Effects of Roadway and Traffic Characteristics on Accidents Frequency at City Entrance Zone

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Abstract

More than 60% of accidents in Iran occur within 30 kilometers of cities entrance roads. Therefore the number of accidents per kilometer in these regions, in contrast to the other parts of roads is very considerable. The city of Tehran, as the capital of Iran, is the cross point of major arterials of passenger and freight transportation. Thus the evaluation of road safety, entering and exiting the city in the 30 kilometers buffer, can be considered to improve countrywide road safety. To investigate the effects of roadway characteristics and traffic conditions, including number of traffic violations, on accident frequency within 30 km of Tehran entrance roads, Poisson and Negative Binomial regression model were calibrated in this study. Although the goodness of fit index in Poisson model is much greater than the Negative Binomial model, the accident data dispersion in this study implies that Negative Binomial model is more appropriate to show the influences of effective variables. According to results of modeling, the variables including average daily volume, share of heavy vehicles, average daily speed violations and number of direct accesses and interchanges have effective influence on accident frequencies. Controlling access to roads and using effective actions to reduce the speed and number of speed violation can be accounted as effective policies to reduce accident frequencies within 30 km of Tehran entrance roads.

Keywords: Accident frequency modeling, city entrance zone, Poisson and negative binomial regression models, speed violations, reducing speed and controlling accesses

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1. Introduction

Transportation, and in particular road transport, is one of the fundamental sectors in the economy of each country and it is also one of the key indicators of each country's development. In this regard, safety management and reduction of road accidents seem to be the key issues. Every day more than 3,000 people die in accident and its injuries worldwide. Road traffic injuries are currently estimated to be the ninth leading cause of death across all age groups globally, and are predicted to become the seventh leading cause of death by 2030 [World Health Organization, 2015].

The study on facts and figures in the statistical yearbooks of transportation in Iran shows that in 2015, more than 100 thousand accidents occurred on rural roads of the country, which decreased by 1.1% compared to the previous year, 2014. Also, in 2015, 10860 people died due to rural road accidents, that is equivalent to 65.5 percent of the total number of people who died in urban, suburban and rural accidents in Iran in this year. This percentage has decreased by 0.8% compared to the last year [Road Maintenance and Transportation Organization (RMTO), 2016].

According to the economic studies by the Iran Ministry of Roads and Urban Development, the direct and indirect costs of accidents in Iran, based on the prices of 2007 and including subsidies, were estimated at an annual rate of 180,000 billion IRRials (3.6 billion USD) [Pak Gohar et al. 2012]. This estimation for the year 2007 has been 6.23% of the country's GDP. Considering the growth rate of 6.7% of the country's GDP in the same year, it can be concluded that the cost of driving accidents eliminates almost the entire GDP growth.

The result of the survey on the number and severity of the vehicles collision with each other or with pedestrians shows that in recent years, more than 60 to 70 percent of road accidents in Iran have occurred in the cities entrance zones. This area (the cities entrance zones), which is called by the country's national safety literature, 30 kilometers buffer of cities entrance, covers a large part of the casualties and costs of road accidents. The emphasis by researchers and rural transport police experts on the considerable number of accidents and resulting casualties in this zone indicates the need for extra attention and more researches on this area.

Considering the importance of the above issue, in this study the factors influencing the occurrence of accidents within 30 kilometers of Tehran entrance roads are investigated using the accidents database of rural traffic police. Using this dataset, the number of accidents is modeled and, factors that can reduce these accidents and their consequent injuries and fatalities are determined accordingly. Tehran has a distinct position because of its national and international status and its connection to the most important road arterials. Hence, identifying factors and providing solutions in this city can be also used as guidance for other cities in the country, albeit with some adjustment.

In the predicting models, the relationship between the number of accidents in a segment of a road is determined by its characteristics. These models, in addition to determining the probability and number of accidents, can be used to calculate changes in the rate of accidents due to changes in characteristics of a roadway and traffic conditions, and thus identify the necessary steps to reduce the accident rate. In this paper, two popular models of Poisson regression and Negative Binomial are used to estimate the number of accidents in the entrance roads of Tehran, within 30 km of the city’s entrance. According to data dispersion and goodness of fit indexes, the best model is introduced and important variables affecting the occurrence of accidents are identified. Using these variables, solutions to improve the safety within 30 km of Tehran entrance roads can be provided.

In this research, after reviewing the studies regarding safety analysis within 30 km of cities, the structure of the Poisson and Negative Binomial models is described to estimate the number of accidents. In the next section, the database and the scope of the study are summarized. The estimated models and analyzing their coefficients are presented in the next section. Finally, the results of this research are presented in the conclusion section.

