

Environmental Factors Affecting the Frequency of Traffic Accidents Leading to Death in 22 Districts of Tehran during 2014–2016

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Abstract

Background: In many developed and developing countries, a significant proportion of deaths from road traffic accidents occur in the passages within cities. Considering the importance of this issue, this study was conducted to determine the environmental factors affecting the frequency of deaths in 22 areas of Tehran. **Materials and Methods:** In this study, the statistical population consisted of traumatic traffic incidents during the period of 2014–2016, all of which were studied. The data necessary for conducting the study were extracted from the traffic police databases, Tehran Municipality, and the Statistics Center of Iran. In order to analyze the role of regional and environmental factors in the frequency of traffic accidents related to pedestrians in geographic units (22 districts of Tehran), the Poisson regression and geographically weighted regression models were used. The likelihood ratio test was used to compare the models. The goodness-of-fit of models was evaluated using R^2 , Bayesian information criterion, and Akaike's information criterion statistics. **Results:** In this study, 519 incidents were studied, 175 of which (33.7%) were related to motorcyclists, 174 (33.5%) related to automobile drivers, and 170 (32.8%) pedestrians. The frequency distribution of the incidents studied varied in Tehran's 22 districts. The incidence of accidents in the central regions of Tehran was lower, while marginal areas located in the north, south, east, and west of Tehran had the highest frequency of fatal accidents. The both final Bayesian Poisson and GWR models showed that the relationship between the length of highways and educational land used with dependent variable was statistically significant. **Conclusion:** Various demographic and environmental variables play a role in determining the distribution pattern of these types of events. Through regional planning, proper traffic management, controlling environmental risk factors, and training people the pedestrian safety in Tehran can be improved.

Keywords: Environmental factors, geographic information system, statistical models, traffic accidents

INTRODUCTION

The incidence of traffic accidents has increased dramatically over the past decade. In other words, population growth, urbanization, and machine life have all increased the use of vehicles to move cargo and passengers.^[1] This phenomenon, in particular in developing countries, has led to an increase

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in deaths and injuries from driving accidents, because as the number of vehicles increases, the infrastructures necessary to improve the safety of their commute have not been established.^[2-4]

Traffic accidents are one of the main causes of death and disability, causing annual death of 1.24 million and injuries to tens of millions of people worldwide.^[5] Most deaths and injuries caused by accidents occur among young people at the productive and active ages. According to the World Health Organization, in the middle-income and lower-middle-income countries, the highest proportion of deaths from accidents is associated with young people (15–30 years old).^[6] Studies have shown that most traffic accidents, especially accidents involving pedestrians and particularly in high-income countries, occur in the passages within cities. For example, in the EU countries, 70% of these events occur in cities.^[7]

Considering the importance of this issue in recent years in various parts of the world, different methods of spatial analysis and various statistical models have been used to study the role of various environmental factors in the spatial distribution and severity of traffic accidents in urban areas. Noland and Oh in the state of Illinois studied the impact of road construction on road accidents and their rate of death.^[8] Hajar *et al.* evaluated the environmental risk factors of traffic accidents in highways in Mexico.^[9] Rivara and Barber of Tennessee University studied pediatric injuries in Memphis in terms of environmental and demographic factors.^[10] Ayati and Abbasi studied the efficiency of Poisson models, negative binomials, accumulated Poisson, and accumulated negative binomials for modeling traffic accidents in interstellar highways.^[11] Anastasopoulos and Mannering studied the efficiency of regression models based on count data, including Poisson regression and its derivatives, which consisted of negative binomials and zero-inflated models in the study of the frequency of traffic accidents.^[12] Sasidharan and Menéndez who used the partial proportional odds model as an intermediate model for ranked and nonranked models studied factors related to the severity of traffic accidents in pedestrians, and compared partial proportional odds, ordered logit, and multinomial logit for predicting the severity of traffic accidents.^[13]

