three models. Considering that the value greater than 0.9 represents model fit, these indices showed good fitting of data with the hypothetical models (Table 2).

4. Discussion

SEM latent variables and constructs consist of two components: a structural component that specifies the structural relationships between latent variables, and a measurement model that defines the relationship between latent and observed variables (24,26). Latent and observed variables are the two basic concepts in statistical analysis, especially factor analysis and SEM. Latent variables, known as exogenous variables, are variables that could not be directly measured. Therefore, researchers use the observed criteria or items that constitute the questionnaire items to measure latent variables (26).

Transportation researchers have recently used SEM to analyze driving behavior questionnaires (22,27). Regardless of difference between methods used in studies on traffic accidents, injury severity of occupants could not be employed as a valid variable to investigate accident or crash severity. This is because vehicle safety design could better protect passengers by preventing the penetration of force and pressure into the passenger compartment and cabin, and the reported

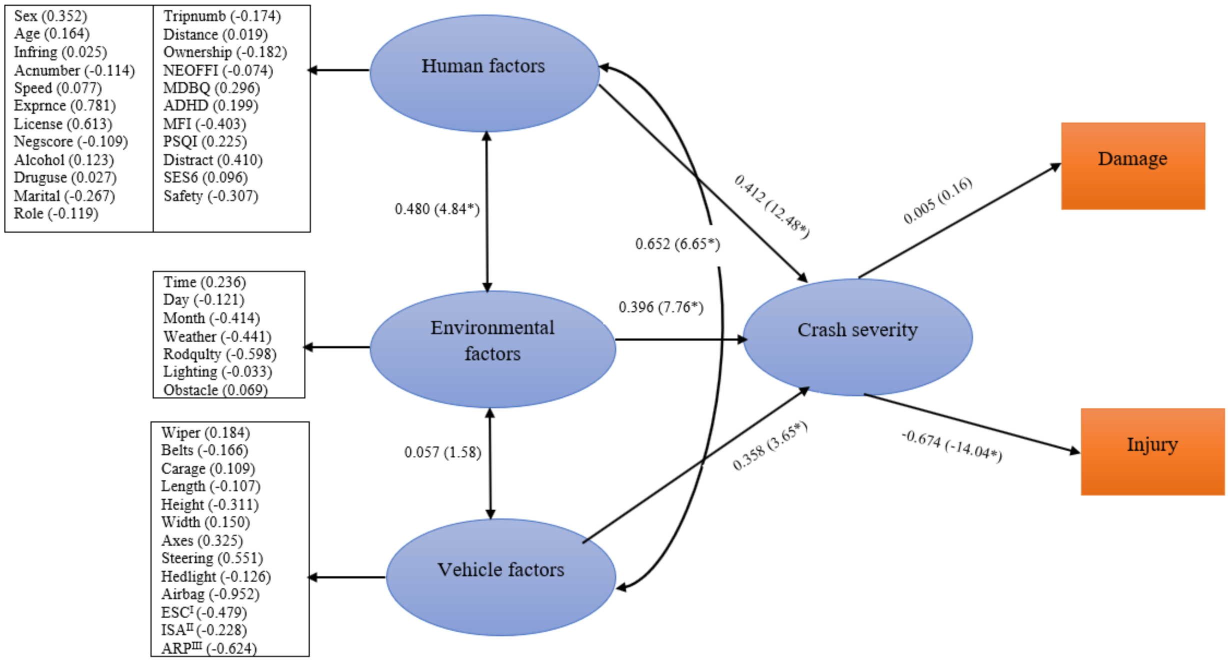


Figure 1 Structured equations model with data of foreign vehicles
The numbers on the arrows and those in the parentheses indicate the estimated coefficients and t-value, respectively, and in the component part of the factors, the numbers inside the parentheses represent the estimated coefficients.
I. Electronic stability control; II Intelligent speed adaptation; III. Active rollover protection