2. Literature Review

Today, experts and researchers consider an accident as a complex phenomenon that human factors, roadways and vehicles characteristics form the three main pillars of that. Of course for road, not only its geometric condition, but also its environmental conditions should be considered. An accident results from a defect in one of these three factors or their mutual defect in a hazardous state that can lead to traffic causalities. Among the main components of an accident, a human factor is the strongest one. Thus, it is logical that society concentrates its effort on that component. Table 1 shows the share of each of the factors affecting road accidents in Iran [Salmani et al., 2007].

Over the past few decades, several studies have been done to assess the views and opinions of experts on the road safety factors worldwide. Older and Spicer [1986] argue that driving accidents can be seen as a result of three factors including the driver, environment and vehicle. Shinar [1988] believes that in most accidents the main cause has been human behavior.

Table 1. The share of main factors affecting roadway accidents in Iran

Factor	Share (%)
Human only	57
Road only	3
Vehicle only	2
Combination of human and road	26
Combination of human and vehicle	6
Combination of road and vehicle	1
Combination of human, road and vehicle	4
Unknown factors	1
Total	100

In the most studies in field of road accidents, human is considered as the most important factor in occurring of such accidents. Therefore most studies concentrated on this factor. Also, many of transport and traffic problems in Iran are due to drivers' behavior., and the main reason for that is the lack of awareness, adequate education and neglecting the rights of other users [Salmani et al., 2007].

Speed is one of the main causes of accidents and fatalities worldwide. High speed increases the likelihood and the severity of accidents [Dashtestaninejad et al. 2018]. Almost all researchers in transport and traffic safety believe that speed is one of the main factors of accidents and increased fatalities. In addition, it has been shown that the speed difference between vehicles also increases the probability of vehicle collisions [Hauer, 1971].

The relationship between speed and safety is based on two principles. Firstly, the relationship between speed and accident severity, as it has been proven that the risk of the death of car occupants due to collision at 80 km/h speed is 20 times higher than a collision at a speed of 30 km/h [Haj Hashemi, 2014]. The second is the relationship between speed and accident frequency. The studies stated that every kilometer per hour increase or decrease in speed can lead to a 3% percent increase or decrease in accident rate [Saffarzadeh, 2012]. Considering the undeniable role of speed in road accidents, the implementation of traffic calming and speed reduction techniques seems to have a significant effect on the reduction of road accidents and fatalities and irreparable costs of them.

The studies carried out by the Iran Road Maintenance and Transportation Organization (RMTO) show that 70% of the country's road accidents occur at a distance of 20 km from the toll plaza and police station at city entrance roads which is approximately equal to 30 km to real city entrance point. This indicates that most of accidents occur in city entrance zones [RMTO, 1999].

[Khabiri and Ahmadinejad 2003], identified causes of accidents within the 30 km of city entrance roads such as unauthorized construction, lots of land uses around the roads, existence of many accesses to the roads, and the lack of complete separation of rural and urban traffic. Based on their study the vehicles' movement with different speeds is the main cause of accidents.

In the research by Shafabakhsh and Mousavi the mixture of traffic with different destinations recognized as one of accidents' causes in entrance zones of cities. According to the results of this study, various types of traffic flows occur at the entrance of the cities, which result in different performance of drivers. This leads to heterogeneous traffic of vehicles resulting in accidents [Shafabakhsh and Mousavi, 2006].

Haghighi et al. [2014] studied the effectiveness of road surface marking on reducing the speed of vehicles and increasing the safety at the entrances of cities. By studying the speed of vehicles at the city entrance of their case study in two periods, before and after the operation, they examined the rate of vehicle speed reduction due to the road surface marking. The speed data collection for this study was carried out in three steps: before the action, shortly after the action (short run) and after the action (long term). Their results showed that the speed of vehicles in the short run after the action has the average decrease of 3.2 km/h compared to the before action situation. In the long term (after the action) compared to the before action, this reduction has been 2.4 km/h. According to their results, the effect of these measures has been less in the long run.

[Haghighi et al. 2015] in another study on the effect of perceptional traffic calming measures on reducing the speed at cities' entrances in both the real world and the driving simulator environment, categorized traffic calming methods into two categories of physical and perceptional. Perceptional methods of traffic calming are divided into three groups of increasing enforcement limitation (such as the use of speed control equipment), intelligent variable signs for determining the speed limit, and marking and signing. In this research, by designing roadside signs and marking and locating those properly at the entrance of one of the cities of Mazandaran province in Iran, the average speed of drivers before and after the implementation were compared. The results of this study showed that after the implementation, the average speed of light and heavy vehicles decreased by 3.05 and 1.93 km/h, respectively. In the simulation environment, the average decrease of speeds taken under the influence of the measures is significant and more than the field.

