Investigating the effectiveness of geometric and human factors on the severity of urban crashes

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Abstract
Traffic safety is a major priority for multiple relevant organisations seeking to reduce accidents and traffic fatalities; considering the importance of this issue, it is necessary to provide solutions to reduce both the frequency and severity of such problems. The purpose of this study is thus to investigate the factors affecting the severity of urban crashes. To this end, accidents in the city of Zanjan were analysed using a Pearson’s chi-square test with a confidence level of 95%. The dependent variable was accident severity as judged by injury and property damage, and the independent variables were type of collision, general cause of accident, road type, road surface conditions, road geometry, lighting conditions, engine power of the at-fault vehicle, and gender of the at-fault vehicle’s driver. The results showed that side-to-side collisions have the lowest probability of injury or property damage. The highest probability of injury or property damage is caused by speeding. Furthermore, increase in engine power of the at-fault vehicle caused the probability of property damage to increase, and male drivers were found to experience more severe crashes in urban roads than female drivers. Appropriate recommendations were thus provided.

Keywords: urban crashes, accident severity, data analysis, Pearson’s chi-square test, SPSS

1. Introduction
With the recent increase in vehicle accidents and related problems and issues, raising both public and specialist awareness of related concerns is necessary. Despite the importance of transportation systems, the extent of traffic management and engineering issues, and the provision of various services to drivers and other beneficiaries, few solutions have been presented to support improvement. The possibility of predicting the occurrence of crashes and of developing a model that shows the conditions that encourage traffic accidents is one of the main objectives of transportation engineers and planners. Thus, monitoring vehicle and driver conditions is necessary to allow data collection and analysis of the huge volumes of data required to predict and discover patterns and certain rules., as such knowledge can be used to analyse traffic accidents data to develop understanding of how the behavioural characteristics of drivers and road conditions affect crashes, allowing decision makers to prioritise policies enhancing traffic safety. This paper thus applies various data mining algorithms to existing data sets to determine which human and traffic factors affect crashes; a pattern is thus provided and interpreted, and relevant solutions presented.

2. Literature Review
Studies analysing accidents are mostly based on statistical models, such as linear regression models, logarithm regression models including natural logarithms, Poisson, and negative binomial models. In such
models, the relationship between the types of crashes and traffic, geometric, human characteristics, and environmental factors are investigated. In some research, multinomial linear regression models are used to predict accidents, based on the hypothesis that the number of crashes, or crash rate, is a linear function of different environmental characteristics such as traffic volume, weather, geometric and driving conditions and so on; Lee is one of the researchers who has addressed this issue [1].

In another study by Jones, Janssen, and Mannering in Seattle, USA, crashes were analysed using a Poisson model, and an accident database was used for variable determination. The variables consisted of traffic volume, travel behaviour, and geometric variables [2].

Wang (2006) investigated the relationships between crash severity and collision type and several different effective factors. He categorised crashes into seven types by collision type:

- single-vehicle collision
- rear-end collision
- head-on collision
- rear to rear collision
- angle collision
- side-to-side collision in the same direction
- side-to-side collision in opposite direction

His results showed that 30% of all crashes and 60% of fatal crashes in two-lane rural highways in northern states of USA were single-vehicle collision, but that, while only 2% of all crashes in the USA were head-on crashes, they were responsible for one fifth of fatal crashes. Crash severity for vehicles that had head-on collisions or single-vehicle collisions was greater generally than in other type of crashes [3].

Dang et al. investigated the severity of head-on crashes in state of Connecticut using an ordered probit model; their data analysis showed that wet pavement surfaces and night-time incidents had high correlations with crash severity, while increasing line width reduced crash severity [4].

Mercier et al. investigated the effects of the age and gender of driver on injury in head-on crashes using logistic regression. The hypothesis used in their study was that probability of injury for the elderly in head-on crashes was higher than for young people due to physiological changes in the body on aging [5].

Age and gender are two important characteristics of human that have clear impacts on crashes. Ageing and gender combinations lead to different behaviours and reactions in drivers and each behaviour profile can be categorised into smaller parts to examine the underlying reasons [6].

Adulthood includes three periods, youth, middle age and old age. In youth, physical growth reaches its maximum, while ageing leads to reduced vision, increased illness, reduced physical strength and other negative impacts that have led researchers to investigate this factor as an effective element in crash severity. Mannering investigated the characteristics of male and female drivers in terms of risk of crashes. He attempted to consider the issue from various aspects by using a risk function, yet determined that there were no significant differences between male and female drivers in terms of crash risk. Laapotti and Keskinen investigated differences in crash patterns in male and female drivers, evaluating the results using a 4-step model. They found that female drivers were often in more crashes than male drivers, particularly due to responses to poor traffic conditions and a lack of proficiency in manoeuvring rather than reasons such as speeding and driving while intoxicated. In terms of driving behaviour, male drivers experienced more crashes in which they were found to be in non-compliance with regulations [7], [8].

