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An Investigation on Pedestrian Accident Severity in Urban Streets Using Path Analysis

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Keywords

Pedestrian,
Accident,
Urban streets,
Path analysis.

Abstract

Pedestrians are known as the most vulnerable road users because in most accident cases, they cause the serious or fatal injuries. Indeed, pedestrian injuries and fatalities in accidents constitute a world concern. On the other hand, approximately 50 percent of all traffic accident victims in developing countries are pedestrians. Also, the results of the researches in Iran show that 39 percent of all crash fatalities are pedestrians. According to the importance of this issue in Iran, this paper investigates the pedestrian accident severity for urban streets accidents in Rasht, Iran. Accidents data were obtained from the Rasht traffic police database in the period of March 2014 to March 2015. In order to estimate the effects of variables on pedestrian accidents, path analysis which have the ability of explaining the direct and indirect impacts of the independent variables on dependent variables, is applied. The effects of human factors (age and gender), environmental factors (weather conditions, lighting condition and way type), time variables (day of crash and time of crash) and vehicle factor (vehicle at-fault) on the pedestrian accidents severity were estimated. Results of the path analysis showed that the day of crash had a greatest direct impact on the pedestrian accident severity and time of the crash had greatest indirect effect on it. Also, the path analysis illustrated the insignificance of the surface conditions on the pedestrian accident severity.

1. Introduction

Pedestrians are known as the most vulnerable road users as they includecthe serious or fatal injuries in most accident cases. Also, pedestrians are at the risk of direct collision with vehicles. In the event of an accident, they took serious damages and their survival chances are far less than other road users [1]. On the other hand, approximately 50 percent of all traffic accident victims in developing countries are pedestrians. Also the results of researches in Iran show that 39 percent of all crash fatalities, who are almost 11000 people, are pedestrians. This estimation is two times greater than the total annual fatalities of accidents in four Scandinavian countries (Sweden, Denmark, Norway and Finland) and total annual fatalities in England.

Previous studies showed that various factors affect on the frequency and severity of an accident that can be classified into three general categories which are human factors, environmental factors and vehicle factors. Research by Treat et al. into the relative proportion of contributing factors on accidents showed that human factors had greatest impact on accidents occurenec (almost 90% of all accidents) [2]. A large body of previous literature has used a variety of modeling techniques to study factors that affect the frequency and severity of pedestrian accidents over some time period. Usually, regression techniques such as Porbit, Logit and mix have been used to analyze pedestrian accident severity. Petch and Henson [3] noted that in order to explain the involving factors on child pedestrian accidents, it was necessary to analyze this type of accidents at the sub-district level. Dommes [4] used a training program for older pedestrians and examined age-related differences in street-crossing behaviors before and after training programs. The results indicated that the training program produced important and significant benefits. His previous research also suggested that elderly pedestrians are the most vulnerable. Starnes et al. [5] investigated the impact of gender on pedestrian accidents with cars. The population of this study included 6965 patients. Generally, 20.7 percent of all patients were in the age group < 15 years, 60.5 percent of all patients in the age group 15–55 years, 7.6 percent of all patients in the age group 56–65 years, and 11.1 percent of all patients in the age group > 65 years. Pelvic fractures were more common in females than the males. This difference was

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present in all age groups that came above, but particularly in the age groups 56–65 years and > 65 years and males in the age group 15–55 years were more likely to had tibia fractures.

Jensen investigated the pedestrian's safety in Denmark in the face of two-wheeled vehicles. The investigation revealed that lower speed limits, reducing the severity of accidents and casualties. After the speed limitation in Denmark in 1974, average speed about 6 km/h and consequently pedestrian accidents reduced about 25 percent. In 1985, speed limits in urban areas revised and reduced from 60 to 50 km/h. In effect of this change in speed limits, flow rate about 2-3 km/h and pedestrian fatalities reduced about 31 percent [6]. In this regard, Page [7] investigated the effect of speed limits on reducing pedestrian casualties in France. In this country, speed limits was reduced from 60 to 50 km/h in 1990. Also, the speed of vehicles on the main roads of the country during the days was reduced from 65 km/h to 60 km/h but average speed during the nights remained unchanged. The results showed that by reducing the speed limits in this country, within 2 years, pedestrian casualties in urban areas 12.3 percent and in rural roads 10.2 percent were reduced.