[Afandizadeh and Golshan Khavas 2006] by using the road traffic accident database of Iran during the years 1991 to 1997 and regression methods developed a safety model for the entrance of cities. Their results showed that the Exponential models has the best fit on the data of physical and demographic characteristics and crashes occurring within 30 kilometers buffer around cities. Independent variables of their model include path width, traffic volume, number of accesses to the main route, city population, and slope and length of the route.

In a recent study by Dashtestaninejad and co-authors, discrete choice models were used to predict severity of accidents at the city entrance. The results showed that driver characteristics such as age and education level, traffic volume in road, number of speed violations, type of collision and number of heavy vehicles involved in accident had important role in describing accident severity. According to these variables, reducing average speed near the city could be accounted as effective policy to reduce accident severity within 30 km of city entrance roads.[Dashtestani nejad et al. 2018]

Besides the studies in Iran, most of studies in other countries referred to speed management as the issue in this context. Among various types of methods for speed management, traffic calming is one of the most widely used practices worldwide [Haghighi et al., 2015]. In the following, several studies on traffic flow calming are reviewed. These studies examine the impact and evaluation of methods used to calm traffic flows.

A study by Donnell and Cruzado [2008], examined the effect of speed feedback sign on reducing the average speed of vehicles in speed change areas of rural roads in the state of Pennsylvania, USA. The results of this study, based on a pre and post study using vehicle speed data in 17 speed change areas, showed that the average speed of vehicles in 13 locations, after installation of speed feedback signs decreased by 10 km/h.

In the other study, Abate et al. [2009] studied the effect of traffic calming devices on vehicle speed at the entrance of small cities in Italy. Many transit routes pass through small communities in Italy are part of inter-state routes or high speed roads. As a result, high-speed vehicles enter these areas and pass through these areas keeping their high speed. In this study, the effect of using gateway traffic calming, including the use of signs and boards, road marking, and the reduction of the width of the route has been investigated. The results of this study, which were carried out using vehicle speed data before and after the implementation of actions at the entrance of one of these communities, indicated that the average speed of vehicles at the entrance to the settlement has been 60 km/h, which decreased by 19% to 48 km/h. Meanwhile, the average speed of vehicles has risen again after crossing the communities. This topic was investigated in another study using driving simulator [Galante et al. 2010]. The results indicated that the speed reduction can be effectively seen in range of 9 to 16 km/h.

The effect of traffic calming devices on speed reduction was investigated in the study by Vaitkus et al. [2017]. To determine the effect of speed humps, six groups of vertical speed calming measures (speed humps and a raised pedestrian crossing), were installed on a 1.6 km long section. In addition to determine the distance of impact of speed humps on the speed, they were installed at a distance of 300 m from each other. The results showed that the speed humps did not have enough prevention effect on reducing the speed and near 60% of drivers still had the speed higher than posted speed. Also, the speed, 120 m after the speed hump again reaches the speed limit. So the speed hump is not effective alone and cannot reduce the speed to safe range properly.

In another study, the effectiveness of various traffic calming measures including two types of speed humps, speed tables, and chicanes from the perspectives of traffic performance and safety, and also environmental and public health impacts was evaluated [Lee et al, 2013]. In this study, researcher used microscopic traffic simulation model to evaluate traffic calming measures under identical conditions. The results showed that the chicanes had the best performance in terms of speed reduction and acceleration noise.

The mentioned researches emphasize on the importance of special attention on city entrance zones safety. But their main focus has been on simple analysis of before and after action data, especially in small cities entrance zones. Thus, studies on determining the effective variables to predict and model accidents frequency in this area are still needed. So, the main goal of this study is modeling accidents frequency within 30 km of a metropolitan area entrance zone and determining the effectiveness of change in independent variables on accidents frequency reduction. Considering number of recorded traffic violations, as a human factor, beside the geometric characteristics of roadway and usual traffic parameters, can increase the power of predicting model and effectiveness of safety actions in the mentioned areas.

3. Accident Frequency Estimation Models' Structures

In order to estimate the number of accidents or, in other words, the probability of occurrence of accidents, various models are used. In this section, two important and fashionable models are used to estimate and describe the accidents frequency.

