

## ORIGINAL RESEARCH

# Factors with the Highest Impact on Road Traffic Deaths in Iran; an Ecological Study

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**Abstract:** **Introduction:** The largest proportion of road traffic deaths (RTDs) happen in Low and Middle Income Countries (LMICs). The efforts for decreasing RTDs can be successful if there is precise information about its related risk factors. This study aimed to determine economic, population, road, and vehicle factors with the highest impacts on RTDs in Iran. **Methods:** This is an ecological study, which has been done using covariates including: the population density, economic growth, urbanization, distance traveled (km) in 100 thousand people, the length of urban roads, the length of rural roads and the Vehicle per 1000 population for each province of Iran in 2015. The covariates considered had been gathered from different sources and to determine which one of the covariates has an effect on RTDs, the Negative Binomial (NB) regression model was used. **Results:** The mean number of RTDs per 100000 population was  $474 \pm 70.59$  in 2015. The highest and lowest rates of death belonged to Fars and Qom provinces, respectively. The results of the univariate model showed the population density as the only covariate of RTDs ( $p=0.001$ ). Also, among other covariates, GDP was the only variable with a p-value equal to 0.2. In the multivariate NB model, it was seen that the population density ( $p=0.001$ ), and GDP ( $p=0.02$ ) significantly correlated with RTDs. For a unit (Million Rial) increase in the GDP of the province, the number of deaths decreased by as much as 0.0014. In addition, for a unit increase in population density, the number of deaths went up by as much as 30. **Conclusion:** Population density and GDP had positive and negative effects on the number of fatal road traffic injuries, respectively. By considering these factors in presentational and controlling programs on road traffic injuries, it is possible to decrease the RTDs.

**Keywords:** Death; accidents; traffic; mortality; multiple trauma

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## 1. Introduction

Road traffic crashes (RTCs) are one of the main causes of death in all ages, especially among the 15-29 year-old people all over the world. The cost of RTCs is approximately 3% of Gross Domestic Product (GDP), which rises to 5% in Low and Middle Income Countries (LMICs). The increasing trend

of RTCs is higher among the countries, which experience the rapid growth of population, urbanization, and motorization (1, 2). A high proportion of road traffic deaths (RTDs) happen in LMICs. There is a rapid increase in income and economic development in LMICs, which causes rapid change and motorization. However, the issues of road safety, related infrastructure development, safety improvement of vehicles, and changing the effective policies are not in accordance with economic changes, urbanization, and motorization, which leads to manifestation of many problems related to road safety (1, 3).

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In high-income countries, road safety system has managed well in accordance with motorization and economic growth. In these countries, actions such as developing the safer roads, safer vehicles, and effective road safety management system have led to a significant reduction in RTDs (1, 2). According to international reports, for the first time in history, the global urban living population exceeded 50% of the total population in 2007 and it is constantly rising. By 2020, about 70% of the world population will live in urban areas (4). The world is rapidly urbanizing with extensive changes in population, sustainable mobility feature and the effects of intelligent electronic systems on road safety (1, 4). In some countries such as Iran, the rate of urbanization is higher than economic growth (5). However, effective efforts have not been made to improve safety in the road network and vehicles, in spite of increasing the number of vehicles and the length of roads (1, 6). So in some provinces in Iran, the large number of vehicles and increasing travels in and out of cities make them prone to RTCs (7). In Iran, evaluating the condition of road safety, using the Road Safety Development Index (RSDI), showed that they are not in a good condition regarding road network safety despite little improvements (8). Meanwhile, road network is used for more than 90% of total national shippings in Iran (9).

It is expected that RTDs will impose a heavy cost on communities if effective efforts are not made (10). The governments can make effective efforts to decrease RTCs only if there are valid and reliable data regarding road traffic injuries and deaths (11). In many LMICs, there are no accurate epidemiologic data on RTCs. Using statistical methods can be helpful for determining the factors affecting injuries or deaths (12, 13). According to global status report on road safety 2018, the estimated rate of road traffic deaths per 100000 populations is 20.5 around the world (1). There is no information on the risk factors of RTD in Iran. This study was conducted to determine factors with the highest impacts on RTDs in economic, population, urbanization, length of roads, and vehicle per 1000 population categories using count regression models.