Schneider et al. studied on the factors affecting on the pedestrian accidents. The results showed that the traffic, pedestrian and vehicles volume and length of the section, directly associated with the pedestrian accidents [8]. Lee and Abdel-Aty [9] analyzed the prevalence and injury severity of the pedestrian crashes at intersections in Florida. They used four years data from 1999 to 2002. Some of the significant factors affecting accident injury severity included pedestrian age, adverse weather and bad lighting conditions, and vehicle size. For example, the results showed that pedestrian injuries involving larger vehicle had severe injury more than crashes involving a passenger car. Kim et al. [10] used a mixed logit model to examine the pedestrian-injury severity in the pedestrian crashes by using collision data from 1997 to 2000 from North Carolina. They found several predictors to the probability of fatal (or severe) injuries. Examples of these predictors include darkness without streetlights, trucks utility vehicles, speeding involvement, freeway sections and increase in pedestrian age. They also found that the effect of pedestrian age was normally distributed across observations and the older pedestrians, increase the probability of fatal injury substantially.

Jang et al. used six years data for pedestrian accidents in San Francisco, California, to identify factors that affect the prevalence and severity of pedestrian crashes. They used an ordered probit model and found that drinking problems, cell phone use, and age(below 15 or above 65)increased pedestrian injury severity. Environmental factors that were associated with high pedestrian severity included night, weekends, and adverse weather. They also found that larger vehicles such as trucks, and buses were associated with increasing pedestrian injury severities compared to passenger cars [11]. Mohamed et al. used two pedestrian injury severity datasets from New York City and Montreal, and applied the ordered probit and multinomial logit models to analyze the severity of pedestrian accidents. Several variables, such as presence of larger vehicles, night without enough light, and frequency of mixed land use, were found to increase the probability of fatal pedestrian accidents in both locations [12].

Haleem et al. identified and compared the significant factors that affecting pedestrian accident injury severity at signalized and unsignalized intersections. At signalized intersections, higher AADT, higher speed limit, and percentage of heavy vehicle; very old pedestrians, adverse weather, faulty pedestrians, and dark lighting situation were associated with higher pedestrian injury severity. The results showed that a one-percent higher heavy vehicle percentage increases the probability of severe crashes. At unsignalized intersections, middle age and older pedestrians, at-fault pedestrians, dark lighting conditions and higher speed limit were associated with higher pedestrian accidents severity. [13]. Bargegol and Farghedayn [14] used Rough set theory to investigate the pedestrian accidents. The results of their study showed that a high percentage of pedestrian road accidents occurred at road with high speed limits. Also, they found out that the older pedestrians are at greater risk of fatal accidents.

According to the previous studies about pedestrian accidents, this study conducted to find the direct and indirect impact of various factors on the pedestrian accident severity in urban streets. In this paper, the effects of human factors (age and gender), environmental factors (weather conditions, lighting conditions and way type), time variables (time of crash and day of crash) and at-fault vehicle on the pedestrian accident severity were examined. In order to estimate the effective variables on pedestrian accident severity, accidents data were obtained from the Rasht traffic police database in the period March 2014 to March 2015. To achieve the main goal of this paper, which was estimating direct and indirect impact of various factors on the pedestrian accidents severity, path analysis has been used which is able to analyze the direct and indirect effects of independent variables on the dependent variable and capable of examining the unpredictable relation between variables.

2. Data collecting and Methodology

2.1. Location

Rasht is the largest city on Iran's Caspian Sea coast. According to the official census in 2011, the resident population of this city were reported as 639,951 people. Rasht daily fix floating population over 1200000 people. Also, geographically Rasht is located at 49 degrees and 36 minutes east longitude and 37 degrees and 16 minutes north latitude and its distance from Iran's capital is 300km. Rasht has a humid subtropical climate that makes this city one of the wettest city in Iran. Rasht has certain Mediterranean climate features such as a drier summer, but is also relatively continental and has cooler winters and higher seasonal temperature change more than any city in Iran [15].