3.1 Poisson Regression Model

When the average frequency of traffic accidents is low in one segment, the Poisson model can be used. This model can well simulate the occurrence of discrete and scarce events. The relationship between the expected accident frequencies in the segment (i) and the road parameters x_{i1}, x_{i2}, ..., x_{iq} in this model is defined in the form of Equation 1:

$$\ln(\mu_i) = \beta_0 + \sum_{j=1}^{q} \beta_j x_{ij} \qquad or$$
$$\mu_i = e^{\beta_0 + \sum_{j=1}^{q} \beta_j x_{ij}} \tag{1}$$

In this structure, it is assumed that the accident frequency in the model follows the Poisson distribution with the mean μ_i. Then, the probability that a segment with the certain set of predictive variables, experiences y_i accident, is expressed as follow:

$$P(y_i) = \frac{\mu_i^{y_i} e^{-\mu_i}}{y_i!} \tag{2}$$

The Poisson distribution has only one parameter, which is the mean μ_i. Assuming the Poisson distribution, the regression coefficients are calculated using the maximum likelihood method. The most important feature of Poisson distribution is that the mean equals to the variance which can be known as its restriction. If the variance of accident frequency is significantly different from the mean, the Poisson regression would be inappropriate. In this case, if the variance is much greater than the mean, Negative Binomial regression can be applied as an alternative.

3.2 Negative Binomial Regression Model

Negative Binomial distribution is a discrete distribution that provides another model for high-dispersion data, such as accidents data. Unlike the Poisson distribution, the distribution of the Negative Binomial has two parameters. The relationship between the frequency of accidents and the parameters of the corresponding road is as follow:

$$\mu_i = e^{(\beta X_i + \varepsilon_i)} \tag{3}$$

Where ε has gamma distribution (Γ(.)) with mean of 1 and variance of α^2. Here it is assumed that the accident frequency, y_i, follows the distribution of Negative Binomial terms with the parameters μ and α. The probability that a segment defined by a certain set of predictive variables, experiences y_i accident, is expressed as follow:

$$P(y_i) = \frac{\Gamma\left(\left(\frac{1}{\alpha}\right) + y_i\right)}{\Gamma\left(\left(\frac{1}{\alpha}\right) * y_i\right)} \left(\frac{\left(\frac{1}{\alpha}\right)}{\left(\frac{1}{\alpha}\right) + \mu_i}\right)^{\frac{1}{\alpha}} * \left(\frac{\mu_i}{\left(\frac{1}{\alpha}\right) + \mu_i}\right)^{y_i} \tag{4}$$

The mean and the variance of the Negative Binomial distribution of the accident data are μ_i and $\mu_i + \alpha\mu_i^2$, respectively. Like the Poisson model, regression model coefficients are calculated using the maximum likelihood method.

4. Database Description

As mentioned in the introduction, the case study used to model the accidents frequency is Tehran city in this study. So the characteristics of highways connecting Tehran to the whole country road network, in the 30 km buffer around the city, are considered for modeling (Figure 1). According to Figure 1, 10 highways are included in the 30 km buffer of Tehran entrance zone.

Given the significant details of the information and the breakdown of accidents in different days of a year and different highways, aggregation of data for a single segment in different days of a year, or based on the months of a year are possible. The different aggregations result in different models for estimating the number of accidents. By aggregating data for different segments of roads (highways connecting Tehran to the country road network) in different days of the year (2015), there will be 2645 data to estimate the model. However, many of the variables related to road environment and geometry such as the number of accesses, interchanges and the speed limit, have a constant value in a significant number of observations and do not vary day by day, and therefore their impact is not well captured in the model. In order to capture the effects of such variables in this study, the aggregation has been done for highways based on the months of the year (2015), resulting in 120 observations. Table 2 shows the descriptive analysis of the main variables of modeling database. It should be noted that the variables stated in the day scale, relates to the days with at least one accident.

The dependent variable of the modeling is the number of monthly accidents in the highways' segments located in 30 km buffer around city. The maximum observed value for this variable is 114 accidents per month and is related to the Jajrood Exwy (Express Way) and the lowest value is 1 accident per month and is related to the Hemat Exwy. As can be seen in this table, the variance of accident frequency is much greater than the mean. In this situation, using the Negative Binomial model is more appropriate than the Poisson model. But in literature, some studies used both Poisson and Negative Binomial models to compare the results and goodness of fit [Levy et. al, 2008, Qadeer, 2007, Srinivas et. al, 2007]. So, in this study, both models will be calibrated.

One of the important independent variables in modeling is traffic volume. This parameter was recorded by using installed loop detectors along roadway. The maximum average daily traffic volume is about 240 thousand vehicles belonging to the Karaj Fwy (Free Way), and the minimum of this variable is about 13 thousand and is related to the Qom Exwy. The average speed in the highways ranges from 54 to 100 km, with an average of about 80 km/h.