## 2. Methods

### 2.1. Study design and setting

This is an ecological study, which was carried out with the aim of modeling RTDs by studying population density, economic growth, urbanization rate, number of travels, the length of roads, and the number of the vehicles per 1000 population as covariates in all provinces (31 provinces) of Iran using the data of 2015.

### 2.2. Data gathering

In this study, the considered covariates were gathered from different sources. The statistics of RTDs, as a dependent variable in count regression models, were obtained from the Ministry of Health and Medical Education (MOHME). In Iran, registering and collecting the vital data is done by different organizations such as; the National Organization for Civil Registration (NOCR) (as the governmental system that records the vital events), the Iranian forensic Medicine Organization (as a reference point for unnatural deaths), the medical council (as a non-governmental organization for registering all health care professionals), municipalities (as an organization responsible for cemetery in rural and urban areas), and ministry of health and medical education (14). The national reports of World Health Organization in RTDs are prepared by forensic medicine organization (1, 2). However, MOHME is the only registration system, which is based on the International Classification of Disease (ICD) standards. According to the findings of a study in 2009 in Iran, the coverage rate of MOHME registration system is nearly complete (15).

The explanatory variables in this study included: urbanization rate in each province (percent), road length (km), Gross domestic product (GDP) (as an economic factor), population density, the number of vehicles per 1000 population, and the distance traveled per 100000 population (km). Iran is subdivided into thirty-one provinces and all data were in the province level. The GDP information of each province was obtained from Tehran Chamber of Commerce, Industries, and Agriculture in 2011 (16). The population of provinces and their urbanization rate were gathered from population census, which has done by the statistical center of Iran (17). The distance (km) traveled per 100000 population by different vehicles was obtained from the information technology office at the Ministry of Road and Transportation (9). The number of registered vehicles was obtained from the Law Enforcement Force of Iran, statistical office (18). The length of road data in each province was obtained from the statistical center of Iran, the transportation sector statistic (17).

### 2.3. Statistical Analysis

At first, the Poisson distribution was assessed. In the Poisson model, the mean and the variance should be equal. An over-dispersion in data was found using test of over-dispersion parameter alpha by running the same model using negative binomial distribution. The parameter alpha value equals to 0.305. This strongly suggests that alpha is non-zero and the negative binomial model is more appropriate than the Poisson model (19). The analysis was done in two steps using univariate and multivariate models. The variables with a p-value of less than 0.2 in univariate analysis, entered the multivariate



ate regression model (20). Finally, factors affecting RTDs and their effect sizes were identified. STATA software, edition 14, was used for analyzing the data.

### 3. Results

The results of the study showed that the mean number of RTDs per 100000 population was  $474 \pm 70.59$  in 2015. The highest and lowest rates of death per 100000 population according to Poisson model were related to Fars and Qom provinces, respectively. The highest rate of GDP belonged to Tehran, Khuzestan, Isfahan, and Razavi Khorasan provinces. The highest and lowest traveled distances per 100000 people (km) were seen in Ilam and Qazvin provinces, respectively. The population density was highest in Tehran and lowest in Kohgiluyeh and Boyer-Ahmad provinces. The overall urbanization rate in the country (all provinces) was 69.76%. Qom, Tehran, and Alborz had the highest rates of urbanization, respectively. Also, the lowest rates of urbanization were seen in Sistan and Baluchestan, Golestan, and Hormozgan provinces. The highest number of vehicles per 1000 people was observed in Tehran and the lowest in Sistan and Baluchestan. The longest rural roads belonged to Fars, Khuzestan, and Razavi Khorasan, respectively. Also, the shortest rural roads belonged to Qom, Alborz, and Ilam, respectively. About the urban and suburban regions, the highest roads belonged to Sistan and Baluchestan, Fars, and Khorasan Razavi, respectively (table 1).

The results of univariate analysis using negative binomial model is shown in table 2. The results of the univariate model showed population density as the only covariate of RTDs ( $p=0.001$ ). Also, among other covariates, GDP was the only variable with a  $p$ -value equal to 0.2. So, population density and GDP were the covariates selected to enter multivariate negative binomial model. In the multivariate NB model, it was seen that population density ( $p=0.001$ ), and GDP ( $p=0.02$ ) both significantly correlated with RTDs (table 3). The value of the  $\beta$  parameter for GDP was equal to -0.0014. In other words, for a unit (Million Rial) increase in the GDP of the province, the number of deaths decreases by as much as 0.0014. Also, the value of the  $\beta$  parameter for the population density was equal to 30.48. This value means that, for a unit increase in population density, the number of deaths rises by as much as 30.

