IJE TRANSACTIONS C: Aspects Vol. 30, No. 12, (December 2017) 1814-1821

International Journal of Engineering

Journal Homepage: www.ije.ir

RESEARCH NOTE

Relationship between Pedestrians' Speed, Density and Flow Rate of Crossings through Urban Intersections (Case Study: Rasht Metropolis)

I. Bargegol[a], V. Najafi Moghaddam Gilani*[b], F. Jamshidpour[c]

[a] *Department of Civil Engineering, Faculty of Engineering University of Guilan, Rasht, Iran*
[b] *Highway and Transportation Engineering, Faculty of Engineering, University of Guilan, Iran*
[c] *Transportation Engineering, Managing Director of Transport and Traffic, Rasht Metropolitan Municipality, Rasht, Iran*

PAPER INFO

Paper history:
Received 17 June 2017
Received in revised form 18 August 2017
Accepted 08 September 2017

Keywords:
Pedestrian
Crosswalk
Intersection
Speed
Density
Flow Rate

ABSTRACT

Travels within the city are done in different ways, by vehicle or on foot. Thus, inevitably, a part of the travel is always done on foot. Since intersections as traffic nodes are determinant factor in transportation network capacity, any disruption in them leads to severe reduction in network capacity. Unfortunately, pedestrian behavior has received little attention in Iran. While this is a very important and effective part of traffic engineering. In some cases, pedestrians are the main cause of increasing road users' delay, therefore, the most important action before anything, is identifying the characteristics of pedestrians. Identifying issues such as speed, volume and density of pedestrians are necessary to control the traffic flow and delay, and can lead to better design of facilities associated with pedestrians. Cases that are studied in this study are: the relationship between speed, density and pedestrians' flow rate while crossing the street. In this study, the data was collected by filming four intersections in Rasht Metropolis for 15 hours, and the number of pedestrians crossing that were studied was 8489. Two intersections had traffic lights and the other ones had no traffic lights. Then, the relationship between speed, density and volume of pedestrians were obtained by determining the variables of speed, density and volume of pedestrians and using linear and nonlinear regression method and finding the correlation coefficient between the variables. The results showed that for pedestrians, there is a relationship between the flow rate and density with a high correlation coefficient in crossing through crosswalk (R^2=0.99) and outside the crosswalk (R^2=0.99). But the relationship between speed and flow rate was not significant (crossing through crosswalk, R^2=0.29 and outside the crosswalk, R^2=0.24); furthermore, speed and density had no significant relationship (crossing through crosswalk, R^2=0.36 and outside the crosswalk, R^2=0.28).

***doi**: 10.5829/ije.2017.30.12c.01*

1. INTRODUCTION

Walking is one of the modes of transportation that can communicate a private environment, the environment and the community in the absence of other means of transportation, especially motor vehicles [1]. One of the important issues in the discussion of the pedestrians is their impact on the transportation network which refers to chaotic presence of pedestrians on the streets and at unauthorized times when crossing the intersection. Both urban and rural roads safety is significantly dependent on the actual behavior of the users. This behavior is affected by their attitudes, beliefs and expectations. Consequently, understanding the beliefs and attitudes may contribute to understanding the traffic behavior [2, 3]. According to the diverse habits of walking, pedestrian behavior difference due to individual characteristics such as gender, age [4], number of people in a group [5], clothing, even the cultural and economic level of the individual, we will have a huge variety of items such as the type of decision to cross the intersection, walking speed and people's volume in the day hours; but cars behavioral diversity is much less than pedestrians. The volume and capacity of intersections and behavior of drivers have been studied over and over again; but the issue is less about pedestrians. So, controlling vehicles is much easier than

*Corresponding Author's Email: vahid.moghaddam90@gmail.com (V. Najafi Moghaddam Gilani)

Please cite this article as: I. Bargegol, V. Najafi Moghaddam Gilani, F. Jamshidpour, Relationship between Pedestrians' Speed, Density and Flow Rate of Crossings through Urban Intersections (Case Study: Rasht Metropolis), International Journal of Engineering (IJE), TRANSACTIONS C: Aspects Vol. 30, No. 12, (December 2017) 1814-1821

pedestrians, because vehicles have less specific diverse behavior than pedestrians.