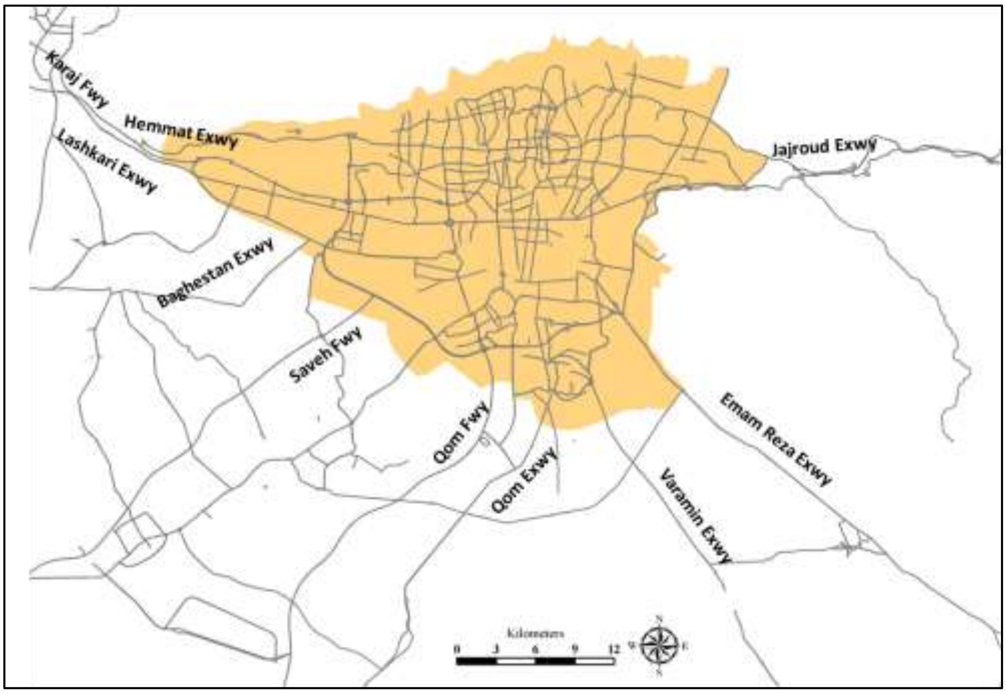

Figure 1. Main entrance highways included in 30 km buffer around Tehran

Table 2. Descriptive analysis of variables of modeling database

Variable	Average	Minimum	Maximum	Std deviation
Number of monthly accidents per highway	43	1	114	25
Traffic volume (vehicles per month)	1,860,166	43,395	6,452,256	1,564,941
Average traffic volume (vehicles per day)	86,057	12,701	243,544	55,198
Average share of heavy vehicles of daily traffic volume (%)	6	0	26	5
Average speed of the highway (km / h)	78	54	100	10
Number of speed violations per month	2830	59	27,876	5,014
Number of speed violations per day	168	3	1,843	296
Number of safe distance violations per month	11,266	129	34,111	9,623
Number of safe distance violations per day	668	22	5,342	737
Number of accesses to the highway	18	4	35	11
Number of interchanges in the highway	2	0	6	2
Number of lanes in the highway	3	2	4	1
Speed limit (km/h)	106	90	120	15

The lowest number of speed violations, occurred in a month and a day, are related to the Qom Exwy, which were reported as 59 and 3 violations, respectively. For the number of recorded violations related to safe distance, the average monthly and daily violations are 11266 and 668, respectively, far beyond the speed limit' violations number. All these variables are recorded using series of loop detectors, installed by RMTO along the roadways surface. The average number of access points to the highway within the 30 km buffer around Tehran is equal to 18 access points, and the average number of interchanges in this area is equal to 2. The average number of lanes for highways is

3 lanes and the average speed limit is around 106 km/h.

5. Modeling Results and Discussion

By using all variables described in the previous section and determining the Pearson and spearman correlation indexes between variables, the best model for estimating the number of accidents using the Poisson distribution was estimated. This model is presented in Table 3.

The goodness of fit of the model is equal to 0.365. It has a high value compared to safety prediction models and indicates that the model is better than the mean value of observations significantly. According to the z statistic, it is also clear that all variables are statically significant at 95% confidence level (the z value in 95% confidence level is about 1.96).

Investigating the coefficients of the variables shows that:

- The coefficient of daily volume variable is positive and indicates the effect of increasing volume on the occurrence of accidents;

- The coefficient of poor visibility variable is positive and indicates that in the absence of proper vision, the probability of an accident increases. The poor visibility variable, which is a dummy variable, equals 1 for a road, if it is mentioned as the main reason for at least 5% of accidents in that road, and 0 otherwise. The main reason of accident is determined by Traffic Police officer, presented in the field when accident occurred.

- The coefficient of the heavy vehicle share is negative and indicates a lower accident rate if heavy vehicles are present. This variable, like the other traffic related variables is recorded by loop detectors.