Islam and Mannering investigated injury severity in male and female drivers in single-vehicle crashes using a multinomial logit model. The results showed a significant difference in factors leading to increased injury severity in male and female drivers. Laapotti and Keskenin investigated differences between young male and female drivers in fatal crashes deemed to be due to the driver's inability to control the vehicle. The results showed that the probability of crash occurrence due to driver's inability to control a vehicle was equal for male and female drivers. However, it was observed that when men lost control of vehicles, it tended to lead to single-vehicle crashes, while when women lost control, it led to serial crashes [9], [10].

Massie et al. investigated the rate of crashes in Finland in terms of age and gender. The results showed that the occurrence probability of severe and fatal crashes for male drivers was higher than for female drivers; most female drivers’ crashes involved less severe injury and property damage [11]. Laapotti et al. also investigated the behaviours of male and female drivers in crashes, finding that female drivers played lesser
roles in the occurrence of crashes and committed fewer violations over a specific length of roadway. Female drivers had better status in terms of increasing traffic safety and compliance with regulations than men. They also showed that traffic behaviours of drivers from 1978 to 2001 remained almost the same [12]. Olabarri et al. conducted a cross-sectional study using the National Crash Register. The dependent variables were head-on crashes with injury (yes/no) and drivers involved in head-on crashes (yes/no). Factors associated with head-on crashes and with being a driver involved in a head-on crash versus being involved other types of crash were studied using a robust multivariate Poisson regression model to estimate proportion ratios (PR) and confidence intervals (95% CI). These showed that the lower probability observed on roads with median strips pointed to these as effective measures to reduce severe collisions [13]. A number of studies in other countries have demonstrated the effectiveness of the installation of measures such as central separation between opposing lanes [14], [15], [16]. As recommended by Hosseinpour et al. the installation of centreline median barriers on undivided roadways seems to be the most effective countermeasure; however, due to the great expense associated with the installation and maintenance of continuous median barriers, for lower risk locations, centreline rumble strips may be effectively installed to reduce crossover collisions [17].

3. Statistical test
The main objective of this paper is to identify determinants of the severity of urban crashes. To achieve this, all independent variables were categorized and a Pearson's chi-square test with a P-Value of 0.05 used to investigate the relationship between each independent variable and crash severity. By using this test, the significance of independent variables in describing the response variable with the desired safety factor of 95% was evaluated, and the effect of independent variables on the dependent variable obtained by application of statistical analysis and graphs. In this study, IBM SPSS-21 software was used for all statistical analysis.

4. Variable definitions
One of the more frequently used methods of crash investigation in the literature is modelling crash severity using either unordered (multinomial logit, nested logit, or mixed logit) or ordered (ordered logit or probit) discrete outcome models. Both ordered and unordered models have benefits and limitations, and the choice of one method over the other is governed by the availability and characteristics of the data, taking such trade-offs into consideration [18], [19], [20].

In terms of available data for the current study, the database of urban crashes in Zanjan city in 2014 is in three parts: crash details, vehicles involved, and casualties. After modifying the data, 1,440 cases were used for statistical analysis.

Eight geometric and traffic independent variables were then investigated, as presented in Table 1. In order to investigate the risk of collision of independent variables, the Mann-Kendall non-parametric test (discrete variables) is used. The correlation between predictor variables was less than 0.5, which implies they are independent of each other. In Table 1, the categories considered for all variables and the frequency of each category are presented. All independent variable were categorised and subject to statistical analysis. The independent variables included crash severity, type of collision, general cause of accident, road type, road surface condition, road geometry, lighting condition, engine power of at-fault vehicle, and gender of at-fault vehicle’s driver.

| Table1- frequency of independent variables for different type of crashes |
|--------------------------|--------------------------|----------|
| Variable                | Category                | Percent  |
| Crash severity          | Injury                  | 80.7%    |
|                         | Property damage         | 19.3%    |
| Type of collision       | Side-to-Side            | 9.3%     |
|                         | Rear-End                | 19.6%    |
|                         | Rear-to-Side            | 27.0%    |
|                         | Collision with pedestrian| 38.9%    |
|                         | Head-on                 | 5.2%     |
| General cause of accident| Deviation from route    | 12.6%    |

3
5. Results and Discussion

In this study, the effect of each independent variable on urban crash severity was individually evaluated and the results of the Pearson’s chi-square test used for this purpose for all independent variables are presented in table 2. The results show that for the variables “type of collision”, “general cause of accident”, “road surface condition”, “engine power of at-fault driver’s vehicle” and “at-fault driver’s gender” there is a significant relationship with crash severity at a significance level of 95% (sig<0.05). There was no significant relationship between crash severity and “road type”, “road geometry”, and “lighting condition”. Analytical graphs of the significant variables are thus presented.