The number of studies in the field of pedestrian is very low compared to other issues of traffic and most of the studies about pedestrian behavior were focused on the sidewalks, walking systems design, and also pedestrian safety and less focus was conducted on the pedestrian behavior, and concepts such as speed, density, volume, crossing through crosswalk and outside the crosswalk, etc. However, worthwhile researches have been done in various countries in order to better understand the behavior of pedestrians and create more facilities for these groups of users. In this paper, the relationship between speed, density and flow for different states is obtained by studying the behavior of pedestrians, crossing through crosswalk and outside the crosswalk and the time of crossing (either pedestrian green time or red time for crossing) thereby using linear and non-linear regression analysis. Finally, it was observed that there is a relationship with a high correlation coefficient between flow rate and density.

2. LITERATURE REVIEW

Hughes [6] provided a model based on differential equations which analysed the pedestrians' movement in a whole scale and based on a goal of the movement of a big group of them. This group of the pedestrian moved constantly and their flow was described as speed and density. The place and time were also modelled by the independent and constant variables. In this model, the flow relations, density, and speed were determined like the fluid mechanics and other similar physical systems. In a broad community, the pedestrians formed a range of motion, like particles in a fluid, which had the qualities similar to the qualities of the fluids.

In a study on the pilgrims' movement in Mecca in 2007, Helbing et al. [7] proposed a figure density of the pedestrians based on simulation. This figure was based on a modelling of the pedestrians' movement on the basis of the social force, and it was used to compare the density values in the simulation.

Liu et al. [8] obtained the density-speed and density-flow relations in some functions by gathering data of the characteristics of the pedestrians' flow in the staircases of some pedestrians' distributional centers in China, such as Shanghai Subway and Shanghai Train station. They also compared the pedestrians' flow in the staircases with the vehicles' flow.

Chen et al. [9] investigated the longitudinal flow of pedestrians in roofed passages and to collect data, they studied flat surface, descending staircase, ascending staircase and two-sided staircase in Shanghai Metro Station which has a large volume of passengers. They obtained walking flow parameters including speed, density and volume in low and high density conditions using a video capture and then analysed the information to find the relationships between the data. Finally, they used statistical regression and reality compatibility to determine pedestrian traffic flow model of the speed-density and volume-density and relationship in order to use all observed facilities.

Plaue et al. [10] examined the density of pedestrians. They filmed the pedestrians in a roofed building to collect information and then used mathematical models and experimental data for numerical simulation and finally suggested a method for calculating the density of pedestrians.

Plaue et al. [11] proposed a method to calculate the density of pedestrians. They discussed different ways to calculate the density and compared them for different population and geometric conditions. Eventually, they provided an algorithm to calculate the density.

Tang et al. [12] compared the speed and density of pedestrians in Japan and China to illustrate the different characteristics of pedestrians behaviour in different cultural backgrounds. They stated that the relationship between speed and density of pedestrians is a key point in walking. The necessity and importance of pedestrians behaviour is also noted in this paper and finally it was concluded that the speed and density are low in leisure time, and high in rush hour, speed in stepped passages is lower than flat ones and finally it was concluded that in China, people use shortcuts to reach their destinations faster but in Japan, people move faster.

Shafabakhsh et al. [13] simulated the pedestrians to estimate the impact of elderly population on pedestrian movement flow in the sidewalk using micro-simulation method.

Rastogi et al. [14] by collecting the pedestrian movements in 19 locations in 5 cities in India and classifying the pedestrians based on the width found that the relationship between speed and density in sidewalks with various widths is an exponential relationship. They also suggested that the narrowness of the sidewalks leads to the reduced free flow speed.

Bargegol et al. [15] with modeling of 8541 pedestrians' flow data in two sidewalks and a walkable street in Rasht found that the optimal density and the capacity of the flow rate in all facilities of the sidewalks and walkable streets of Rasht are 2.83 (Ped/m^2) and 96 (Ped/m/min), respectively.

In this paper, "free crossing conditions" means conditions in which the pedestrians in green time and without any interference caused by cars, cross the street; while "crossing with interferences in pedestrians green time", are conditions in which, despite green traffic light, pedestrians are affected by the vehicles interferences when crossing the street. Interferences of vehicles include: turning right, stopping on the crosswalk (while pedestrians are crossing through crosswalk), stopping behind the lines (while pedestrians are crossing outside the crosswalk or among the cars) and movements of cars leaving the intersection at the end moment of the phase and at the last moment when they face with phase change before the full exit. Also, "pedestrians crossing when it is red" (green for cars), is a condition in which the pedestrians crossed the street with severe impact of passing vehicles. Meanwhile, according to the Highway Capacity Manual, 15th percentile speed, is considered the speed equal to the cumulative frequency curve for pedestrians.