- The coefficient of the average daily speed violation is positive, which indicates an increase in the number of accidents due to increase in the average traffic speed beyond the posted speed.

- The access and interchange coefficients are also positive indicating an increase in the number of accidents due to an increase in the number of direct access to the road and, consequently, an increase in vehicle interference. This situation is due to improper access connections and unsafe merging/diverging maneuvers.

To analyze the value of the coefficients obtained for the model, it should be noted that these values are related to the power of the exponential model (Equation 1). So the elasticity at the mean value of variables can be interpreted as follow:

Table 3. The best calibrated Poisson model

Variable	Coefficient	Std. deviation	z value
Daily average volume (thousand vehicles)	0.0031	0.0003	9.47
Poor visibility	0.5579	0.0379	14.68
The share of heavy vehicles (percentages)	- 0.0101	0.0044	- 2.29
Average daily speed violation	0.0005	0.0001	7.19
Number of access	0.0011	0.0002	4.23
Number of interchange	0.1223	0.0088	13.76
Constant	3.19	0.0565	56.53

- Increasing the daily volume by 1% increases the accident rate by 0.0031 times the highway volume. Considering that the average daily volume of the highways is 86.66 thousand vehicles, with an increase of 1% by volume, average monthly accidents is increase by 0.267%.

- Decreasing the average number of daily violations by 1% also reduces the number of accidents by 0.0005 times the number of speed violations. Thus, with a 1% reduction in the number of speed violations for an average value of 168 violations per day, monthly accidents decrease by 0.084% in average.

- Decreasing the number of direct accesses to each highway by 1% reduces accidents by 0.0011 times the number of accesses. Thus, with a 1% reduction in the number of accesses for an average number of accesses equals to 18, the number of average monthly accidents reduces by 0.022%.

- By reducing the unsafe interchange access by 1%, the number of accidents is reduced by 0.1223 times the existing number of interchanges. For the average number of interchanges equals to 2.3, the number of average monthly accidents reduces by 0.298%.

As mentioned before, according to data dispersion, the model which is more appropriate to estimate the effects of variables on accident frequency is the Negative Binomial model. Using the same data bank with the Poisson model, the best Negative Binomial model for estimating the number of accidents in this study is presented in Table 4

According to the z statistic, it is clear that all variables are statistically significant at the confidence level of 95%.

Although the calibrated Negative Binomial regression model, due to data dispersion in this study, is more appropriate to predict accidents frequency, the goodness of fit of this model is 0.08 which is less than the Poisson model. The share of heavy vehicles and Number of access, which have the lowest z statistics among the variables appeared in Poisson model, are not significantly different with zero in Negative Binomial model calibration. So they are not appeared in final Negative Binomial model.

Similar to the Poisson regression model, the elasticity is defined in this model as the product of parameter and expected value of related variable at specific level. So the elasticity at the mean value of continuous variables can be interpreted as follow:

- Regarding the coefficient of daily average volume, with increase of volume by 1%, the number of accidents increases by 0.0047 times the existing volume. Considering that the average daily volume of the highways is 86.66 thousand vehicles, with an increase of 1% by volume, average monthly accidents is increase by 0.407%.

- By examining the coefficient of number of interchanges, it can be claimed that by reducing the number of interchanges by 1%, the number of accidents decreases by 0.1427 times the number of interchanges. Therefore, considering the average number of existing interchanges, the number of accidents decreases on average by 0.33%.

- Regarding the coefficient of average daily speed violation, with a decrease of 1% of the number of daily speed violations, the number of accidents reduces by 0.0009 times the number of violations. For an average number of speed violations equal to 168 violations per day, this reduction is equal to 0.151% of average daily accidents.

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Table 4. The best calibrated Negative Binomial model

Variable	Coefficient	Std. deviation	z value
Daily average volume (thousand vehicles)	0.0047	0.0011	4.10
Poor visibility	0.6864	0.1516	4.53
Average daily speed violation	0.0009	0.0003	4.00
Number of interchange	0.1427	0.0286	4.98
Constant	2.96	0.1109	26.69
A	0.2709	0.0405	-

The comparison between variable elasticity in the Poisson model and the Negative Binomial model indicates that the influences of same variables in these models on accident frequency are stronger in Negative Binomial model. Figure 2, shows the change in accidents frequency, due to 10% change in three continuous effective variables of Negative Binomial regression model.