### 4. Discussion

The findings of NB model showed that the effects of population density and GDP on RTD were statistically significant. Population is one of the factors affecting RTDs. In the Global Status Report on Road Safety (GSRRS) in 2018, the mortality of RTCs was estimated using NB model. In this report, the covariate of population was introduced as an effective factor in

RTCs (1). Some issues emerged following population growth such as: high density of population in cities (21), increase in the number of vehicles, changes in the population demographics, and changes in transportation (22). In LMICs, there is rapid growth in urban areas regardless of related infrastructure and facilities. This issue leads to manifestation of some road traffic related problems including: property damage, injuries, and deaths (23, 24). In Iran, the population has been growing in recent decades and there has been an extensive migration from rural areas to urban areas (7). It should be noted that population growth does not cause an increase in RTCs and their related deaths in all countries. According to GSRRS of WHO in 2018, the number of deaths in Germany (with a population of 81914672), which has a population similar to Iran (with a population of 77447169), was about one fifth compared to Iran (3206 versus 15932) in 2016 (1). Therefore, Germany and Iran have a similar population, but the number of deaths is not the same. One of the reasons for this difference is discrepancy between rapid growth of population and capacity building in the transportation system (21)(25). While in many high-income countries, the increase in population has been followed by effective changes in the transportation system. For example, the increasing trend of the population has caused the shift from private motorized transport to public transport, or has led to making the infrastructure for cycling or walking instead of using a motorized vehicle. Moreover, the rapid changes in vehicle technologies and their improvement by applying intelligent systems have caused improvement in the safety and prevention of crashes and related deaths (26). Along with population growth, there are some changes in demographic characteristics. For example, in many countries the elderly population has an increasing trend. According to WHO report in 2015, the proportion of elderly people in Iran (people 60 years or above) will double during 2015-2030 (27). The findings of other studies show that the most important injury among the elderly people is road traffic injuries, which has the highest incidence, death rate and Disability Adjusted Life Years (DALY) among them (28).

GDP (as an economic factor) was the second factor affecting RTDs in this study. Most studies in this area have used economic indicators such as GDP (29). It was shown that with a raise in GDP, the number of deaths has decreased in provinces. The findings of earlier studies showed that road traffic deaths will increase with launch of development. The rate of RTDs will begin to decrease when exceeding a threshold level in economic status (30, 31). In the early stages, economic growth leads to an increase in vehicles and this condition leads to increase in their related injuries and deaths. This is more important for LMICs, which are mostly in the early stages of economic developing. The findings of a study in 1975-1988 showed that the rate of road traffic deaths in