3. METHODOLOGY

In this study, we used library method to achieve goals; then we applied field method using camera for video recording in order to collect data which includes pedestrians' different behavioral characteristics such as gender, age, type of dressing, type of movement (group, non-group), direction (through crosswalk, out of crosswalk), crossing time (the pedestrian green time, pedestrian red time) and the crossing conditions (in conditions of free and without interference impact from vehicles, in conditions with the impact of interfering vehicles). Next, 8489 pedestrians were evaluated by statistical tests. The used statistical tests were: correlation test with Spearman correlation coefficients and the linear and nonlinear regression.

3. 1. Case study This study was conducted in the metropolis of Rasht. This city is one of the Iranian metropolises and the capital of Guilan province in north. Rasht is located at 49˚36' E and 37˚16' N and its distance from Tehran (Capital of Iran) is 325 km. This city with 180 square kilometre area is located in a flat and level land and is 5 meters over international waters and 7 meters above sea level. According to the official census in 1390, its population is 639,951 and the population density was announced 4340 people per square kilometre. Its climate is temperate and very humid and annual rainfall is about 1500 mm [16].
In this study, four important and busy intersections of the city were selected, two of which had traffic lights and the other two intersections were without traffic lights. After filming, statistical record was started. First, the pedestrians were to count as the following outline:

- The number of people crossing through the crosswalk,
- The number of people crossing outside the crosswalk and regardless of the crosswalk,
- The number of people crossing at the pedestrians green time,
- The number of people crossing at the pedestrians red time and regardless of the traffic lights,
- The number of people crossing at the pedestrians green time but with interference of vehicles turning right, cars left from the light in the intersection and cars stopped on the crosswalk line,
- The number of two-member, three-member or rarely four-member groups considering the 5 conditions above.

3. 2. Statistical Analysis Method In many cases, researchers conduct study to examine the relationship between two random variables. In these circumstances of the relationship between two quantitative variables, measures called Pearson Correlation Coefficient were used. Usually in investigating the correlation between two variables, the values are dependent on each other. In analysing the correlation between two variables one may not select any of the two variables as the reason for the other. Primarily for the study of harmony between two variables, researcher looks for measures having the following features:

- Does not depend on the unit of tow community.
- Is bounded.

The data set used in a correlation test including values obtained from the two variables X and Y can be in the form of a bivariate random sample (X1,Y1),..., (Xn,Yn). Study of the relationship between variables is performed by correlation analysis, which indicates that there is a linear relationship between two variables. The correlation coefficient formula is as Equation (1):

$$r = \frac{Cov\,(X,Y)}{S_x S_y} = \frac{\sum_{i=1}^{n}(x_i-\bar{x})(y_i-\bar{y})}{\sqrt{[\sum_{i=1}^{n}(x_i-\bar{x})^2][\sum_{i=1}^{n}(y_i-\bar{y})^2]}} \quad (1)$$

The correlation coefficient is always a value between zero and one (-1 < *r* < +1) and according to the value of *r* in different states will have different interpretations of the relationship between X and Y.

- *r* = 1, in this state: correlation is complete and direct, and increasing the value of *x*, the value of *y* definitely increases.
- *r* = -1, in this state: correlation is complete and inverse, and increasing the value of *x*, the value of *y* decreases.
- -1 < *r* < 0, in this state: correlation is incomplete and inverse, and increasing the value of *x*, the value of *y* partially decreases.
- 0 < *r* < 1, in this state: correlation is incomplete and direct, and increasing the value of *x*, the value of *y* partially increases.
- *r* = 0, there is no linear relationship (For example, the relationship may be a quadratic).

Zero correlation coefficient does not mean there is no relationship between two variables, but there is no linear relationship between two of them. The reason for this is that the formula for the Pearson correlation coefficient only measures the linear relationship. In one-way correlation test, the following assumptions are examined as Equation (2):

$$1\begin{cases}H_0: r = 0\\ H_1: r > 0\end{cases} \qquad 2\begin{cases}H_0: r = 0\\ H_1: r < 0\end{cases} \tag{2}$$

The direction of inequality is determined according to estimates for sample *r*. If *r* is positive, we use test (1) and if it is negative, we use test (2). The value of Pearson correlation coefficient, indicates the severity of the relationship, this measure evaluates the strength of linear relationship between the variables x and y. If the Pearson value is between zero and 0.3, it is weak, between 0.3 and 0.6, it is medium and above 0.6 it is strong. This measure is conventional, but it is usually used in interpreting the results and different studies. It was first introduced by Karl Pearson, an English famous scientist, that's why it's called the Pearson coefficient. This coefficient is defined as Equation (3):

$$r = \frac{S_{xy}}{\sqrt{S_{xx}S_{yy}}} \tag{3}$$

In the context of regression, the purpose is to obtain a mathematical relationship between one or more independent variables and a dependent variable in order to predict the dependent variable value using the value(s) of the independent variables. Therefore, in regression, not only is the correlation between several independent variables and a dependent variable is evaluated, but also the type and shape of the mathematical relationship is determined. In simple linear regression, the relationship between the independent variable x and the dependent variable y is in the form of a straight line and the equation is written as y = αx + β. α and β are called the regression parameters, α is constant and β is the slope of the line. Estimation of α indicates the predicted value of y for x = 0 and estimation of β indicates the extent of y change if x increases for one unit. In the linear regression, it is assumed that y is normally distributed.