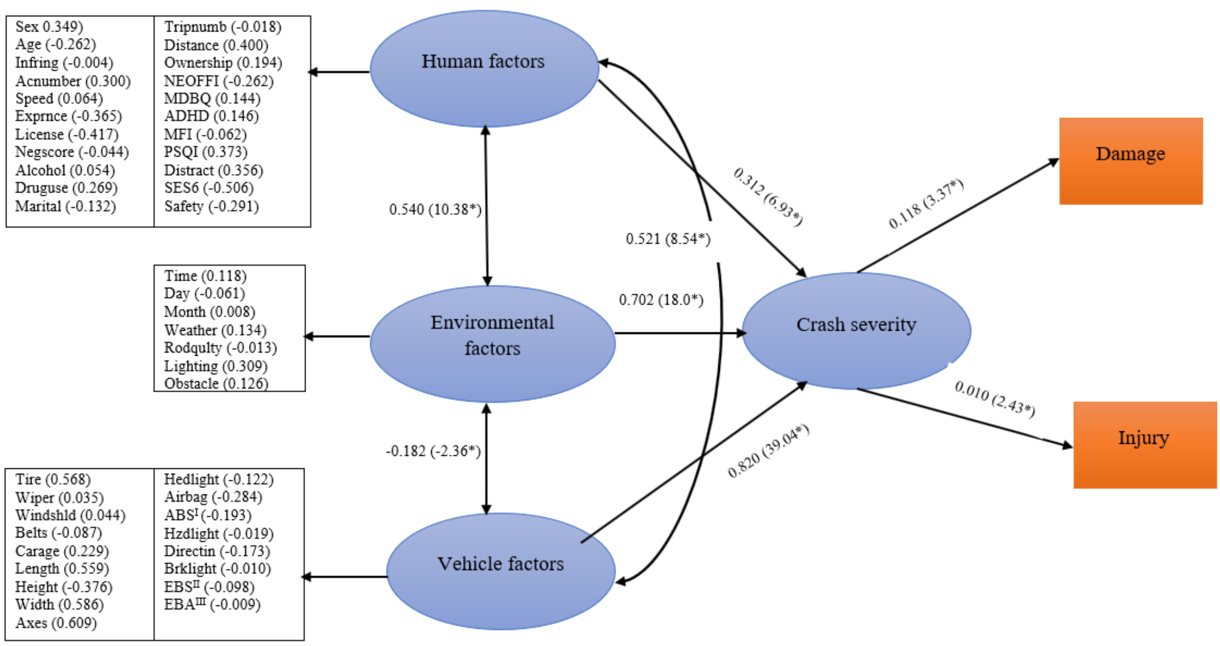


Figure 2 Structured equations model with data of domestic vehicles
The numbers on the arrows and those in the parentheses indicate the estimated coefficients and t-value, respectively, and in the component part of the factors, the numbers inside the parentheses represent the estimated coefficients.
I. Anti-lock braking system, II. Electronic braking system, III. Emergency braking assistant

damage severity could be biased under the influence of accident victims' description, complaints, and responses. Thus, most researchers use vehicle damage as an indicator of crash severity or combine vehicle damage with injury severity (7).

In the present study, a combination of observed variables (vehicle damage and driver injury) were used as indicators of the latent variable of crash severity.

Among the components of the vehicle factor related to vehicle safety as a latent variable in both groups, windshield wipers, vehicle headlights, and vehicle age in foreign vehicles group, and windshield and tires in the domestic vehicles group were indirectly correlated with crash severity. Using tires, windshield wipers, windshield, and headlights of high quality and fastening the seat belt reduced crash severity. Increase in the vehicle age increased crash severity in both groups, which was probably due to greater caution of drivers with new vehicles as well as wear and tear of old vehicles and their lack of safety. This finding was in line with studies conducted in Ethiopia and Nepal (24,28,29).

Vehicle length had a negative and indirect effect on crash severity in foreign vehicles group, while this variable had a positive and indirect effect on crash severity in the domestic vehicles group. Thus, longer vehicles had less and more severe accidents in foreign and domestic groups, respectively. Vehicle height had a negative and indirect effect on crash severity in both groups. Thus, increase in the vehicle height decreased accident severity, probably due to drivers' better view, sufficient mastery, and vehicle timely control. Vehicle width and distance between two axles were positively and indirectly correlated with crash severity in both groups. The greater the vehicle width and distance between the two axles, the higher the crash severity.

Having an energy-absorbing steering wheel had a positive and indirect effect on crash severity in foreign vehicles group. Crash severity was higher among vehicles that did not have an energy-absorbing steering wheel. Various studies have reported the effect of airbag on reducing crash severity and accident deaths (30). The present study indicated that the number of vehicle airbags, had an indirect effect on crash severity. Increase in the number of airbags decreased crash severity. This finding has been confirmed in some previous studies emphasizing the existence of side airbags in vehicles (31). Having intact ABS, hazard light, directional light, brake, EBS, and EBA was negatively and indirectly correlated with crash severity in the domestic vehicles group. Thus, having such facilities reduced crash severity in this group. Moreover, having ESC, ISA, and ARP was negatively and indirectly correlated with crash severity in foreign vehicles group, i.e., these three technologies reduced crash severity in this group.

The latent variable of crash severity was directly and positively correlated with injury and vehicle damage in the domestic vehicles group, so that increase in crash severity in this group increased vehicle damage as well as driver and passenger injuries. This finding was consistent with that of Kim et al. (25). Injury severity had a direct and positive effect on vehicle damage in foreign vehicles group, while it had an inverse effect on driver and passenger injuries. Thus, severe accidents led to fewer injuries in this group, which was probably due to safety mechanisms such as airbags that work better in severe crashes.

In the structural section of the models, the latent variable of human factor had the greatest impact on crash severity in foreign vehicles group, indicating driver injury and vehicle damage. The environmental factor had a positive effect on crash severity. These results were consistent with those of Lee et al. and Kim et al. (8,25). The vehicle factor had a positive effect on crash severity. In the domestic vehicles group, the vehicle and human factors had the maximum and minimum impacts on accident severity, respectively, indicating vehicle problems in domestic vehicles had a significant impact on crash severity. In the group consisting of both types of vehicles, the vehicle and human factors had the maximum and minimum impacts on accident severity.