In Iran, in recent years, due to the increase in the production of automobiles, the traffic volume has increased dramatically in the passages within and out of cities. Based on the statistics published by the forensic organization, 15,932 deaths and 33,307 injuries occurred due to traffic accidents during 2016.^[5] Because in Iran, a large proportion of traffic accidents are caused by environmental factors, especially the quality of roads and streets, and on the other hand, the capacity of the passageways in terms of their capacity to bear traffic load and also the mixing of various vehicle types has exacerbated the role of other factors in driving accidents.^[14,15]

Investigating the intra-urban axes, especially heavy-traffic and populated cities such as Tehran in terms of environmental factors which influence driving accidents can be effective in

identifying these factors more precisely and determining the contribution of each of them to the occurrence of accidents. Using the results of such studies, better planning can be done to reduce these risk factors. Therefore, this study aimed to provide models for determining the effective factors in the frequency of deaths in Tehran during the period of 2014–2016.

Tehran, the capital city of Iran, with 612 km² area, is located in the north of the country. The population of Tehran, according to 2005 census was 7,803,883,^[16] whereas the number of stationary population is estimated to be 8,089,766 now. Tehran, which is the center of business and industry in Iran, is divided into 22 districts, 134 counties including Tajrish and Rey, and 560 traffic zones.^[17] Daily, there are 15–19 million Interurban travels which hamper traffic control strategies.^[18] Construction of highways, develop public transportation systems, and different traffic legislations are part of such strategies. Development of subway roads was another strategy which was responsible for moving 129 million passengers on 2011.^[19] Tehran is ranked as the 25th populated cities worldwide and is estimated to become more dense in 2030.^[20]

MATERIALS AND METHODS

The present study was cross-sectional research in which the statistical population consisted of traffic incidents during the years of 2014-2016 in Tehran, all of which were studied. The data necessary for conducting the study were extracted from the traffic police databases of Tehran, Tehran Municipality and the Statistics Center of Iran. The definition of independent variables is provided in [Table 1].^[17]

Statistical analyses were performed in two descriptive and analytic parts, using SPSS (version 20; SPSS Inc., Chicago, Ill., USA) to descriptive analysis, using Arc-GIS (version 10.2; ESRI Inc, Redlands, CA, USA) to draw descriptive maps, using SAS (version 9.4; SAS Institute Inc., Cary, NC, USA) to fit Bayesian Poisson regression models and GWR (version 4; Department of Geography, Ritsumeikan University, Japan) to fit GWR model. To describe the quantitative data, the absolute and relative frequencies, mean, standard deviation, minimum, and maximum were used. The zoning maps were used to show the distribution of incidents based on geographic units.

Regression models were used to analyze the role of local and regional factors in the frequency of traffic accidents in geographic units (22 districts of Tehran). Because the dependent variable in these units is the number or density of traffic accidents in geographic units, the Poisson regression model was used. An important feature of the Poisson regression model is the equation of mean and distribution variance, which in practice may not be held, and more dispersion may occur. To estimate the Poisson regression coefficients, the maximum likelihood method is used.^[11,21] Due to the low number of study units that are included in 22 districts of Tehran municipality and not providing the necessary assumptions for using the conventional Poisson model, the univariate and multivariate Bayesian Poisson Regression models were

