Effective environmental factors on geographical distribution of traffic accidents on pedestrians, downtown Tehran city

Ali Moradi, Hamid Soori¹, Amir Kavousi², Farshid Eshghabadi³, Shahrzad Nematollahi⁴, Salahdien Zeini⁵

ABSTRACT

Introduction: In most countries, occurrence of traffic causality is high in pedestrians. The aim of this study is to geographically analyze the traffic casualties in pedestrians in downtown Tehran city.

Methods: The study population consisted of traffic injury accidents in pedestrians occurred during 2015 in Tehran city. Data were extracted from offices of traffic police and municipality. For analysis of environmental factors and site of accidents, ordinary least square regression models and geographically weighted regression were used. Fitness and performance of models were checked using the Akaike information criteria, Bayesian information criteria, deviance, and adjusted $R^2$.

Results: Totally, 514 accidents were included in this study. Of them, site of accidents was arterial streets in 370 (71.9%) cases, collector streets in 133 cases (25.2%), and highways in 11 cases (2.1%). Geographical units of traffic accidents in pedestrians had statistically significant relationship with a number of bus stations, number of crossroads, and recreational areas.

Conclusion: Distribution of injury traffic accidents in pedestrians is different in downtown Tehran city. Neighborhoods close to markets are considered as most dangerous neighborhoods for injury traffic accidents. Different environmental factors are involved in determining the distribution of these accidents. The health of pedestrians in Tehran city can be improved by proper traffic management, control of environmental factors, and educational programs.

Key Words: Environmental factors, geographic information system, pedestrians, road traffic accidents, statistical modeling

INTRODUCTION

Traffic accidents are among the main causes of mortality and morbidity worldwide.¹ Pedestrians are considered as most vulnerable users of passages. In many developing and developed countries, pedestrians consisted of most traffic accidents deaths. According to statistics, during 2008, 7638 pedestrians in 23 European countries deceased because of traffic accidents which consist of 20% of deaths of traffic accidents.² In 2010, 4280 pedestrians in the USA lose their lives because of traffic accidents.

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According to Tehran city,[6] presents the final model of effective factors in accidents. GWR and GWR models were proposed first by Fotheringham et al. GWR models were further used for assessment of inner-city passages with a focus on environmental factors, especially in crowded cities such as Tehran, can help determining the role of these factors in accidents. This study is designed to the determination of environmental factors on the incidence of traffic injury accidents in pedestrians and prognosis of these in high-risk areas in Tehran city.

There has been an increase of inner and outer city traffic burden during recent years due to increasing automobile manufacturing in Iran, whereas the passages are not equivalently expanded. Therefore, a large proportion of traffic accidents can be attributable to environmental factors such as quality of roads and passages. On the other hand, the capacity of roads and mixing of different motor vehicles might interact with the role of other factors. Assessment of inner-city passages with a focus on environmental factors, especially in crowded cities such as Tehran, can help determining the role of these factors in accidents. This study is designed to the determination of environmental factors on the incidence of traffic injury accidents in pedestrians and prognosis of these in high-risk areas in Tehran city.

METHODS

This cross-sectional study was conducted on injury traffic accidents in pedestrians which occurred in region coded 6 in downtown Tehran city during April 2014 to March 2015. Data were extracted from traffic police and the municipality offices. Using the Universal Transverse Mercator coordinate system to precisely locate the accidents, geographical information in different layers were collapsed and maps were created.

Spatial and statistical analyses were carried out by Arc-GIS; ESRI, Redlands, California USA, Stata; StataCorp LLC Texas, USA and geographically weighted regression (GWR) software. Ordinary least square (OLS) and GWR models were further used for assessment of environmental factors on the site of accidents. GWR models were proposed first by Fotheringham et al. GWR is an extension of the global model where parameters vary in space according to the geographic coordinates.

This model estimates parameters differently according to their geographic coordinates on $V_i$ and $U_i$ as follows:

$$ y_i = \beta_0 + \sum_{j=1}^{P} \beta_{ij} x_{ij} + \epsilon_i $$

Regression model based on geographic information weights provides a unique regression equation for every spatial observation resulting in $R^2$ based on $\beta_i$ and $\beta_j$ statistics. Based on a combination of least square and weight matrix, every point with less distance to $W_i$ has more weight and $j$ and $i$ used to prognosis the outcome according to the following: longer distance between $j$ and $i$ contributes to more weight.[10]

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

Goodness-of-fit and performance of the models were assessed by the Akaike information criteria (AICs), Bayesian information criteria (BICs), adjusted $R^2$, and percent of deviance explained. Koenker statistic (BP) for stability and Jarque–Bera statistic for bias assessment of OLS estimations were further used. Moreover, multicollinearity of variables was assessed by variance inflation factor (VIF).