In foreign vehicles group, although vehicle and environmental factors were important, managing human factors could have a greater effect on reducing crash severity. In the domestic vehicles group, while human and environmental factors were important, improving vehicle safety could greatly reduce accident severity. In the structural section of models, since human, environmental, and vehicle factors were latent variables, their values were not directly calculated. However, these values could be useful and informative because standard parameters were used.

5. Conclusion

Vehicle factor had a high impact on crash severity in the national license plate and domestically-manufactured vehicle group, indicating the necessity of improving vehicle safety. Further use of this method could support modification of SEM technique in the study of traffic safety and provide a basis for confirmatory and comparative analyses.

6. Declarations

6.1. Acknowledgement

We would like to appreciate the vice-chancellor for research and technology of Shahid Beheshti University of Medical Sciences, Traffic Research Center of Tabriz University of Medical Sciences and all professors and participants for their cooperation in conducting the research.

6.2. Authors' contribution

Contribution to conception and study design: AZ, HS; data collection and data analysis: AZ, HSB, AK; drafting of manuscript: AZ, HSB; discussing and appraising context of manuscript: AZ, HS, HSB; approval of the final version: AZ, HS, AK, HSB.

6.3. Conflict of interest

There is no conflict of interest.

6.4. Funding

Funds have not been received from any organization.

6.5. Ethical consideration

This paper is a part of a PhD dissertation in epidemiology approved by Ethics Committee of Shahid Beheshti University of Medical Sciences in 2021 with reference number of

IR.SBMU.PHNS.REC.1399.126.

References

1. Global status report on road safety 2018. Geneva: World Health Organization,2018. Licence: CC BY-NC-SA 3.0 IGO.
2. Zampetti R, Messina G, Quercioli C, Vencia F, Genco L, Di Bartolomeo L, et al. Nonfatal road traffic injuries: can road safety campaigns prevent hazardous behavior? an Italian experience. Traffic Inj Prev. 2013;14(3):261-6.
3. Ozanne-Smith J, Schaumann JL, Oxley J. Injuries in adolescents: the public health response. International handbook on adolescent health and development. 2017:71-92.
4. World Health Organization. Global status report on road safety 2015. Geneva: World Health Organization; 2015.
5. Ameratunga S, Hijar M, Norton R. Road-traffic injuries: confronting disparities to address a global-health problem. Lancet. 2006;367(9521):1533-40.
6. Road safety statistics at regional level. Eurostat statistics explained. Available in: ec.eropa.eu/eurostat/statistics-explained/index.php?title=Archive:Road_safety_statistics_at_regional_level.
7. Wang K, Qin X. Use of structural equation modeling to measure severity of single-vehicle crashes. Transp Res Rec. 2014;2432:17-25.
8. Lee JY, Chung JH, Son B. Analysis of traffic accident size for Korean highway using structural equation models. Accid Anal Prev. 2008;40(6):1955-63.
9. Golob TF. Structural equation modeling for travel behavior research. Transp. Res. B: Methodol. 2003;37(1):1-25.
10. Hoyle RH. Handbook of structural equation modeling: The Guilford Press ;2012.
11. Kline RB. Principles and practice of structural equation modeling, 3^{rd} ed.The Guilford Press; 2011.
12. De Pelsmacker P, Janssens W. The effect of norms, attitudes and habits on speeding behavior: scale development and model building and estimation. Accid Anal Prev. 2007;39(1):6-15.
13. De Pelsmacker P, Janssens W. The effect of norms, attitudes and habits on speeding behavior: scale development and model building and estimation. Accid Anal Prev. 2007;39(1):6-15.
14. Costa PT, McCrae RR (1992). Revised NEO personality inventory (NEO-PIR) and NEO five-factor inventory (NEO-FFI) professional manual. Odessa, FL: psychological assessment resources.
15. Alavi SS, Mohammadi M, Soori H, Mohammadi Kalhori S, Sepasi N, Khodakarami R, et al. Iranian version of Manchester driving behavior questionnaire (MDBQ): psychometric properties. Iran J psychiatry. 2016;11(1):37-42.
16. Daigre Blanco C, Ramos-Quiroga JA, Valero S, Bosch R, Roncero C, Gonxalvo B, et al. Adult ADHD self-report scale (ASRS-v1. 1) symptom checklist in patients with substance use disorders. Actas Esp Psiquiatr. 2009;37(6):299-305.
17. Shahid A, Wilkinson K, Marcu S, Shapiro CM. Multidimensional fatigue inventory (MFI). STOP, THAT and One Hundred Other Sleep Scales: Springer Science & Business Media; 2012.
18. Buysse DJ, Reynolds CF 3rd, Monk TH, Berman SR, Kupfer DJ. The Pittsburgh sleep quality index: a new instrument for psychiatric practice and research. Psychiatry res. 1989;28(2):193-213.
19. Shiri P, Soori H, Hashemi-Nazari SS. Study of most important factors of voluntary engagement in distraction and susceptibility to involuntary distraction related to road traffic injuries. J Saf Promot Inj Prev. 2019;7(1). [Persian].
20. Abobakri O, Sadeghi-Bazargani H, Asghari-Jafarabadi M, Aghdam MB, Imani A, Tabrizi J, et al. Development and psychometric evaluation of a socioeconomic status questionnaire for urban households (SESIran): the preliminary version. Health Promot Perspec. 2016;5(4):250-60.
21. Muthén LK, Muthen BO (1998-2017). Mplus user's guide: statistical analysis with latent variables, Eighth Ed. Los Angeles, CA: Muthén & Muthén; 2017.
22. Hassan H, Abdel-Aty M. Analysis of drivers' behavior under reduced visibility conditions using a structural equation modeling approach. Transp Res F: Traffic Psychol Behav. 2011;14:614-25.
23. Kupek E. Beyond logistic regression: structural equations modelling for binary variables and its application to investigating unobserved confounders. BMC Med Res Methodol. 2006;6:13.
24. Shaaban K, Gaweesh S, Ahmed MM. Investigating in-vehicle distracting activities and crash risks for young drivers using structural equation modeling. PLoS One. 2020;15(7):e0235325.
25. Kim K, Pant P, Yamashita E. Measuring influence of accessibility on accident severity with structural equation modeling. Transportation research record. 2011;2236:1-10.
26. Sheykhfard A, Haghighi F, Nordfjærn T, Soltaninejad M. Structural equation modelling of potential risk factors for pedestrian accidents in rural and urban roads. Int J Inj Contr Saf Promot. 2021;28(1):46-57.
27. Al Reesi H, Al Maniri A, Plankermann K, Al Hinai M, Al Adawi S, Davey J, et al. Risky driving behavior among university students and staff in the Sultanate of Oman. Accid Anal Prev. 2013;58:1-9.
28. Akloweg Y, Hayshi Y, Kato H. The effect of used cars on African road traffic accidents: a case study of Addis Ababa, Ethiopia. Int J Urban Sci. 2011;15(1):61-9.
29. Mishra B, Sinha ND, Sukhla S, Sinha A. Epidemiological study of road traffic accident cases from Western Nepal. Indian J Community Med. 2010;35(1):115-21.
30. Cummings P, McKnight B, Rivara FP, Grossman DC. Association of driver air bags with driver fatality: a matched