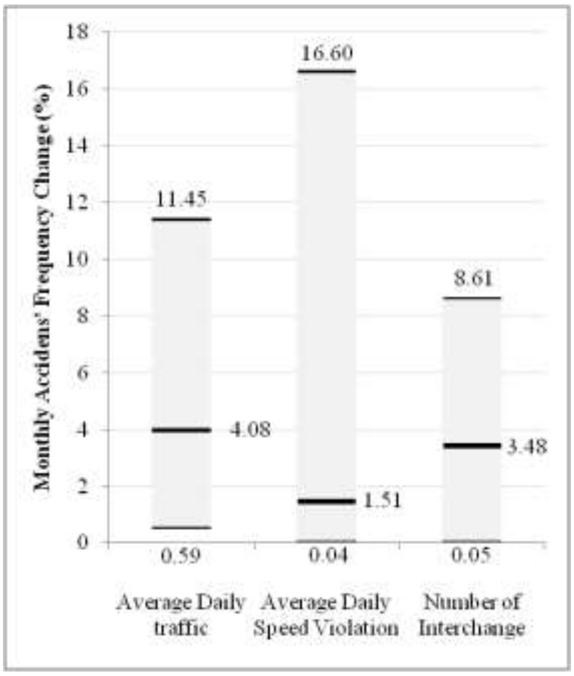

Figure 2. The change in monthly accidents frequency of highways due to change of 10% in Negative Binomial model variables

In Figure 2, besides the average change in monthly accidents due to change of 10% in variables, the minimum and maximum of monthly accidents changes in highways are also presented. According to this figure, the widest range of changes is related to average speed violations. If speed violation prevention by 10% can be achieved, accidents in one of the highways will be reduced by up to 17%. Whereas this variable is a controllable factor by using various enforcements and road engineering techniques, more emphasize on its important role should be done.

6. Conclusion

In order to estimate the number of accidents within the 30 km of Tehran entrance roads, information from 10 entrance highways of Tehran, during one year was used in this study. In addition to the accident database, traffic data such as traffic volume, number of speed limit violations, number of safe distance violations and heavy vehicles share are extracted from the database of RMTO. Using these data, Poisson regression and Negative Binomial models were calibrated to estimate the number of accidents.

In the Poisson model, the goodness of fit of the model was equal to 0.365, which is an acceptable and suitable value for accidents models. In this model, average daily volume, existence of poor visibility in the highway, heavy vehicle share of traffic, average daily speed violation, number of access and interchange in highway were effective variables in describing the number of monthly traffic accidents.

In the Negative Binomial model, the goodness of fit of the model was 0.08. According to this indicator, this model has a lower goodness of fit compared to the Poisson. But, on basis of accident data dispersion, this model is more appropriate to predict the effects of variables on accident frequency. In this model, average daily volume, average daily speed violations and number of highway interchanges within the scope of the study area were used to estimate the number of accidents. Among these variables, the speed limit violation is a variable that can be used as a control variable to reduce the number of accidents. Four overall outcomes of this study can be summarized as follow:

1- The accident data dispersion implies that Negative Binomial regression model compared to Poisson regression model, is more appropriate to estimate the effects of descriptive variables on accident frequency in 30 kilometer buffer around city.

2- The goodness of fit for Poisson model is much higher than the Negative Binomial model. This situation implies that, regardless of data dispersion, Poisson model can predict the mean of accident frequency more accurately while the variance of predictions is not consistent with the real condition.

3- The most important variables affecting the number of accidents include average daily volume, existence of poor visibility in road, average daily speed violation and number of access and interchange in highways.

4- According to the results of modeling, and effective variables controlling the number of accidents, solutions related to gradual and safe speed reduction and traffic calming within the 30 km of Tehran entrance roads, and control and reduction of unsafe accesses should be considered as useful and effective solutions to improve the road safety in these high-risk areas. According to the Negative Binomial model results, 10 percent reduction in speed violations may lead to 1 to 17 percent reduction in monthly accidents frequency in entrance roads, which is very notable. On basis of this fact, practitioners and authorities can plan actions to control speed and related violations more efficiently.

7. Acknowledgment

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8. References

- Abate, D., Dell'Acqua, G., Lamberti, R. and Coraggio, G. (2009) "Use of traffic calming devices along major roads thru small rural communities in Italy", 88th Transportation Research Board Annual Meeting, USA.

- Afandizadeh, S. and Golshan Khavas, R. (2006) "Developing a model for determination the road safety index in city entrance zones", Journal of Transportation Research, Vol. 3, Issue 4, pp. 223-242. (In Persian)

- Dashtestaninejad, H., Amiri, M. and Ehsani Sohi, M. (2018) "Discrete Choice Models to Predict Severity of Accidents near the City of Tehran (30 kilometer buffer)", The 17th International Conference on Traffic and Transportation Studies, Tehran, Iran. (In Persian)

- Donnell, E. T. and Cruzado, I. (2008) "Effectiveness of speed minders in reducing driving speeds on rural highways in Pennsylvania", Federal Highway Administration, No. FHWA-PA-2007-023-510401-12.