RESULTS

Overall, 514 accidents were included in this study. Figure 1 shows that the frequency of accidents was highest in neighborhood coded 17 (Valiasr square) and lowest in neighborhood coded 6 (Ghezel Ghal-e) by 86 and 6 cases, respectively. The highest density of occurrence was seen mostly in neighborhoods near main markets.

We found no specific accident patterns by population density of region coded 6 such a way that there were few accidents in high-density neighborhoods and also high accidents in low-density neighborhoods [Figure 2].

Figure 3 shows that high proportion of accidents occurred in arterial streets and 370 cases (71.9%), 133 cases (25.2%), and 11 cases (2.1%) were occurred in arterial, collectors, and highways, respectively. The density of accidents was also higher around some bus stations.

Table 1 presents the final model of effective factors in frequency of injury accidents on pedestrians in 18 neighborhoods of region coded 6. Applying OLS regression model on the geographical distribution of injury accidents on pedestrians yielded statistically significant relationship between geographical units.
with a number of bus stations, number of crossroads, and land utilization. Unbiasedness and stability of OLS estimates were further confirmed by Koenker (BP) and Jarque–Bera statistics. The existence of multicollinearity was also refuted by VIF values [Table 2].

Table 3 presents the results of GWR model. Considering a number of included variables and AIC values, GWR seems to be a superior method for assessment of geographically effective factors on pedestrians compared to OLS. GWR showed that local changes of geographical units strongly determine the number of accidents. In other words, increasing number of crossroads, commercial utilizes, and recreational spaces may lead to increased number of accidents in geographical units. On the other hand, the most important factors for reducing number of accidents in geographical units include increase of pedestrian’s bridge, long distance from downtown, and increase residential land utilization.
Figure 4 shows the number of predicted accidents in each of geographical units according to GWR estimations. This figure shows that the predicted accidents for neighborhoods downtown and near markets are more striking.

**DISCUSSION**

We found that Southern neighborhoods, especially neighborhood coded 6 (Valiasr square) which was ranked before as the most dangerous neighborhood for traffic accidents,\[8\] are still carrying the title. This part of the city has a lot of commercial, administrative, and educational centers that lead to high population density in these areas. This is consistent with the reports of Tehran office of research and plan which stated that region coded 6 has the fourth dense population (10,240 people in 1 km$^2$) and the second commute load (952,984 commutes/day)\[11\] in Tehran city.

We have found that the distribution of injury accidents has no apparent pattern by population density. High density of accidents was observed both in high dense and low dense areas. Having drawn Figure 2 according to residents of the city, high density of South and Southeast areas can be attributed to high number of commutes and passengers in those areas.\[13\] Several studies in the United States including Cottrill and Thakuriah in Chicago,\[12\] Sebert Kuhlman et al. in Denver City,\[13\] Siddiqui et al. in Florida,\[14\] Ukkusuri et al. in New York City,\[15\] and McArthur et al. in Michigan\[16\] also found significant a positive correlation between population density and frequency of traffic accidents on pedestrians.

![Figure 3: Distribution of injury pedestrian-related crashes in neighborhood of Tehran’s downtown according to some type of land uses and streets 2014–2015](image)

### Table 2: Pedestrian injury crash final ordinary least square model for neighborhoods in Tehran’s downtown

| Covariates          | Coefficient | SE  | P      | VIF  |
|---------------------|-------------|-----|--------|------|
| Number of bus stations | 2.00        | 0.76| 0.02   | 3.11 |
| Number of intersections | 0.33        | 0.10| 0      | 2.66 |
| Residential land used | 33.13       | 23.08| 0.18  | 2.59 |
| Parks land used     | 56.60       | 21.26| 0.02  | 1.91 |
| Industry land used  | 547.59      | 476.66| 0.28  | 2.32 |
| Transportation land used | 503.89   | 319.63| 0.14  | 2.41 |
| Cultural land used  | 1006.31     | 384.73| 0.02  | 2.38 |
| Total land used     | 69.68       | 46.06| 0.16  | 2.95 |
| Intercept           | −101.80     | 40.91| 0.03  |  -   |

**Overall model results**

- Joint F-statistic: 0
- Joint Wald statistic: 0
- Koenker (BP) statistic: 0.56
- Jarque–Bera statistic: 0.38
- AIC: 163.6
- Adjusted $R^2$: 0.86