cohort study. BMJ. 2002;324(7346):1119-22.

31. Braver ER, Kyrychenko SY. Efficacy of side air bags in reducing driver deaths in driver-side collisions. Am J Epidemiol. 2004;159(6):556-64.

Appendix 1 Latent construct and description of variables

Variable (component)	Description	Description and coding of input value
	Human factors	
Sex	Gender	1=male, 2=female
Age	Age	Continuous scaled variable
Infring	Number of infringements over the past year	Continuous scaled variable
Acnumber	Number of accidents over the past year	Continuous scaled variable
Speed	Speed of the car in a recent accident	Continuous scaled variable
Exprnce	Number of years of driving experience	Continuous scaled variable
License	Number of years the driver has had a valid driver's licenses	Continuous scaled variable
Negscore	Number of negative scores in a recent year	Continuous scaled variable
Alcohol	Alcohol consumption (use of alcohol in recent accident)	1=yes, 2=no
Druguse	Use of drugs in recent accident	1= yes, 2=no
Marital	Marital status	1=married, 2=single, 3=divorced, 4=whose spouse has died
Role	Traffic role of the individual in recent accident	1=driver, 2=passenger
Tripnumb	Number of trips on Tabriz-Jolfa route during the last year	Continuous scaled variable
Distance	Distance traveled from the point of departure to the point of accident (km)	Continuous scaled variable
Ownrship	Car ownership status	1=owner, 2=rental, 3=loan, 4=stolen
NEOFFI	NEO-five-factor inventory (FFI) questionnaire	Continuous scaled variable (0-240)
MDBQ	Manchester driving behavioral questionnaire	Continuous scaled variable (0-90)
ADHD	Attention-deficit hyperactivity disorder questionnaire	Continuous scaled variable (0-72)
MFI	Multidimensional fatigue inventory questionnaire	Continuous scaled variable (20-100)
PSQI	Pittsburgh sleep quality index	Continuous scaled variable (0-21)
Distract	Distraction (engagement)	Continuous scaled variable (0-156)
SES6	Socio economic status (6-question)	Continuous scaled variable (4-27)
Safety	Vehicle safety knowledge measurement questionnaire (VSKMQ)	Continuous scaled variable (0-117)
	Environmental factors	
Time	Time of accident (hours)	1=24-6, 2=6-12, 3=12-18, 4=18-24
Day	Accident day (days of the week)	1=Saturday, Sunday, Monday, Tuesday, Wednesday, 2=Thursday, Friday (weekend)
Month	The month of the accident	1=High-traffic months (March, April, and September) 2= Low-traffic months (January, February, May, June, July, August, October, November, and December)
Weather	Weather conditions on the day of the accident	1=sunny, 2=snowy, 3=rainy, 4=windy, 5=foggy, 6=sleet, 7=hail
Rodqulty	Road quality condition on the day of the accident	1=dry, 2=snowy, 3=damp and rainy, 4=glacial, 5=covered by accident debris or oily
Lighting	Air lighting in the event of an accident	1=darkness of night, 2=daylight, 3=sunrise or sunset, 4=night with spotlight
Obstacle	Dealing with an obstacle (existence or collision with an obstacle during an accident)	1=no, 2=traffic sign, 3=guardrails, 4=obstacle in the middle of the road, 5=tree, 6=ditch,7=falling from the bridge, 8=others (animal, bike, pedestrian)
	Vehicle factors	
Tire	Quality of car tires before the accident	1=yes, 2=no
Wiper	Quality of car wipers before the accident	1=yes, 2=no
Windshld	Quality of car windshields before the accident	1=yes, 2=no
Belts	Having or not having a seat belt as well as using or not using a seat belt	1=no seat belt, 2=has a seat belt but the driver did not use it, 3=has a seat belt and seat belt was used by the driver
Carage	How many years have passed since the production of the car?	Continuous scaled variable
Length	Car length (mm)	Continuous scaled variable
Height	Car height (mm)	Continuous scaled variable
Width	The distance between the wheels (mm)	Continuous scaled variable
Axes	The distance between the axes (mm)	Continuous scaled variable
Steering	Having an energy-absorbing steering column	1=yes, 2=no
Hedlight	Having headlights and if they were intact or damaged	1=no, 2=yes-damaged, 3=yes-intact
Aairbag	Having an airbag	0=no airbag, 1=1 airbag, 2=2 airbags, 3=3 airbags, 4=4 airbags, 5=5 airbags, 6=6 airbags, 7=more than 6 airbags
ABS	Having anti-lock brakes system and its condition	1=no, 2=yes-damaged, 3=yes-intact
Hzdlight	Having hazard lights and their condition	1=no, 2=yes-damaged, 3=yes-intact
Directin	Having signal lights or directional signals and their condition	1=no, 2=yes-damaged, 3=yes-intact
Brklight	Having brake light and its condition	1=no, 2=yes-damaged, 3=yes-intact