2.2. Data Collecting

In most countries, the traffic accidents are recorded in accident reports by police officers, and the accident data is stored in a database. In Iran, accident data stored in traffic police dataset. The data used for this study collected from accident data which recorded in Rasht traffic police. In

current paper, among 2032 accidents that happened in urban streets of Rasht during March 2014 to March 2015, 557 accidents in which pedestrians were involved were used for analysis. According to the factors examined in the previous studies and due to limitations in the dataset that used for this paper and missing some factors such as ADDT and speed limit, factors that have been used in this paper are shown in Table 1. Thus 11 variables used as independent variables and one variable used as the dependent variable. The dependent variable in this study is the pedestrian accident severity and independent variables include weather condition (3 groups), lighting condition (3 groups), time of the crash (5 groups), surface condition (2 groups), day of crash (2 groups), driver age (in years), driver gender (2 groups), pedestrian age (in years), pedestrian gender (2 groups), way type (2 groups) and at-fault vehicle (4 groups).

Table 1. Definition of Variable

Variable	Variable Values	Variable Type
Accident severity	1- Injury 2- Fatal	Dependent
Weather condition	1- Clear 2- Cloudy 3- Rainy	Independent
Lighting condition	1- Day 2- Sunset 3- Night with enough light 4-Night without enough light	Independent
Time of crash	1- 0 am – 7 am 2- 7 am – 12 am 3- 12 am – 4 pm 4- 4 pm – 8 pm 5- 8 pm – 0 pm	Independent
Surface condition	1- Dry 2- Wet	Independent
Day of crash	1- Saturday to Wednesday 2- Weekend	Independent
Driver's age	By year	Independent
Driver gender	1- Male 2- Female	Independent
Pedestrian age	By year	Independent
Pedestrian gender	1- Male 2- Female	Independent
Type of way	1- Main 2- inferior	Independent
At-fault Vehicle	1- Passenger car 2- Van 3- Motorcycle 4- Heavy Vehicle	Independent

2.3. Path Analysis

Path analysis is a straightforward extension of multiple regression. Its aim is to provide estimates of the magnitude and significance of hypothesized causal connections between sets of variables. This type of model has the ability to examine unpredictable relationships between test variables, whether it is direct or indirect and to choose the most appropriate model. In fact, path analysis calculates the extended effect of each independent variable on the dependent variable directly and indirectly. The calculation of the path means finding the relationship between the correlation coefficients and path coefficients for each independent variable in the equation, path coefficients show the expected change in the dependent variable due to one unit change in the independent variable.

In Figure 1, the two exogenous variables (variable 1 and variable 2) are modeled as being correlated and as having both types of effects (direct and indirect) on variable 4. In most models, the endogenous variables are also affected by other factors which are outside of the models (e_i). The effects of such extraneous variables are displayed by the error terms in the model. If the variable affected only one variable, then the coefficient is equal to the correlation coefficient.

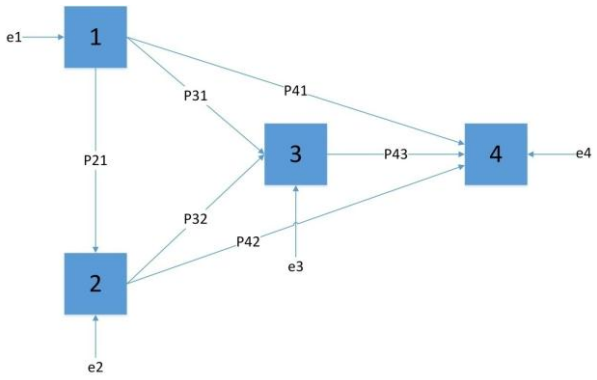

Figure 1. Experimental path analysis model

$$Z_1 = e_1$$
$$Z_2 = P_{21}Z_1 + e_2 \quad (1)$$
$$Z_3 = P_{31}Z_1 + P_{32}Z_2 + e_3$$
$$Z_4 = P_{41}Z_1 + P_{42}Z_2 + P_{43}Z_3 + e_4$$

There is four general principles for charting a path as

1) No ring allowed
2) No commute between variables allowed
3) The maximum number of allowed correlation between endogenous variables equal to the number of paths
4) Evaluation of the model performance

The main differences between the path analysis and regression analysis are listed as below

1) In regression analysis, dependence of a dependent variable on other variables (independent variables) checked in only one equation, but in path analysis, dependence of a dependent variable on other variables (independent variables) checked in several equations.
2) Regression shows the direct impact of the independent variables on the dependent variable, but path analysis have ability to explain the direct and indirect impact of the independent variable on the dependent variable.
3) Path analysis shows the fake relationships between variables, which means how much of this impact is due to the independent variable and how much is caused by external variables in the analysis.