**Table 1:** Distribution of the studied variables among provinces

| Province                          | GDP (Mil-<br>lion Rials) | Traveling<br>(km<br>per<br>100000<br>population) | Population<br>density<br>(2015) | Urbanization<br>rate<br>(Per-<br>cent) | Number of<br>RTD | RTD<br>rate<br>per<br>100000<br>population<br>(Adjusted) | Vehicle<br>per<br>1000<br>popu-<br>lation | Rural<br>Roads<br>(Km) | Urban<br>and<br>Suburban<br>Roads (Km) |
|-----------------------------------|--------------------------|--|---------------------------------|--|------------------|--|---|------------------------|--|
| Country                           | 6225659738               | 59.55  | 1.00                            | 69.76                                  | 14716            | -  | 19.22                                     | -                      | -                                      |
| East Azer-<br>baijan              | 207139439                | 42.61  | 0.0490                          | 71.9                                   | 1007             | 26.26  | 10.96                                     | 6203                   | 3464                                   |
| West Azer-<br>baijan              | 125717289                | 42.70  | 0.0408                          | 65.4                                   | 727              | 22.42  | 12.42                                     | 5107                   | 2948                                   |
| Ardabil                           | 57913670                 | 58.29  | 0.0160                          | 68.2                                   | 179              | 13.92  | 11.21                                     | 3711                   | 1599                                   |
| Isfahan                           | 85400000                 | 71.83  | 0.0642                          | 88                                     | 723              | 14.31  | 21.06                                     | 4517                   | 5414                                   |
| Alborz                            | 416864342                | 43.01  | 0.0335                          | 92.6                                   | 252              | 9.71   | 3.95                                      | 907                    | 393                                    |
| Ilam                              | 67161398                 | 214.08   | 0.0072                          | 68.1                                   | 155              | 26.67  | 14.41                                     | 1425                   | 1482                                   |
| Bushehr                           | 212663477                | 66.10  | 0.0143                          | 71.9                                   | 309              | 27.51  | 27.63                                     | 1894                   | 2121                                   |
| Tehran                            | 1436431500               | 69.59  | 0.1652                          | 93.9                                   | 233              | 11.83  | 34.37                                     | 1589                   | 983                                    |
| Chaharmahal<br>and<br>Bakhtiari   | 40099640                 | 55.87  | 0.0118                          | 64.1                                   | 182              | 19.50  | 13.95                                     | 1667                   | 1296                                   |
| South Kho-<br>rasan               | 28958350                 | 116.42   | 0.0096                          | 59                                     | 198              | 25.74  | 11.86                                     | 6686                   | 4455                                   |
| Razavi Kho-<br>rasan              | 331292272                | 97.58  | 0.0803                          | 73.1                                   | 1598             | 25.15  | 19.60                                     | 7044                   | 6412                                   |
| North Kho-<br>rasan               | 34956332                 | 59.83  | 0.0109                          | 56.1                                   | 190              | 20.90  | 16.11                                     | 2322                   | 1359                                   |
| Khuzestan                         | 836240240                | 40.66  | 0.0592                          | 75.5                                   | 822              | 17.16  | 20.23                                     | 8477                   | 5276                                   |
| Zanjan                            | 52830070                 | 34.12  | 0.0132                          | 67.3                                   | 207              | 19.56  | 14.03                                     | 3590                   | 1658                                   |
| Semnan                            | 55759341                 | 58.66  | 0.0087                          | 79.8                                   | 161              | 23.92  | 15.25                                     | 1434                   | 1600                                   |
| Sistan and<br>Baluches-<br>tan    | 75230327                 | 63.88  | 0.0345                          | 48.5                                   | 741              | 26.54  | 9.69                                      | 7401                   | 8010                                   |
| Fars                              | 262027801                | 69.99  | 0.0607                          | 70.1                                   | 1608             | 33.62  | 22.20                                     | 8522                   | 7430                                   |
| Qazvin                            | 84992827                 | 30.42  | 0.0159                          | 74.8                                   | 261              | 20.88  | 13.93                                     | 3239                   | 1341                                   |
| Qom                               | 59519554                 | 56.05  | 0.0159                          | 95.2                                   | 54               | 4.37   | 18.91                                     | 703                    | 678                                    |
| Kurdistan                         | 60784463                 | 44.87  | 0.0200                          | 70.8                                   | 428              | 27.88  | 9.83                                      | 4218                   | 1819                                   |
| Kerman                            | 164052960                | 40.58  | 0.0395                          | 58.7                                   | 852              | 27.33  | 16.67                                     | 6494                   | 5692                                   |
| Kermanshah                        | 106086048                | 51.30  | 0.0247                          | 75.2                                   | 484              | 24.48  | 11.49                                     | 4364                   | 2841                                   |
| Kohgiluyeh<br>and Boyer-<br>Ahmad | 143413674                | 31.90  | 0.0088                          | 55.7                                   | 116              | 16.50  | 11.31                                     | 2868                   | 1512                                   |
| Golestan                          | 70512931                 | 48.59  | 0.0234                          | 53.3                                   | 444              | 23.33  | 16.06                                     | 3103                   | 1231                                   |
| Gilan                             | 126890610                | 42.69  | 0.0319                          | 63.3                                   | 355              | 13.95  | 13.27                                     | 6445                   | 1891                                   |
| Lorestan                          | 70281385                 | 50.54  | 0.0222                          | 64.5                                   | 360              | 19.82  | 14.41                                     | 5177                   | 1856                                   |
| Mazandaran                        | 202791471                | 33.23  | 0.0410                          | 57.8                                   | 773              | 24.29  | 14.86                                     | 4769                   | 2332                                   |
| Markazi                           | 125424307                | 42.35  | 0.0180                          | 76.9                                   | 270              | 18.36  | 16.03                                     | 3608                   | 1845                                   |
| Hormozgan                         | 132781740                | 43.74  | 0.0219                          | 54.7                                   | 420              | 24.56  | 23.06                                     | 5341                   | 2897                                   |
| Hamadan                           | 88881887                 | 61.07  | 0.0220                          | 63.1                                   | 433              | 24.12  | 16.01                                     | 2991                   | 2036                                   |
| Yazd                              | 108536644                | 63.60  | 0.0140                          | 85.3                                   | 174              | 15.97  | 31.04                                     | 2580                   | 2295                                   |