Appendix 1 Latent construct and description of variables (continued)

Variable (component)	Description	Description and coding of input value
EBS	Having electronic braking system and its condition	1=no, 2=yes-damaged, 3=yes-intact
EBA	Having emergency brake assist (autonomous emergency brake) and its condition	1=no, 2=yes-damaged, 3=yes-intact
ESC	Having electronic stability control and its condition	1=no, 2=yes-damaged, 3=yes-intact
ISA	Having intelligent speed adaptation and its condition	1=no, 2=yes-damaged, 3=yes-intact
ARP	Having active rollover protection and its condition	1=no, 2=yes-damaged, 3=yes-intact
	Crash severity	
Damage	Damage to car	1=no damage, 2=light or superficial, 3=moderate damage, 4=severe or heavy damage, 5= total damage
Injury	Injury of driver (KABCO scale)	1=no injury, 2=possible injury, 3=evident injury, 4=disability, 5=death

Appendix 2 Sample descriptive analysis (continuous scaled variables)

Variable	Components	Foreign vehicles				Domestic vehicles				P-value	Total			
		N	Percent	Mean	Median	N	Percent	Mean	Median		N	Percent	Mean	Median
Age		252	100	40.19	40.00	400	100	40.11	38.00	0.909	652	100		
Infringement number	0	11	4.4			52	13				63	9.6		
	1	18	7.1			76	19				94	14.4		
	2	54	21.4			110	27.5				164	25.2		
	3	78	31	3.00	3.00	120	30	2.10	2.00	0.000	198	30.4	2.50	3.00
	4	48	19			28	7				76	11.7		
	5	33	13.1			1	0.3				34	5.2		
	6	10	4			1	0.3				11	1.7		
	7	0	0			12	3				12	1.8		
	Sum	252	100			400	100				652	100		
Accident number	0	15	6			13	3.3				28	4.3		
	1	104	41.3			230	57.5				334	51.3		
	2	96	38.1	1.60	2.00	123	30.8	1.40	1.00	0.002	219	33.6	1.50	1.00
	3	28	11.1			31	7.8				59	9.0		
	4	9	3.6			3	0.8				12	1.8		
	Sum	252	100			400	100				652	100		
Speed		252	100	89.90	90.00	400	100	91.10	95.00	0.512	652	100	90.60	90.00
Experience		252	100	9.41	9.00	400	100	13.50	11.50	0.000	652	100	11.90	10.00
License		252	100	12.87	12.00	400	100	15.40	14.00	0.000	652	100	14.40	12.00
Negative scores	0	245	97.2			372	93				617	94.6		
	1	0	0			10	2.5				10	1.5		
	2	0	0	0.14	0.00	7	1.8	0.20	0.00	0.391	7	1.1	0.17	0.00
	5	7	2.8			11	2.8				18	2.8		
	Sum	252	100			400	100				652	100		
Time		252	100	14.58	15.50	400	100	15.4	15.00	0.028	652	100	15.08	15.00
Car age		252	100	5.27	5.00	400	100	7.75	7.00	0.000	652	100	6.79	6.00
Trip number		252	100	7.32	5.00	400	100	3.94	3.00	0.000	652	100	5.25	4.00
Distance		252	100	43.00	40.00	400	100	37.53	30.00	0.004	652	100	39.65	35.00
Length		252	100	4525.4	4535.5	400	100	4212.6	4345.0	0.000	652	100	4333.5	4408.0
Height		252	100	1604.4	1565.0	400	100	1452.3	1455.0	0.000	652	100	1511.1	1460.0
Width		252	100	1869.5	1834.0	400	100	1696.0	1694.0	0.000	652	100	1763.0	1720.0
Axes distance		252	100	2686.5	2700.0	400	100	2541.2	2600.0	0.000	652	100	2597.4	2670.0
NEOFFI		252	100	126.24	123.50	400	100	133.78	134.50	0.000	652	100	130.87	130.0
MDBQ		252	100	49.68	50.00	400	100	38.72	39.00	0.000	652	100	42.96	44.00
ADHD		252	100	16.35	15.00	400	100	19.91	20.00	0.000	652	100	18.53	19.00
MFI		252	100	50.32	51.00	400	100	54.95	54.00	0.000	652	100	53.16	54.00
PSQI		252	100	4.54	5.00	400	100	5.78	6.00	0.000	652	100	5.30	5.00
Distraction		252	100	49.69	49.00	400	100	67.90	72.00	0.000	652	100	60.86	64.00
SES6		252	100	20.74	21.29	400	100	12.66	12.32	0.000	652	100	15.78	14.28
Safety		252	100	94.47	96.00	400	100	56.97	56.00	0.000	652	100	71.46	61.00