Table 2. Results of Pearson’s chi-square test for independent variables

| Variable                                      | Chi-square value | Degree of freedom | Significance level |
|-----------------------------------------------|------------------|-------------------|--------------------|
| Type of collision                             | 12.49            | 4                 | 0.000              |
| general cause of accident                     | 8.09             | 3                 | 0.004              |
| Road type                                     | 19.89            | 1                 | 0.08               |
| Road surface condition                        | 32.3             | 1                 | 0.008              |
| Road geometry                                 | 5.89             | 1                 | 0.2                |
| lighting condition                            | 15.68            | 1                 | 0.09               |
| Engine power of at-fault driver’s vehicle     | 10.33            | 4                 | 0.001              |
| At-fault driver’s gender                      | 14.66            | 1                 | 0.03               |

5.1. Type of Collision

The results showed that, in collisions with pedestrian, there is the highest injury to property damage ratio and in a side-to-side collision of two vehicles there is the lowest injury to property damage ratio. Further, according to the results, after collision with a pedestrian, head-on crashes, rear-to-side collisions, rear-end and side-to-side collision have the highest injury risks, respectively. The results of this study are thus compatible with those of Wang [3].
5.2. General Cause of Accident
According to the data analysis, the highest injury to property damage crash ratio is due to the general cause “speeding” (fig. 2). The lowest injury to property damage ratio is due to driver inattention. In fig. 2, the relationship between crash severity and general cause of accident is presented in increasing order.

5.3. Road Surface Condition
Based on the results of this study, on roads with wet surfaces, the injury to property damage ratio is higher than on roads with dry surfaces. As seen in fig. 3, roads with wet surfaces, whether due to natural (rain) or unnatural reasons, have higher crash severity than roads with dry surfaces. Zuxuan et al. introduced road surface wetness as an effective factor in crash severity (Deng et al, 2006).
5.4. Engine Power of at-fault Driver’s vehicle

This variable has not been used in previous studies. As presented in table 1, the engine power of vehicles were available in continuous format, but the statistical analysis evaluated these into three classifications: less than 1300cc, 1300 to 1800cc, and more than 1800cc. The results showed that with the increase of engine power of the at-fault driver’s vehicle, property damage to injury crash ratios increase. Thus, with the increase in engine power of the at-fault driver’s vehicle, the crash severity reduces. The relationship between crash severity and classification of engine power of at-fault driver’s vehicle is presented in fig. 4.

5.5. At-fault Driver’s Gender

As seen in fig. 5, for female drivers, the injury to property damage ratio is lower than for than male drivers. In fact, the results of this study clearly show that male drivers experience more severe crashes in urban roads than female drivers. Some other studies in this field have seen similar results (Mannering, 1993; Laapotti, et al, 2004; Massie, et al, 1998; Laapotti, et al, 2003).
6. Conclusion and Recommendation
With the modern increase in car accidents and related complications, enhancing the safety of roadways, particularly urban roadways, is vital. Thus, it is necessary to study ways to reduce the number and severity of crashes.

To achieve the main objective of this study, identification of variables having an effect on crash severity in urban roads, all independent variables were categorised and a Pearson's chi-square test with a P-Value of 0.05 was used to investigate the relationship between each independent variable and crash severity. According to the results of this study, the highest injury to property damage ratio occurs due to the general cause of speeding. As crash severity has a direct relation with momentum of different objects, the higher the speed of vehicle in a crash, the higher the momentum and thus the higher the crash severity.

Furthermore, statistical analysis showed that on roads with wet surfaces, crashes were more severe than on roads with dry surfaces. On roads with wet surfaces, drivers require more length of road to stop the car due to the friction reduction between car tires and road pavement. Thus, the speed of collision on wet roads is higher than on dry roads, and crash severity is higher. Reduced sight distance in rainy weather may also be a reason for high crash severity on wet roads. An increase of engine power in the at-fault driver’s vehicle, reduces crash severity, however. Cars with higher engine power are usually safer, and in crashes featuring safer cars, the injury probability for drivers and passengers is reduced. It was also concluded that male drivers experience more severe crashes than female drivers. The lower driving speeds of female drivers and their additional attention while driving compared to male drivers leads to reduced injury in crashes.

According to the results, the following suggestions are provided to reduce the number and severity of urban crashes:

As speeding causes the most severe urban crashes, it is suggested that by traffic enforcement cameras placed by police on urban roads may reduce speed violations by drivers.

In roads with wet surfaces in rainy weather, crash severity is higher; thus, it is suggested that improving the level of knowledge of drivers about the need to drive carefully in such conditions, it may be possible to reduce the injury crash probability. However, as the number of rainy days in Zanjan city is relatively high, a special lighting system to be used for rainy and foggy conditions, particularly on roads with high numbers of crashes, may also be useful.

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