3. Results and Discussion

One of the main objectives in the path analysis is to identify the degree of correspondence between experimental data and theoretical models. In order to understand the degree of correspondence between empirical data and theoretical model, the goodness of fit indexes are being used. Those tests showed an acceptable level and obtained value in Table 2.

The results of Table 2 show that the model which used for this test, in addition to have the appropriate fit (RAMSEA=0/031), has the ability of explaining high percentage of the factors affecting the dependent variable (pedestrian accidents severity). Also, low-value of CMIN/DF (CMIN/DF<2) shows that the model has good performance and the paths we choose for this analysis are correct.

Table 2. Acceptable level and obtained value for the goodness of fit

Criterion	Obtained value	Acceptable level	Description
CMIN/DF	1/536	1<CMIN/DF<3	Under 2 and less is better
RMSEA	0/031	RMSEA< 0.08	Closer to 0 is better
GFI	0/983	GFI> 0/090	From 0.7 to 0.9 is also acceptable
AGFI	0/968	AGFI> 0/90	From 0.7 to 0.9 is also acceptable
TLI	0/897	TLI> 0/90	From 0.7 to 0.9 is also acceptable
CFI	0/936	CFI> 0/90	From 0.7 to 0.9 is also acceptable
NFI	0/847	NFI> 0/90	From 0.7 to 0.9 is also acceptable

According to the regression models between data, results of path analysis can be categorized in three groups. First group is the variables with only direct effect, second group is the variables with direct and indirect effect and the third group is variables with no effect on dependent variable. The results of the path analysis are shown in Table 3.

Table 3. Direct, indirect and total effects of independent variables on dependent variable

Variable	Obtained value for effects			Type of effect
	Direct	Indirect	Total	
Day of crash	0.10	0.002	0.102	Positive
Lighting condition	-0.085	0	-0.085	Negative
Time of crash	0.077	-0.050	0.027	Positive
Faulty vehicle	0.064	0	0.064	Positive
Weather condition	-0.044	0	-0.044	Negative
Driver age	-0.085	-0.007	-0.092	Negative
Driver gender	0.021	-0.007	0.014	Positive
Pedestrian age	0.070	0	0.070	Positive
Pedestrian gender	-0.021	0.005	-0.016	Negative
Way type	0.025	0.002	0.027	Positive

Lighting conditions, weather conditions, type of at-fault vehicle and pedestrian age were the four variables which affect pedestrian accidents severity directly. The direct effect of lighting condition on pedestrian accidents severity is -0.085, which means for one unit (standard deviation) Change in lighting conditions, pedestrian accident severity will be reduced as much as 0.085 units. Weather conditions with coefficient -0.044 unit is the next factor that had a negative effect on pedestrian accidents severity. This impact shows that adverse weather condition reduces the severity of pedestrian accidents.

The third variable in this group is the type of at-fault vehicle that directly affects accident severity and the effect of this variable is 0.064. This coefficient shows positive

influence of this variable on the pedestrian accident severity [10, 12, 13]. The last variable that just directly affects the pedestrian accidents severity is pedestrian age, and the effect of this variable is 0.070. This positive effect shows that the probability of severe accidents increases with increasing the pedestrian age [3, 4, 10].

Day of the crash, time of crash, driver gender, driver age, pedestrian gender and way type were the six variables that had both direct and indirect effects on the severity of pedestrian accidents. Day of crash detected as an influential factor on the severity of pedestrian accidents. This variable in addition to the direct impact at a rate of 0.10 units, also had indirect effect at a rate of 0.002 units on the severity of pedestrian accidents. This result shows that weekend positively correlates with the severity of pedestrian accidents. Pedestrian gender in addition to the direct impact at a rate of -0.021 units, also had indirect effect at a rate of 0.005 unit on the severity of pedestrian accidents which means males are at more risk of severe injury in an accident [5]. Time of crash in addition to the direct impact at a rate of 0.077 units, also had indirect effect at a rate of -0.05 unit on the pedestrian accidents severity.