Table 1: Definition of independent variables

Population density	The population divided by area on km ² for of each geographical unit
Percentage of employee at residence	The number of employees divided by total population of each geographical unit (i) Estimation is based on base-year statistics and mathematical modelings. The number of employees per 50 residents with the assumption of at least one employees in any geographical unit, can be obtained using the formula $EMPE_i^t = Max \{EMPE_i^{t-1} (1 + r_{em}^t), P_i^t / 50\}$
Number of parks (green spaces) per km ²	Where EMPE is the number of employees at year <i>t</i> , and <i>r_{em}^t</i> is the rate of employee's growth at the year <i>t</i> Estimated by number of green spaces divided by the area of each geographical unit
Level of development	Indicates the level of development of urban areas. Calculation is based on 7 main criteria namely: Education, housing, employment, biologic environment, access to information, facility, and infrastructures which include 31 indicators, using the AHP model and expert choice software each criteria and sub-criteria mutually were compared relative to each other, evaluated and sorted. Finally by the method of hierarchical clustering, Tehran metropolitan regions in terms of level of development ranked at 1-100
Length of highways/length of all roads (km)	They are designed to facilitate transportation and are among the highest rank of urban roads. Highways are in higher level of speed and movements and have no local access points. Crossroads are usually interchange and are separated by physical objects
Per capita ownership of private cars	Obtained from the results of comprehensive transportation studies in different years. Various economical and mathematical indices have been used for intervals between these studies. It is estimated by $CO^t = CO^b + \frac{0.0016\Delta t^{2.0999}}{1+1.3912e^{0.0928\Delta t}}$
Lack of parking space per km ²	Where <i>Co_b</i> and <i>Co_t</i> are per-capita ownership of private car in base year, and in year <i>t</i> , respectively, and Δt is the difference of years Estimated using the number of private cars stopped in any particular area for any reason except commute. The most common method of estimation is based on times passed for occupational and nonoccupational commutes which involved private car
Land used	Includes of area of each geographical unit used for different utilization. Land utilization is estimated in total or partial. The most important of them in spatial studies include: residential, administrative, business, educational, industrial, and service

AHP: Analytic hierarchy process, EMPE: Number of employees

used. The noninformative normal prior was specified for the regression coefficients. Because of that the variables of residential land used, commercial land used, educational land used, and industry land used had large scale, and hence, the logarithmic transformations were used. The significant levels for univariate and multivariate analyses were assigned 0.25 and 0.05, respectively.

Regarding the fact that ordinary regression models do not consider spatial autocorrelation in spatial data and also the role of the nonstationary part in these data is not considered in the relationship between variables in the calculations, for the analysis of environmental factors affecting the distribution of the incidents also GWR model was used. Fotheringham *et al.* developed this model for studying traffic accidents.^[22] This model is a generalization of the regular regression model. In this model, based on the following equation, the parameters in different locations vary according to their geographic coordinates (*V_i*, *U_i*) from the point *i*.

$$y_i = \beta_0 (u_i, v_i) + \sum_{j=1}^p \beta_j (u_i, v_i) x_{ij} + \varepsilon_i$$

In fact, a regression model based on geographic information weights generates a regression equation for any spatial observation or geographic unit and provides for each point or location *R*², β_0 , β_k , and the *t*-statistic; therefore, this model is based on point equations and predicts the outcome by decreasing the

sizes based on the distance between *i* and *j* using the following equation and according to the combination of the least squares method and the weight matrix (*W* (*i*)). The longer the distance between *i* and *j*, the higher weight the relevant factor will have.^[23]

$$\hat{\beta}_1 = (X^T W(i) X)^{-1} X^T W(i) y$$

$$W(i) = \begin{pmatrix} W_{i1} & 0 & \dots & 0 \\ 0 & W_{i2} & \dots & 0 \\ \cdot & \cdot & \dots & \cdot \\ \cdot & \cdot & \dots & \cdot \\ 0 & 0 & 0 & W_{in} \end{pmatrix}$$

The goodness-of-fit and performance of models were controlled using Akaike's information criterion, Bayesian information criterion, Adjusted R-squared (*R*²), and Percent deviance explained.

RESULTS

In this study, 519 incidents were studied, 175 of which (33.7%) were related to motorcyclists, 174 (33.5%) related to automobile drivers, and 170 (32.8%) pedestrians. The frequency distribution of the incidents studied varied in Tehran's 22 districts. The incidence of accidents in the central regions of Tehran was lower, while the areas located in the north, south, east, and west of Tehran had the highest frequency of fatal

accidents. The most frequent events were in district 4 (57 cases) and the least frequent incidents were in district 10 (6 cases). Table 2 shows the frequency of crashes and independent variables in the models in regions of Tehran in 2014–2016. Furthermore, Figure 1 shows the distribution of the density of the incidents studied in Tehran in the years 2014–2016 in terms of 22 districts

In this study, the relationship between different variables and the frequency of traffic accidents in 22 districts of Tehran was investigated. The variables were divided into three general categories, including population and encounter, road networks, and travel and land use. Table 3 lists the variables entered into the final models of the factors affecting the frequency of traffic accidents in 22 districts of Tehran with their descriptive characteristics, including mean, standard deviation, minimum, and maximum.