- Galante, F., Mauriello, F., Montella, A., Pernetti, M., Aria, M. and D'Ambrosio, A. (2010) "Traffic calming along rural highways crossing small urban communities: Driving simulator experiment." Accident Analysis & Prevention, Vol. 42, Issue 6, pp. 1585-1594.

- Haghighi, F., Yousefi, H. and Yousefi, F. (2014) "Investigating the effect of a specific type of road surface marking on reducing vehicle speed and improving safety at the cities' entrance", 3rd National Conference of Roadway, Railway and Arial Accidents, Zanjan, Iran. (In Persian)

- Haghighi, F., Yousefi, H., Jafari, R. and Akbari, A. (2015) "Investigating the effect of perceptional traffic calming on decreasing the speed at cities' entrance in the real world and driving simulator environment", Journal of Transportation Engineering, Vol. 6, Issue 3, pp. 429-444. (In Persian)

- Haj Hashemi, E., Tashakori Hashemi, M. and Soudmand, S. (2014) "Investigating the role of deterrence of speed control cameras in road accidents: using PSM method in STATA software", First National Road ITS Congress, Tehran, Iran. (In Persian)

- Hauer, E. (1971) "Accident overtaking and speed control", Accident Analysis and Prevention, Vol. 3, pp. 1-13.

- Khabiri, M. and Ahmadinejad, M. (2003) "Investigating the causes of accidents at the cities' entrance in Iran", 10th Students Conference on Civil Engineering, Tehran, Iran. (In Persian)

- Lee, G., Joo, S., Oh, C. and, Choi, K. (2013) "An evaluation framework for traffic calming measures in residential areas", Transportation Research Part D, Vol. 25, pp. 68-76.

- Older, S. J., and Spicer, B. R. (1976) "Traffic conflicts: a developments in accident research", Human Factors: The Journal of the Human Factors and Ergonomics Society, Vol. 18, Issue 4, pp. 35-50.

- Pak Gohar, A. and Kazemi, M. (2012) "Determining the effect of driving error components on the severity of accidents", Rahvar Journal of Research, Vol. 1, Issue 3, pp. 75-102. (In Persian)

- Qadeer, M. (2007) "Road Accident Prediction Models and the Influence of Traffic Flow, Road Length, Road Class and Vehicle Class on Accidents", In Proceedings of the 86th Annual Meeting of the Transportation Research Board, Washington, D.C.

- Levy, A., Wu, Y. and Wang, Y. (2008) "Accident risk modeling for two-lane rural roads in Washington State", In Proceedings of the 87th Annual Meeting of the Transportation Research Board, Washington, D.C.

- Road Maintenance and Transportation Organization (2016) "Statistical yearbook 2015", Deputy of Planning I.R. of Iran Road Administration and Transportation Organization. (In Persian)

- Road Maintenance and Transportation Organization (1999) "Analysis of accidents at city entrance zones", The safety office of I.R. of Road Maintenance and Transportation Organization. (In Persian)

- Saffarzadeh, M., Seyyed Abrishami, E. and Khosravi, H. (2012) "A method for evaluating the performance of speed control cameras in rural roads, case study: Semnan province rural roads", The 12th International Conference on Traffic and Transportation Studies, Tehran, Iran. (In Persian)

- Salmani, M., Ramezanzadeh, M., Derikvand, M., and Sabeti, F. (2007) "Investigating factors affecting road accidents and providing solutions to reduce it, case study: southern villages of Khour and Biabanak, Iran", Journal of Human Geographic Research, Vol. 65, pp. 78-104. (In Persian)

- Shafabakhsh, G. and Mousavi, M. (2006) "Investigating the causes of accidents at the cities' entrance and organizing surrounding areas for immunization", 13th Students Conference on Civil Engineering, Kerman, Iran. (In Persian)

- Shinar, D. (1978) "Psychology on the road: The human factor in traffic safety", John Wiley & Sons, New York, USA.

- Srinivas, C., Dinu, R. R. and Veeraragavan, A. (2007) "Application of Poisson and Negative Binomial Regression of Modeling Road Accidents Under Mixed Traffic Conditions", In Proceedings of the 86th Annual Meeting of the Transportation Research Board, Washington, D.C.

- Vaitkus, A., Čygas, D., Jasiūnienė, V., Jateikienė, L., Andriejauskas, T., Skrodenis, D., and Ratkevičiūtė, K. (2017) "Traffic Calming Measures: An Evaluation of the Effect on Driving Speed", Promet-Traffic & Transportation Vol. 29, issue 3, pp. 275-285.

- World Health Organization (2015) "Global status report on road safety", World Health Organization, Switzerland.