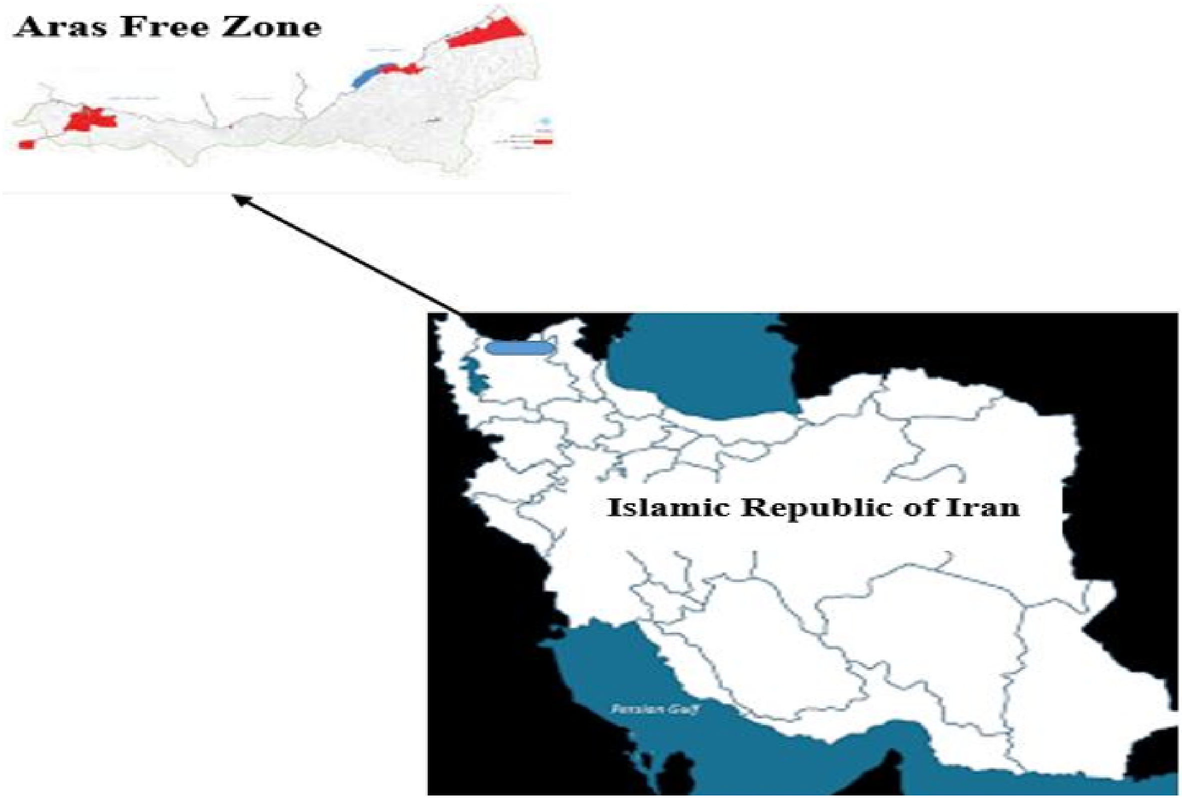
N: Number

Appendix 3 Sample descriptive analysis (ordinal scaled variables)