RTD: Road Traffic Deaths

Malaysia and Colombia had increased; yet, it had decreased in high-income countries by as much as 25-50% (32). The results of a study in Brazil in 2008 showed that in the previous decade the north and north-east areas with low GDP had higher rates of death in comparison with other areas with high GDP (33).

In Iran, the high rate of road traffic deaths correlates with the

number of vehicles. The number of vehicles has raised following economic growth, which is in its early stage in Iran (5). According to reports of statistical center of Iran, the rate of motorization (the number of vehicles per 1000 population) was higher than the economic growth rate during the years 1971-2009 (5). In low and middle-income countries, failure to balance economic growth with the motorization can play a

**Table 2:** The results of univariate analysis using the Negative binomial regression model

| Variables                       | Coefficient | SE      | P-value | 95% CI  |        |
|---------------------------------|-------------|---------|---------|---------|--------|
|                                 |             |         |         | Low     | Upper  |
| Population Ratio                | 22.06       | 5.45    | 0.001   | 11.37   | 32.75  |
| Urbanization Ratio              | -0.01       | 0.012   | 0.3     | -0.034  | 0.013  |
| Gross Domestic Product          | 0.0007      | 0.00077 | 0.2     | -0.0006 | 0.002  |
| Vehicle <sup>1</sup>            | 0.013       | 0.024   | 0.5     | -0.03   | 0.06   |
| Urban Road <sup>2</sup>         | 0.0002      | 0.00004 | 0.7     | -0.03   | 0.003  |
| Rural Road <sup>3</sup>         | 0.0002      | 0.00003 | 0.6     | -0.002  | 0.0003 |
| Passenger traveler <sup>4</sup> | -0.0007     | 0.005   | 0.8     | -0.01   | 0.009  |

1. Vehicle per 1000 population, 2 Urban Road (km) in each Province, 3 Rural road (km) in each Province, 4 adjusted per/for population. SE: standard error, CI: confidence interval.

**Table 3:** The results of multivariate analysis of Negative binomial model

| Variables              | Coefficient | SE     | P-value | 95% CI  |          |
|------------------------|-------------|--------|---------|---------|----------|
|                        |             |        |         | Low     | Upper    |
| Population Ratio       | 30.48       | 6.36   | 0.001   | 17.48   | 43.48    |
| Gross Domestic Product | -0.0014     | 0.0006 | 0.02    | -0.0026 | -0.00019 |
| Constant               | 4.32        | 0.19   | 0.001   | 4.95    | 5.70     |
| In alpha               | -1.18       | 0.24   | -       | -       | -        |
| Alpha                  | 0.305       | 0.074  | -       | -       | -        |

SE: standard error, CI: confidence interval.

role in increasing the incidence of road traffic crashes. However, in Iran the rate of road traffic deaths has had a decreasing trend in 2007-2018 (34). So the decreasing effect of GDP on RTCs can be explained considering that economic growth has led to an improvement in road safety and raise in investment in transport infrastructure and this has ultimately led to a reduction in RTDs (5, 35).

## 5. Strengths and Limitations

One of the strengths of this study is that it was implemented at the national level and included provincial comparison. On the other hand, this is an ecological study and this should be noted in the interpretation of results. In an ecological study, the ecological inference fallacy occurs if this will not be considered in the interpretation of ecological level data to the individual level. One of the limitations of this study could be the possible information bias in RTD data obtained from the MOHME.

## 6. Conclusion

The covariate population density increases the fatal road traffic injuries and Gross Domestic Production decreases that. By considering these factors in presentational and controlling programs done on road traffic injuries, it is possible to further decrease road traffic deaths.

## 7. Appendix

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### 7.2. Author contribution

All the authors met the criteria of authorship based on the recommendations of the international committee of medical journal editors.

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### 7.4. Conflict of interest

The authors declare that there is no conflict of interest regarding the present study.



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