**SE:** Standard error, **VIF:** Variance inflation factor, **AIC:** Akaike information criteria

### Table 3: Pedestrian injury crash final geographically weighted regression model for neighborhoods in Tehran’s downtown

| Covariates          | Minimum     | Lower quartile | Median      | Upper quartile | Maximum     |
|---------------------|-------------|----------------|-------------|----------------|-------------|
| Residential land used | −0.142      | −0.142         | −0.141      | −0.141         | −0.141      |
| Commercial land used | 0.384       | 0.386          | 0.389       | 0.390          | 0.391       |
| Educational land used | 0.006       | 0.006          | 0.006       | 0.007          | 0.007       |
| Cultural land used  | 0.179       | 0.181          | 0.182       | 0.183          | 0.185       |
| Parks land used     | 0.272       | 0.277          | 0.280       | 0.283          | 0.287       |
| Number of bus station | −0.096      | −0.094         | −0.092      | −0.089         | −0.086      |
| Number of pedestrian bridge | −0.0168   | −0.167         | −0.166      | −0.165         | −0.164      |
| Number of intersection | 0.421       | 0.424          | 0.426       | 0.427          | 0.429       |
| Passenger transport index | −0.047      | −0.046         | −0.044      | −0.042         | −0.042      |
| Distance from city center | −0.168      | −0.167         | −0.167      | −0.166         | −0.166      |
| Intercept           | −6.193      | −6.192         | −6.191      | −6.190         | −6.190      |

**Overall model results**

- BIC: 83.5
- AIC: 119.4
- Percent deviance explained: 0.86

**AIC:** Akaike information criteria, **BIC:** Bayesian information criteria
We showed that more than 70% of traffic accidents have occurred in arterial and main streets in South and center of region coded 6 which had more traffic load. This finding is consistent with Wier et al. in San Francisco, Mueller et al. in Washington city, Hashimoto in Florida, Cloutier et al. in Canada, and Green et al. in England which all showed that the number of traffic accidents on pedestrians is high in streets and passages with high traffic load. High load of passages in South and center of region coded 6 and proximity to commercial and administrating offices are leading causes of high number of accidents. Further studies investigating causes of this condition as well as planning for organizing measures for vehicles, motorcycles, and pedestrians in Tehran city are imperative.

The results of the final model showed that the incidence of accidents in any geographical unit increases with commercial and cultural land utilization. In other words, traffic accidents occur more often in neighborhoods with more commercial, cultural, and recreational land utilization.

According to our findings, increasing load of passages and number of pedestrians in commercial and recreational areas is one of the reasons for increased traffic accidents. It is noteworthy that studies around the world (e.g., Yao and Loo in Hong Kong, Ukkusuri et al. in New York City, Wier et al. in the USA) have shown that land utilization is one of the main factors affecting the distribution of traffic accidents. Thus, attention to the safety of pedestrians in the reconstruction of old buildings is crucial.

Structural and environmental differences in high- versus low-risk areas indicate that environmental factors play an important role in the distribution of traffic accidents in central parts of Tehran city. Similar studies around the world (e.g., Slaughter et al. in New York City, Anderson in London, Taquechel in Atlanta, Wang and Kockelman in Texas, Siddiqui et al. in Florida, and Sebert Kuhlmann et al. in Colorado) have also emphasized on necessity of expanded specific investigations to determine the role of environmental factors and to develop control strategies for traffic accidents.

In addition, GWR model showed that totally increasing the number of these bridges can decrease the number of accidents. More importantly, suitable and proper location for bridges may encourage pedestrians for using them. Räsänen et al. showed that pedestrians prefer unsafe roads because of improper roads. Availability of these bridges is the main reason for decision about using them. Most people prefer not to use pedestrian bridges because of their unavailability.

This study has some limitations as well. Definition of traffic accidents in Iran is based on 1-month postaccident period whereas we used only the data of traffic police office. Therefore, injury accidents leading to death after 1 month of occurrence also defined as injury accidents. Having not registered the exact coordinates of accidents, registration of these accidents is carried out using supportive points and approximate coordinate system which might be slightly misleading. Determination of the exact location of the accidents sometimes was done using an interview with involved people otherwise remained the same. The environmental consequences might be time-dependent. To solve this issue, we used the latest data and geographical layers or estimates of exact accidents timing for analysis.

The strength of this study was the first systematically usage of traffic police data to find the environmental factors affecting the traffic accidents and frequency of injury accidents on pedestrians.

CONCLUSION

Area zones near center and markets of Tehran city are regarded as the most dangerous areas for pedestrians. The location of most injury accidents is arterial and
More accidents have been occurring in recreational, green spaces, and bus stations. Structural and environmental differences of high- versus low-risk areas demonstrate the importance of these factors in injury accidents on pedestrians. Therefore, expanded and more specific studies would be needed to determine the role of each and every one of these factors, as well as to develop control strategies.

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**Conflicts of interest**
There are no conflicts of interest.

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