Univariable analysis

The Bayesian Poisson model shows the variables including population density, total number of employees at residence, total number of parks, length of highways, Per capita ownership of private cars, level of development, traffic volume, residential land used, commercial land used, educational land used, and industry land used were statistically significant on rate of crash. Each unit increase in population density led to almost 100% decrease in crash rate. In total number of employees at residence, each unit increase in this variable led to 95% increase in crash rate (percentiles interval: [1.85–2.05]). In total number of parks, each unit increase in this variable led to 1% increase in crash rate (percentiles interval: [1.012–1.015]). In length of highways, each unit increase in this variable led to 3.2% increase in crash rate (percentiles interval: [1.030–1.034]). In Per capita ownership of private cars, each unit increase in this variable led to 59% increase in crash rate (percentiles interval: [1.25–2.01]). In the level of development, each unit increase in this variable led to 0.3% increase in crash rate (percentiles interval: [1.001–1.005]). In traffic volume, each unit increase in this variable led to 2% increase in crash rate (percentiles interval: [1.025–1.030]). In residential land used, each unit increase in logarithm of this variable led to 84% increase in crash rate (percentiles interval: [1.75–1.95]). In commercial land used, each unit increase in logarithm of this variable led to 24% increase in crash rate (percentiles interval: [1.18–1.29]). In educational land used, each unit increase in logarithm of this variable led to 66% increase in crash rate (percentiles interval: [1.50–1.82]). In educational land used, each unit increase in logarithm of this variable led to 66% increase in crash rate (percentiles interval: [1.56–1.75]). In industry land used, each unit increase in logarithm of this variable led to 18% increase in crash rate (percentiles interval: [1.16–1.20]) [Table 4].

Multivariable analysis

Length of highways and educational land used were significant in the multivariable Bayesian Poisson model. an adjusted estimate of variable based on multivariable

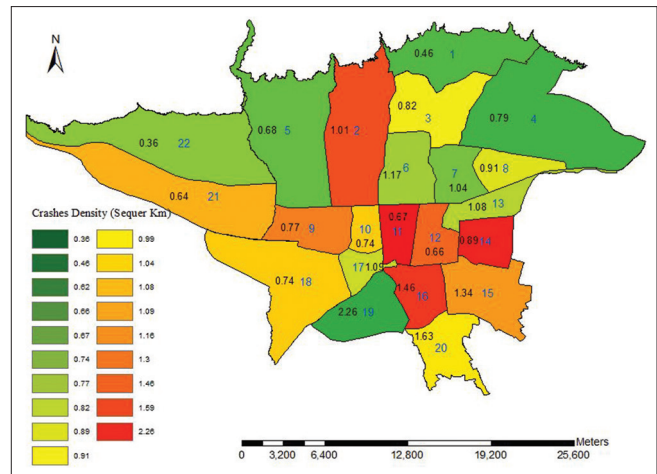


Figure 1: Crashes density in regions of Tehran 2014–2016

model demonstrate that each unit increase in the length of highways led to 2.9% increase in crash rate, presuming that the effect of other variables remains unchanged (percentiles interval: [1.014–1.04]). Moreover by assuming that the effect of all other variables are constant, crash rate with each unit increase in logarithm of educational land used 56% was increase (percentiles interval: [1.07–2.31]) [Table 4].

The GWR model shows that the variables of population density, total number of employees in at residence, total number of parks, length of highways, lack of parking space, per capita ownership of car, level of development, traffic volume, residential, commercial, educational, and industrial land use, are in the final model. In this regard, the relationship between all of them except the traffic volume total number of parks, with the dependent variable (number of accidents) in spatial units has been statistically significant. The direction of the variables of length of highways, the number of employees in the place of residence, educational and industrial land use also level of development with dependent variable has been positive and the direction of population density and residential land used, per capita ownership of car and lack of parking space with dependent variable has been negative [Table 5].