Driver gender in addition to the direct impact at a rate of 0.021 units, also had indirect effect at a rate of -0.007 unit on the pedestrian accidents severity which means female drivers are at more risk of fatal accidents [5]. The next variable which had both direct and indirect effect on the dependent variable is way type. This Variable in addition to the direct impact at a rate of 0.025 units, also had indirect effect at a rate of 0.002 units on the severity of pedestrian accidents that shows the pedestrian accidents severity increase in inferior streets. Finally, driver age in addition to the direct impact a rate of -0.085 unit that indicates the severity of accidents decreases with increasing the driver age, also had low indirect impact at a rate of -0.007 unit on the severity of pedestrian accidents. Among factors that studied in this paper only surface conditions had no significant effect on the dependent variable.

Based on the obtained results, pedestrian accidents severity model for Rasht urban streets shown in Figure 2.

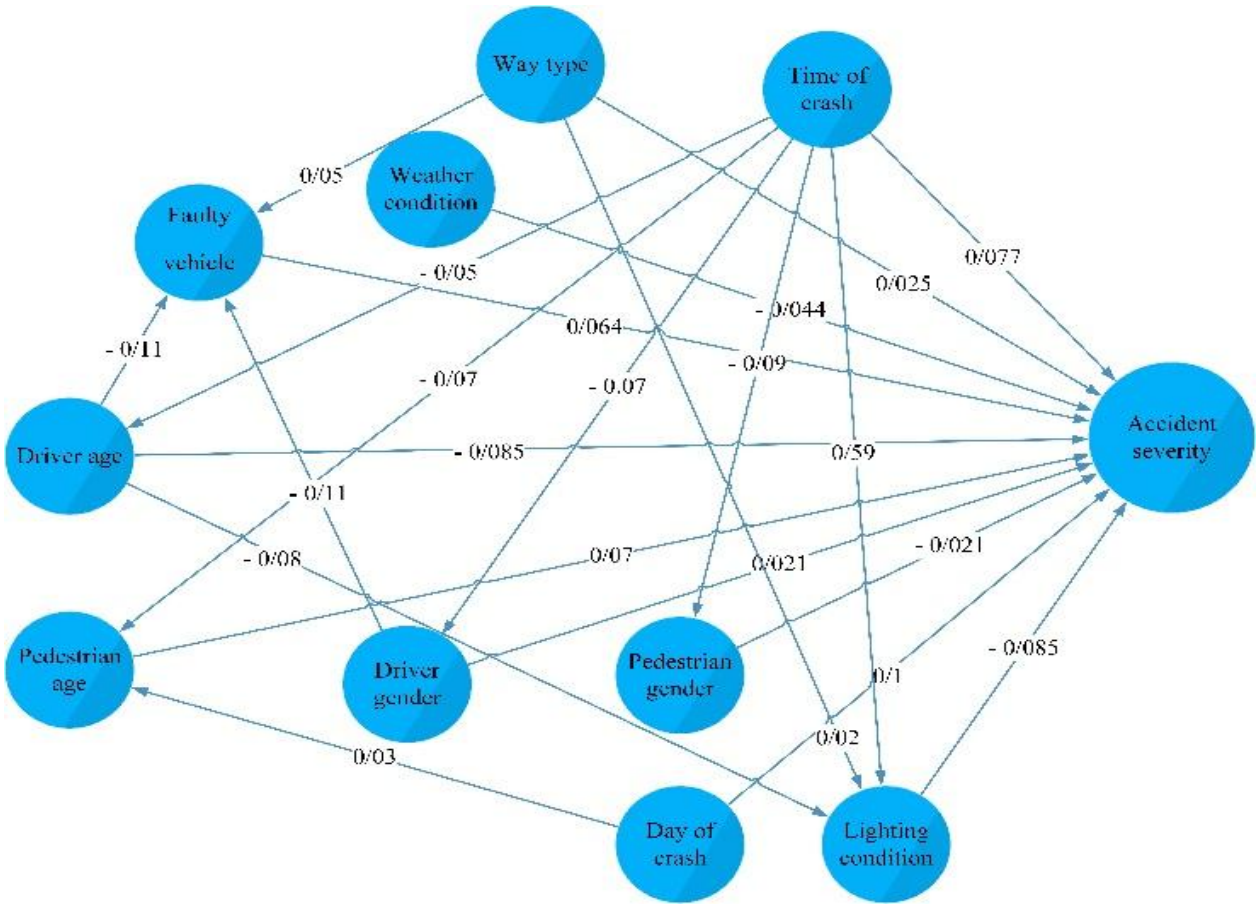

Figure 2. Experimental path analysis model for pedestrian accidents severity

4. Conclusions

In this study, the pedestrian accident severity analyzed by using path analysis. In terms of the factors that affect the pedestrian accidents severity, results of this study show that environmental parameters such dark lighting condition and adverse weather condition had a negative impact on the severity of the pedestrian accidents. This effect probably is due to more cautious driving in the dark night conditions and because people are being used to Rasht's rainy weather on most days of autumn and winter.

