Modeling the effect of age of vehicles in collisions with fixed roadside objects

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ABSTRACT

This study aimed to examine the crashworthiness (CW) index of the five most commonly used Iranian passenger vehicle brands (Pride, Peugeot 405, Peugeot 206, Samand, and Thunder 90) by assessing the effect of vehicle age on driver injury severity in rural fixed-object crashes. Since rural roads have mostly lower safety standards and usage of safety features than urban areas, only rural crash data from Iran (2011-2017) were analyzed. A two-step approach was applied: initially, the Classification and Regression Tree (CART) method identified important variables, and then, Bionamial Logistic Regression modeled the relationships between injury severity and safety performance, using vehicle age and seven additional variables (driver age and gender, lighting conditions, road surface, road type, shoulder type, and seatbelt use) as independent variables. The CW index, based on the odds ratios, exhibited that vehicles over five years old had a 20% increase in odds of fatal or severe injury, which rose to 50% for vehicles over ten years old. Notably, safety performance declines were not uniform. While most brands decreased similarly up to ten years, Samand showed faster deterioration after this period. Conversely, Peugeot 405 and Pars demonstrated slower declines, indicating longer effective lifespans. Additionally, drivers under 25, driving at sunrise, and not wearing seatbelts were identified as high-risk groups across most brands.

KEYWORDS

Crashworthiness, Collision with fixed objects, CART, Binomial Logistic Regression, Vehicle age.

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1. Introduction

The high fatality rates from road crashes in Iran have always been a major challenge, as records show 16,201 deaths and 335,955 injuries in 2017. Notably, the number of fatalities on rural roads has been twice as high as in urban areas [1]. Governments and transportation planning experts have always attempted to reduce traffic crashes and their consequences by implementing various policies and programs.

Most research has analyzed the effect of human and environmental factors on traffic crashes because of their higher contribution. Some studies have investigated the impact of vehicle characteristics on the severity of crash injuries. Huang et al. [2] employed the Bayesian hierarchical ordered logistic model to investigate the crashworthiness (CW) and crash aggressivity (CA) of 23 major vehicle brands in Florida. Volvo was found to be the best in both CW and CA indexes. Other brands such as Cadillac, Infiniti, Lexus, and Mercedes-Benz also had better CW compared to their CA index. However, Pontiac and Volkswagen were identified as having the worst performances.

In Iran, the effects of vehicles on the likelihood of driver injury or death in two-vehicle crashes based on the crashworthiness and crashaggressivity indexes are assessed by Arefkhani et al. [3]. The findings revealed that other crash characteristics such as rural crashes, side-impact crashes, and crashes occurring at sunrise, may significantly increase the likelihood of driver injury or death. Another study by Arefkhani and Tavakoli Kashani [4] analyzed the relation between driver's injury status and crashworthiness capability of the Iranian fleet's 20 most prevalently used vehicle brands using the Binomial Logistic Regression Model. The results revealed that Proton and Hyundai/Light Truck performed best in rollover crashes. However, no specific trend was found regarding the crashworthiness capability of foreign and Iranian brands. Furthermore, the other study by Tavakoli Kashani et al. [4] explored the impact of vehicle type and weight on occupant protection in fixed-object, rollover, and two-vehicle crashes in Iran using the Binomial Logistic Regression model. This study showed that trucks and SUVs perform better than other vehicle types. Moreover, the increased weight did not consistently enhance safety and the least dangerous weight range was 1500 to 2000 kg.

According to the literature review, most of the previous research on injury severity has mainly utilized various logistic models to compare and rank different vehicle brands, specifically vehicle types (such as pickup trucks, buses, and mini-buses) regarding crashworthiness. Additionally, limited research has been conducted on the effect of vehicle age on injury severity, and the majority of these studies have focused on two-vehicle and rollover crashes. The current study aims to fill this gap by comparing the effect of vehicle age on driver injury severity in rural fixed-object crashes. This aim was achieved by examining the crashworthiness index of the five most commonly used Iranian passenger vehicle brands (Pride, Peugeot 405, Peugeot 206, Samand, and Thundar 90) using the Classification and Regression Tree (CART) and Binomial Logistic Regression models.