DISCUSSION

The marginal areas of Tehran, especially areas located in the northwest, east, south, and southwest of Tehran are the most vulnerable areas in terms of fatal traffic accidents. In total, the frequency of driving accidents leading to death in different parts of the city of Tehran was different regarding various variables during 2014–2016. In general, these variables could be categorized into three categories, including demographic variables, transport network, and land use.

This study indicated that the frequency distribution of fatal incidents had a significant relationship with demographic variables, including population density and employment in

Table 2: Frequency of crashes and independent variables in the models in regions of Tehran 2014-2016

Region	Population	Crashes	Area (km ²)	Total land use (km ²)	Number of employees	Number of park	Level of development	Length of highways	Per capita ownership of private cars	Lack of parking space
1	363,751	16	34.5	25.7	2928	45	100	1	0.53	14,433
2	694,468	50	49.6	30.6	4075	38	78	0.73	0.45	24,267
3	288,254	24	29.4	20.4	2977	62	90	0.90	0.62	35,052
4	968,245	57	72.4	40.1	3807	90	60	0.60	0.33	26,036
5	681,463	40	59.0	28.7	3292	91	58	0.58	0.36	22,394
6	219,579	25	21.4	16.2	3002	27	90	0.90	0.51	43,974
7	295,400	16	15.4	10.6	5784	26	72	0.72	0.37	18,256
8	332,818	12	13.2	16.2	7181	24	57	0.57	0.34	11,278
9	168,866	15	19.6	15.2	2348	9	51	0.51	0.27	7417
10	227,635	6	8.1	6.1	8065	16	53	0.53	0.26	5417
11	195,970	8	11.9	9.1	5159	11	55	0.55	0.30	16,232
12	178,478	9	13.6	8.9	3796	15	55	0.55	0.27	29,688
13	198,808	15	13.9	10.2	4455	17	54	0.54	0.35	6664
14	501,155	13	14.6	9.3	10,370	34	52	0.52	0.24	10,774
15	736,507	38	28.5	18.8	6861	48	51	0.51	0.23	6723
16	251,566	24	16.4	12.2	4059	29	51	0.51	0.21	10,779
17	244,369.5	9	8.3	6.1	7507	42	50	0.50	0.20	10,779
18	505,083	28	37.9	15.6	3319	42	49	0.49	0.20	4409
19	306,032	26	11.5	9.2	6543	26	50	0.50	0.20	1317
20	423,469	33	20.3	13.5	5510	57	52	0.52	0.22	9948
21	189,015	33	52.0	38.9	1012	17	51	0.51	0.26	1100
22	118,829	22	61.4	36.9	503	6	53	0.53	0.28	1100

Table 3: Descriptive statistics of independent variables in the models

Variable	Mean	SD	Minimum	Maximum
Exposure variables				
Population density (km ²)	16,649	8582	1935	34,419
Total number of employees at residence	102,982	63,120	30,881	275,759
Employees at residence density (km ²)	4661	2387	502	10,370
Total number of parks	35	23	6	91
Number of parks per km ²	1.58	1.03	0.9	5.07
Level of development	60	15	50	100
Road network and travel variables				
Length of highways/length of all roads	0.3	0.2	0	1
Per capita ownership of private cars	0.3	0.1	0.2	0.7
Lack of parking space per km ²	714	606	17	2189
Land used variables				
Residential land used	8,092,634	4,682,181	2,064,359	20,349,977
Residential land use/total area	0.3	0.1	0.1	0.6
Commercial land used	521,975	495,398	139,707	2,290,825
Commercial land use/total area	0.02	0.01	0.01	0.05
Educational land used	314,472	157,872	61,060	591,062
Educational land used/total area	0.01	0.009	0.0009	0.04
Industry land used	702,163	1,489,559	31,036	6,940,509
Transportation and storage land used	497,527	827,650	41,485	3,243,042

SD: Standard deviation

the place of residence, and the direction of this relationship was negative. In other words, the occurrence of these types of events in areas with high population density and higher employment in the place of residence was significantly less than those with a lower population density and less

employment in the area. This relation could be because the incidence of accidents leading to deaths was lower in the central areas of Tehran, which had a high population density and more employment in their area of residence. Various studies in the United States, including Cottrill and Thakuria in