Variable	Components	Foreign vehicles		Domestic vehicles		P-value	Total	
		Number	Percent	Number	Percent		Number	Percent
Sex	1=male	246	97.6	393	98.2	0.385	639	98
	2=female	6	2.4	7	1.8		13	2
Day	1=non-weekend days (Saturday, Sunday, Monday, Tuesday, Wednesday)	171	67.8	288	72	0.446	107	70.4
	2=Weekend (Thursday, Friday)	81	32.2	112	28		193	29.6
Month	1=high-traffic months (March, April, and September)	70	27.8	102	25.5	0.000	172	26.4
	2= low-traffic months (January, February, May, June, July, August, October, November, and December)	182	72.2	298	74.5		480	73.6
Alcohol consumption	1=yes	8	3.2	24	6	0.072	32	4.9
	2=no	244	96.8	376	94		620	95.1
Drugs use	1=yes	5	2	24	6	0.010	29	4.4
	2=no	247	98	376	94		623	95.6
Weather	1=sunny	110	43.7	261	65.3	0.000	371	56.9
	2=snowy	66	26.2	47	11.8		113	17.3
	3=rainy	51	20.2	38	9.5		89	13.7
	4=windy	5	2	47	11.8		52	8
	5=foggy	20	7.9	7	1.8		27	4.1
	6=sleet	0	0	0	0		0	0
	7=hail	0	0	0	0		0	0
Road quality	1=dry	119	47.2	288	72	0.000	407	62.4
	2=snowy	61	24.2	48	12		109	16.7
	3=damp and rainy	57	22.6	40	10		97	14.9
	4=glacial	15	6	16	4		31	4.8
	5=covered by accident debris or oily	0	0	8	2		8	1.2
Lighting	1=darkness of night	21	8.3	64	16	0.000	85	13
	2=daylight	179	71	280	70		459	70.4
	3=sunrise or sunset	42	16.7	16	4		58	8.9
	4=night with spotlight	10	4	40	10		50	7.7
Obstacle	1=no	151	59.9	282	70.5	0.011	433	66.4
	2=traffic sign	10	4	23	5.8		33	5.1
	3=guardrails	35	13.9	35	8.8		70	10.7
	4=obstacle in the middle of the road	16	6.3	12	3		28	4.3
	5=tree	0	0	0	0		0	0
	6=ditch	0	0	0	0		0	0
	7=falling from the bridge	0	0	0	0		0	0
	8=other (animal, bike, pedestrian)	40	15.9	48	12		88	13.5
Tire	1=yes	252	100	384	96	0.000	636	97.5
	2=no	0	0	16	4		16	2.5
Wiper	1=yes	250	99.2	376	94	0.000	626	96
	2=no	2	0.8	24	6		26	4
Windshields	1=yes	252	100	376	94	0.000	628	96.3
	2=no	0	0	24	6		24	3.7
Seat belts	1=no seat belt	0	0	10	2.5	0.000	10	1.5
	2=has a seat belt but the driver did not use it	110	43.6	155	38.7		264	40.5
	3=has a seat belt and seat belt was used by the driver	142	56.4	235	58.7		378	58
Marital status	1=married	204	81.0	184	46.0	0.000	388	59.5
	2=single	32	12.7	200	50.0		232	35.5
	3=divorced	8	3.2	8	2.0		16	2.5
	4=whose spouse has died	8	3.2	8	2.0		16	2.5
Role	1=driver	247	98	400	100	0.008	647	99.2
	2=passenger	5	2	0	0		5	0.8
Ownership	1=owner	247	98	372	93	0.000	583	89.5
	2=rental	0	0	4	1		40	6.1
	3=loan	5	2	24	6		29	4.4
	4=stolen	0	0	0	0		0	0
Steering folding	1=yes	139	55.2	0	0	0.000	139	21.3
	2=no	113	44.8	400	100		513	78.7

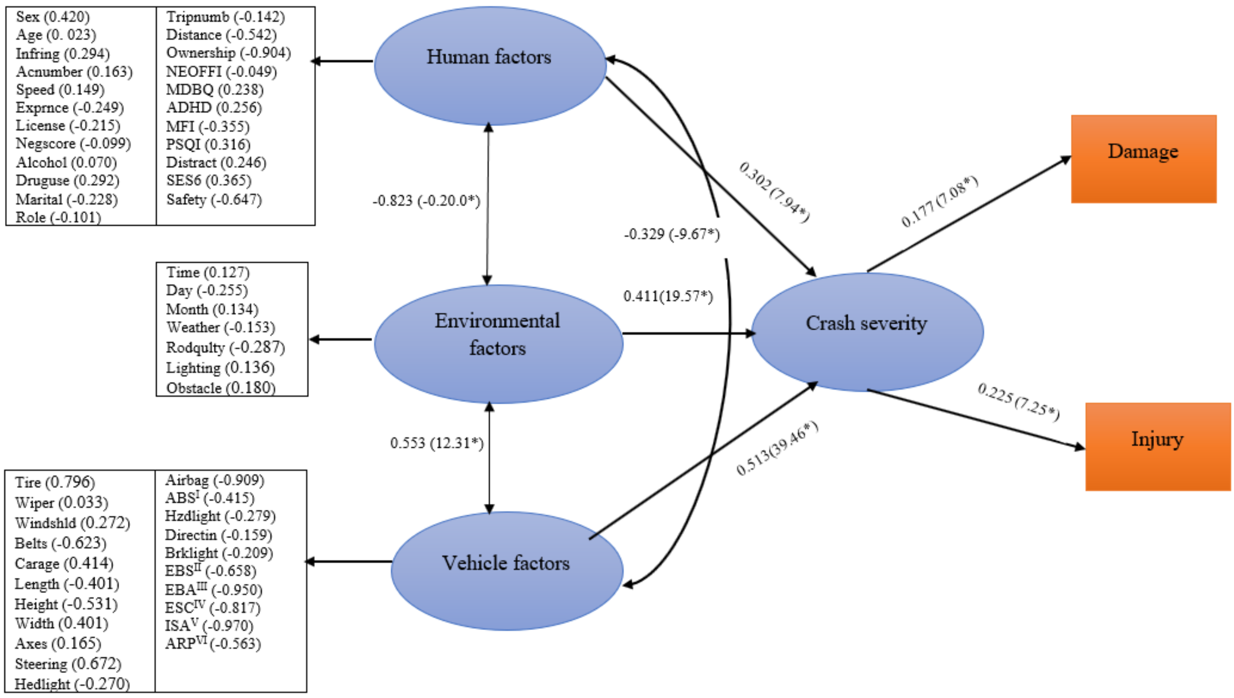
Appendix 3 Sample descriptive analysis (ordinal scaled variables) (continued)