In terms of the relation between the age and accidents severity, results show a direct correlation between pedestrians age and pedestrian accidents severity, but this

result is in contrast with the one related to the driver age. In terms of the relation between gender and pedestrian accidents severity, the obtained results show that the severity of accidents on female pedestrians is less than males, but accident severity for male drivers is more than females. In relation to the time of the crash and the type of at-fault vehicle both of these factors had a positive impact on the pedestrian accidents severity that indicate the increasing severity of pedestrian accidents at peak times as well as the severe injury in accidents which heavy vehicles are involved. Finally about the way type results show that serious accidents occur on secondary roads are more than main roads.

References

[1] Road Safety Manual, PIARC Technical committee on road safety, C13, 2004.

[2] J.R. Treat, N.S. Tumber, S.T. Mcdonald, D. Shinar, R.D. Hume, R.E. Mayer, R.L. Stansifer, N.J. Castellan, trie-level study of causes of traffic accidents: Final report – Executive summary. Bloomington, Inistitute for Research in Public Safety (1979).

[3] R.O. Petch, R.R. Henson, Child road safety in the urban environment, Journal of Transport Geography 8 (2000) 197–211.

[4] A. Dommes, Age-related differences in street-crossing safety before and after training of older pedestrians, Accident Analysis and Prevention 44 (2012) 42– 47.

[5] M.J. Starness, P. Hadjizacharia, L.S. Chan, D. Demetriades, Automobile versus pedestrian injury: does gender matter?, The Journal of Emergency Medicine 40 (2011) 617–622.

[6] S.U. Jensen, Safety of pedestrians and two-wheelers. Road Directorate, Division of Road Safety and Environment, 148 (1998).

[7] Y. Page, En ville et ses effets sur la securite routiere, Les cahiers de 1, Observatoire 1 (1994) 43– 66.

[8] R.J. Schneider, A.J. Khattak, R.M. Ryznar, An accident waiting to happen: a spatial approach to proactive pedestrian planning, Accident Analysis and Prevention 36 (2004) 193–211.

[9] C. Lee, M. Abdel-Aty, Comprehensive analysis of vehicle–pedestrian crashes at intersections in Florida, Accident Analysis and Prevention 37 (2005) 775– 786.

[10] J. Kim, G. Ulfarsson, V. Shankar, F. Mannering, A note on modeling pedestrian-injury severity in motor-vehicle crashes with the mixed logit model, Accident Analysis and Prevention 42 (2010) 1751–1758.

[11] K. Jang, S. Park, S. Kang, K. Song, S. Chung, Evaluation of pedestrian safety: geographical identification of pedestrian crash hotspots and evaluating risk factors for injury severity. Proceedings of the 92nd Annual Meeting of the Transportation Research Board, Washington, D.C. 2393 (2013).

[12] M. Mohamed, N. Saunier, L. Miranda-Moreno, S. Ukkusuri, A clustering regression approach: a comprehensive injury severity analysis of pedestrian– vehicle crashes in New York, US and Montreal, Canada, Safety Science 54 (2013) 27– 37.

[13] K. Haleem, P. Alluri, A. Gan, Analyzing pedestrian crash injury severity at signalized and non-signalized locations, Accident Analysis and Prevention 81 (2015) 14– 23.

[14] I. Bargegol, S. Farghedayn , Analyzing parameters eff effecting pedestrian accidents in urban streets using Rough set theory, 4th International Traffic Accident Conference, University of Tehran, Tehran, Iran, (2015).

[15] I. Bargegol, V.N.M. gilani, M. Ghasedi, M. Ghorbanzadeh, Delay modeling of un-signalized rounabouts using neural network and regression, Computational Research Progress in Applied Scince & Engineering 2(1) (2016) 28–34.