Table 4: Fatal crash univariable and multivariable Bayesian Poisson model for regions in Tehran

Variable	Univariable	Multivariable
	Estimate (percentiles: 25%-75%)	Adjusted estimate (percentiles: 2.5%-97.5%)
Population density	-19.85 (-23.60--19.87)*	-23.08 (-49.46-1.58)
Total number of employees at residence	0.67 (0.62-0.72)*	0.049 (-0.47-0.58)
Total number of parks	0.014 (0.012-0.015)*	0.003 (-0.005-0.0116)
Length of highways	0.032 (0.030-0.034)*	0.029 (0.014-0.043)**
Per capita ownership of private cars	0.47 (0.23-0.70)*	-1.7379 (-4.59-1.12)
Level of development	0.003 (0.001-0.005)*	0.0036 (-0.01-0.02)
Traffic volume	0.028 (0.025-0.030)*	0.00016 (-0.018-0.0197)
Residential land used ^a	0.61 (0.56-0.67)*	-0.10 (-0.51-0.32)
Commercial land used ^a	0.22 (0.17-0.26)*	-0.14 (-0.45-0.17)
Educational land used ^a	0.51 (0.45-0.56)*	0.45 (0.07-0.84)**
Industry land used ^a	0.17 (0.15-0.19)*	0.11 (-0.09-0.32)

*Significant at 0.25, **Significant at 0.05, ^aLogarithmic scale

Table 5: Fatal crash final geographically weighted regression model for regions in Tehran

Covariates	Minimum	Lower quartile	Median	Upper quartile	Maximum
Intercept	2.959	2.964	2.972	2.978	3.027
Population density**	-0.314	-0.302	-0.286	-0.279	-0.168
Total number of employees at residence**	0.067	0.227	0.304	0.378	0.404
Total number of parks	-0.067	0.024	0.032	0.042	0.073
Length of high ways**	0.007	0.025	0.059	0.095	0.325
Lack of parking space**	-0.0287	-0.266	-0.255	-0.241	-0.055
Per capita ownership of car**	-0.383	-0.324	-0.210	-0.145	-0.104
Level of development**	0.074	0.451	0.465	0.486	0.515
Traffic volume	-0.074	0.012	0.073	0.126	0.149
Residential land used ^a	-0.198	-0.174	-0.108	-0.028	0.002
Commercial land used ^{a,**}	-0.220	-0.181	-0.102	-0.033	-0.004
Educational land used ^{a,**}	0.196	0.235	0.270	0.291	0.381
Industry land used ^{a,**}	0.107	0.122	0.150	0.169	0.355

**Significant at 0.05, ^aLogarithmic scale

Chicago,^[24] Sebert Kuhlmann *et al.* from Denver, Colorado,^[25] Siddiqui *et al.* in Florida,^[26] Ukkusuri *et al.* in New York,^[27] and McArthur *et al.* in Michigan^[28] have also showed a significant relationship between population density and frequency of traffic accidents involving pedestrians. However, the direction of the relationship in the mentioned studies has been positive despite the results of the present study. Given that lower density of the fixed population and lower employment in the workplace and at the place of residence will reduce the traffic load of the passages, resulting in increased traffic speed, one of the reasons for this issue is the high traffic speed and increased number and intensity of collision of vehicles with pedestrians in the marginal areas of Tehran, which are often less crowded and have lower employment at work and residence compared to the central regions. Of course, the increase in the density of highways and the low level of pedestrian safety facilities in Tehran compared to the major American cities and cultural differences in terms of following traffic regulations can also lead to these differences.