Variable	Components	Foreign vehicles		Domestic vehicles		P-value	Total	
		Number	Percent	Number	Percent		Number	Percent
Headlights	1=no	0	0	0	0	0.000	0	0
	2=yes-damaged	4	1.6	41	10.3		45	6.9
	3=yes-intact	248	98.4	359	89.7		607	93.1
Airbag	0=no airbag	0	0	34	8.5	0.000	34	5.2
	1=1	0	0	41	10.3		41	6.3
	2=2 airbags	7	2.8	317	79.2		324	34.4
	3=3 airbags	0	0	0	0		0	0
	4=4 airbags	10	4	8	2		18	2.1
	5=5 airbags	0	0	0	0		0	0
	6=6 airbags	140	55.6	0	0		140	21.5
	7=more than 6 airbags	95	37.6	0	0		95	14.5
ABS	1=no	0	0	108	27	0.000	108	16.6
	2=yes-damaged	0	0	0	0		0	0
	3=yes-intact	252	100	292	73		544	83.4
Hazard lights	1=no	0	0	0	0	0.000	0	0
	2=yes-damaged	0	0	57	14.3		57	8.7
	3=yes-intact	252	100	343	85.7		595	91.3
Turn lights	1=no	0	0	0	0	0.000	0	0
	2=yes-damaged	0	0	32	8		32	4.9
	3=yes-intact	252	100	368	92		620	95.1
Brake lights	1=no	0	0	0	0	0.000	0	0
	2=yes-damaged	0	0	20	5		20	3.1
	3=yes-intact	252	100	380	95		632	96.9
EBS	1=no	0	0	242	60.5	0.000	242	37.1
	2=yes-damaged	0	0	13	3.3		13	2
	3=yes-intact	252	100	145	36.2		397	60.9
EBA	1=no	0	0	385	96.2	0.000	385	59
	2=yes-damaged	0	0	0	0		0	0
	3=yes-intact	252	100	15	3.7		267	41
ESC	1=no	75	29.8	400	100	0.000	475	72.9
	2=yes-damaged	0	0	0	0		0	0
	3=yes-intact	177	70.2	0	0		177	27.1
ISA	1=no	6	2.4	400	100	0.000	406	62.3
	2=yes-damaged	0	0	0	0		0	0
	3=yes-intact	246	97.6	0	0		246	37.7
ARP	1=no	159	63.1	400	100	0.000	559	85.7
	2=yes-damaged	0	0	0	0		0	0
	3=yes-intact	93	36.9	0	0		93	14.3
Damage	1=no damage	0	0	0	0	0.006	0	0
	2=light or superficial	188	74.6	274	68.5		462	70.9
	3=moderate damage	59	23.4	92	23		151	23.2
	4=severe or heavy damage	5	2	27	6.8		32	4.9
	5=total damage	0	0	7	1.8		7	1.1
Injury	1=no injury	161	63.9	241	60.3	0.294	402	61.7
	2=possible injury	51	20.2	86	21.5		137	21
	3=evident injury	40	15.9	68	17		108	16.6
	4=disability	0	0	5	1.3		5	0.8
	5=death	0	0	0	0		0	0
	Sum	252	100	400	100	—	652	100



Appendix figure 1 Geographical location of Aras free trade zone

Appendix figure 2 Image of Tabriz-Jolfa road and road police l



Appendix figure 3 Structured equations model with data of total cars (combination of model 1 and model 2) The numbers on the arrows and those in the parentheses indicate the estimated coefficients and t-value, respectively, and in the component part of the factors, the numbers inside the parentheses represent the estimated coefficients.

I: Anti-lock braking system, II: Electronic braking system, III: Emergency braking assistant, IV: Electronic stability control, V: Intelligent speed adaptation, VI: Active rollover protection