2. Methodology

Initially, the Classification and Regression Tree was applied to identify the important factors influencing driver injury severity. Variable importance was determined by using the below formula:

$$VIMX = \sum_{i=1}^{n} \frac{nx_i}{n} (I(C \mid X = X_i) - (c)) \quad (1)$$

When the class variable is considered as C, nx_i represents the number of cases where $X = x_i$, n represents the total number of cases, and I denotes the Gini index, respectively [5]. Crashworthiness index (CWI) in this study is defined as follows: if the injury severity of the driver is injury/death the dependent variable of BLRM would be set 1; otherwise (i.e. No injury), it would be 0, which is defined as formula 2.

$$In[\frac{P(X)}{1-P(X)}] = In[\frac{\frac{1}{1+e^{-(\alpha+\sum \beta_i X_i)}}}{\frac{e^{-(\alpha+\sum \beta_i X_i)}}{1+e^{-(\alpha+\sum \beta_i X_i)}}}] = \alpha + \sum \beta_i X_i \quad (2)$$

It should be noted that $odds = \frac{P(x)}{1-P(x)}$ indicates the probability of the dependent variable X happening, and *Logit P(X)* is the log odds of X. In a logistic regression model, α is background log odds and β_i shows the change in log odds.

In the current study, vehicle age and other variables, including driver age and gender, lighting conditions, road surface conditions, road type, shoulder type, and seatbelt use, were considered independent variables.

3. Results

The important variables identified using the CART method are summarized in Table 1. Figure 1 shows the CW index of vehicles based on their age classifications,

showing the performance of all vehicles declines with age. Drivers in vehicles over 10 years old are about 50% more likely to be injured or killed compared to those in vehicles under 5 years old. The decline in safety performance (CW index) is not the same in all vehicles. The performance of vehicles deteriorates almost uniformly for the vehicles up to the age of 10. After 10 years, the performance of the Samand (odds ratio = 1.79) has been significantly worse than other vehicles, indicating a shorter lifespan. Conversely, the decrease in the performance of the Peugeot 405 has been less pronounced compared to other vehicles.

Table 1. Importance of the variables

Variables	Normalized importance %
Road type	100
Seatbelt	84
Driver's age	70
Vehicle age	49
Lighting condition	48
Road surface	25
Shoulder type	24
Driver's gender	21

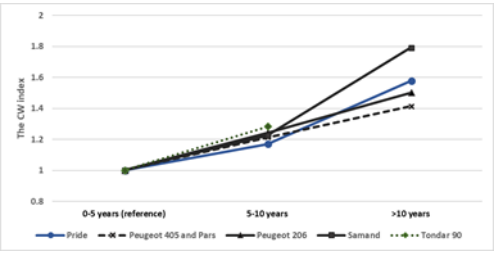

Figure 1. CW index of vehicles baes on their ages

Analysis of control variables reveals that transitioning from freeways to highways, main roads, and subsidiary roads significantly increases the probability of driver injury or fatality. High-risk groups include drivers under 25 years old for most vehicles and drivers over 65 years old for Pride vehicles. Drivers not wearing seatbelts are more likely to be injured or killed in car crashes. Also, crashes during sunrise and night (especially for Samand drivers) increased the risk, while drivers are less likely to be injured or killed on wet, snowy, or icy road surfaces.

4. Conclusions

In this study, the driver protection ability of the five most commonly used Iranian passenger vehicle brands regarding their vehicle ages that were involved in fixed-object crashes based on rural crash data from Iran (2011-2017) was examined. A two-step approach was applied. Initially, the Classification and Regression Tree (CART) method identified important variables, and then, the crashworthiness (CW) index, defined using the Binomial Logistic Regression model was applied to analyze the relationships between injury severity and safety performance. For this purpose, vehicle age and other variables, including driver age and gender, lighting conditions, road surface, road type, shoulder type, and seatbelt use were considered independent variables.

According to these results, safety measures such as raising awareness of drivers under 25 years old by conducting educational programs, enhancing road lighting and pavement quality, and using advanced intelligent and warning systems in vehicles to prevent fatigue and drowsiness, especially during sunrise and nighttime driving. Furthermore, these results are helpful for car manufacturers to enhance the safety performance of domestic vehicles, especially Pride, and introduce policies to increase the frequency of service inspections for vehicles older than ten years. Additionally, the speed of dismantling old vehicles is not compatible with vehicles aging, posing a critical threat and leading to increased fatalities in the future. Therefore, it is recommended that vehicle-renewal programs at the national level be seriously followed.

5. References

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