Frequency of accidents leading to deaths has a significant relationship with the length of highways, which is one of

the most important transport variables. The direction if this relationship is positive. In other words, the incidence of these types of incidents is higher in areas where the density of highways is higher. Given the fact that in these areas more vehicles are moving at high speeds, it can be said that the proportion of severe accidents is increased and thus, the incidence of fatal accidents increases as well. Studies in other parts of the world have also shown such a relationship. Examples include Hashimoto in Florida,^[29] Cloutier *et al.* in Canada,^[22] and Green *et al.* in the UK.^[30] Therefore, it can be said that one of the factors increasing the incidence of road traffic accidents leading to death in Tehran is associated with unsafe highways.

Frequency distribution of incidents leading to deaths has a significant relationship with land use variables, including educational and industrial use. The incidence of these events is higher in the areas with more industrial and educational density. One of the reasons for this issue can be the traffic of more heavy and semi-heavy vehicles for the transfer of industrial materials and products, which consequently leads to an increase in the proportion of severe accidents with light cars, motorcyclists, and pedestrians.

Moreover, one of the reasons for the increased incidence of fatal traffic accidents in Tehran is the insufficiency of safety for students of schools and universities. It should be noted that studies carried out in other parts of the world have shown that one of the factors contributing to the frequency distribution of traffic accidents in urban areas is the use of land in different parts. Examples include Yao and Loo in Hong Kong,^[31] Ukkusuri *et al.* in New York,^[27] and Wier *et al.* in the United States.^[32] Therefore, it is necessary to consider the improvement of the safety of motorcyclists and pedestrians in the development plan of different areas of Tehran, in particular, reconstruction of old textures.

The results indicate that the incidence of fatal accidents decreases with the increase of the developmental level and number of parks in the 22 districts of Tehran. The high incidence of fatal accidents in low developed areas, especially in the south of the city, can be because in these areas, the criteria for improving the safety of the passage of vehicles and pedestrians have not been sufficiently addressed. Moreover, the reason for the reduced frequency of accidents with increasing number of parks can be due to increasing the passengers attraction for leisure and fewer encounters with vehicles. Therefore, by increasing the level of development in different areas of Tehran and increasing the safety of vehicles and pedestrians, the incidence of such events can be reduced.

This study also had some limitations. In Iran, the relation between the deaths of the wounded from traffic accidents and the incident has been defined based on 1 month after the time of death, but in this study, only the data from traffic police have been analyzed according to the method used. Therefore, accidents that have led to deaths within 1 month after the incident have been classified as fatal accidents.

Due to the lack of registration of geographical coordinates of traffic incidents at the time of the accident, their coordinates have been determined approximately during data recording on the computer using auxiliary points and systems for recording spatial coordinates; as a result, the obtained coordinates may have a difference of some meters with the exact coordinates of the accidents.

In a limited number of cases, the auxiliary points recorded by the police were very weak, and it was attempted to determine the exact location of the incident through contact with the people involved in the accident. However, determining the exact location of the occurrence of these cases may be accompanied by some errors.

Occasional environmental events may change over time. To overcome this problem, the latest police data were used to conduct the study while geographic layers and information or estimates of the time of the study or their approximate estimates were used for the analyses.

One of the most important limitations of this study is the low sample size. Because information about independent variables

exists for only 22 districts in the city of Tehran. Therefore, using routine counting models such as Poisson, when entering a large number of covariate in models and assuming normalization, may lead to errors in estimates. For this reason, in this study, we use the Bayesian Poisson models that do not require such assumptions, and its results are compared with the GWR model.

One of the strengths of this study is that by interacting and cooperating with traffic police, systematic information of Tehran police databases was used to determine the environmental factors of traffic accidents while the factors influencing the distribution of fatal traffic incidents were also analyzed and compared.

CONCLUSION

This study is one of the few studies that investigate the spatial risk factors of incidents and traffic accidents in intra-city passages in Iran using geographic information system and regression models. This study initially identified high-risk areas in terms of fatal traffic accidents in Tehran using the geographic information system. Then, using regression models, factors influencing the frequency distribution of the incidents in geographic units (22 districts) were determined. This study showed that if the appropriate information is available about dependent variables and environmental factors, it is possible to determine the factors affecting the distribution of these types of events within the cities using regression models, while more targeted planning can be also done based on the obtained results in order to reduce them.

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Conflicts of interest

There are no conflicts of interest.

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