In the linear regression, dependent variable yi is a linear compound of coefficients (there is no need to be linear to the independent variables). For example, the following simple regression analysis with N points, dependent variable of xi and coefficients of β_0 and β_1 is linear as Equation (4):

$$yi = \beta 0 + \beta 1\chi i + \epsilon i, \quad i = 1, \ldots, \mathrm{N} \tag{4}$$

In both cases, $\in i$ is the error value and footnote i shows the number of each observation (each pair of xi and yi). Having a set of these points, the model can be obtained as Equation (5):

$$yi = \beta 0 + \beta 1\chi i + ei, \quad i = 1, \ldots, N \tag{5}$$

Parameter ei is the residual. $ei = y_{(i)} - y_{(i-1)}$: The common method to obtain parameters is the method of least squares.

In this method, the parameters are obtained by minimizing Equation (6):

$$SSE = \sum e_i^2 \tag{6}$$

In the case of simple regression, the parameters of this method will be equals to Equations (7) and (8):

$$\beta_1 = \frac{\sum(xi-x)(yi-y)}{\sum(xi-x)} \tag{7}$$

$$\beta_0 = y - \beta_1 x \tag{8}$$

Regression is the most widely used statistical methods for the measurement and representation of the relationship model between two variables. Linear regression estimates the coefficients of the linear equation that has the closest match to the observed data. Using the equation of the back line, prediction of subsequent values is also possible. In regression equation, we have an independent variable and a dependent variable and in the multiple regression equation the number of independent variables is more than one. In this study, drawing the scatter plot and curve fitting, the required equations by regression were obtained in SPSS.

4. RESULTS AND DISCUSSION

In this study, the mean crossing speed and 15th percentile of the people crossing in two intersections with traffic lights, in the morning, afternoon and evening, and in two intersections without traffic lights at the peak, according to gender, type of dressing, and single and group movements were taken in accordance with Tables 1 to 3. In two intersections with traffic lights, crossing conditions were divided into three categories:

- Free crossing at pedestrians green time (without being affected by vehicles interferences).
- Crossing at pedestrians green time, so that pedestrians move from among the cars (for pedestrians who cross the areas without crosswalk lines).
- Crossing at pedestrians red time and with the severe impact of vehicles interferences.

At the intersection without traffic lights at the peak of crossing, the condition of crossing were almost identical for all the pedestrians and it was not possible to classify the crossing conditions, because at intersections without traffic lights, there is no specific and safe time for pedestrians to cross. All units in Tables 1 to 3 are based on m/s.

The main purpose of this study is to determine the relationship between speed, density and flow rate of pedestrian that have been addressed in this section. To determine these relations, first, the number of people crossing each intersection through crosswalk or out of crosswalk per minute was obtained by recorded videos.

TABLE 1. Results of the study of signalized intersections in free crossing

Classification	Type of movement	Number of people	Mean speed	Standard deviation	Median	V_{15}	Lowest speed observed	Highest speed observed
Males	Through crosswalk	1380	1.29	0.181	1.29	1.03	0.53	2.22
	Out of crosswalk	322	1.28	0.172	1.29	1.02	0.86	1.90
Women with regular Islamic dressing	Through crosswalk	619	1.19	0.155	1.20	0.94	0.75	1.67
	Out of crosswalk	148	1.20	0.189	1.18	0.94	0.65	1.72
Women with Islamic veils dressing	Through crosswalk	242	1.10	0.152	1.11	0.84	0.61	1.54
	Out of crosswalk	43	1.09	0.178	1.11	0.80	0.79	1.45
Group movements	Through crosswalk	833	1.11	1.132	1.11	0.88	0.91	1.67
	Out of crosswalk	139	1.09	0.158	1.10	0.83	0.74	1.53

TABLE 2. The results of signalized intersections when crossing with vehicles interferences

Classification	Type of movement	Number of people	Mean speed	Standard deviation	Median	V_{15}	Lowest speed observed	Highest speed observed
Males	Through crosswalk	994	1.09	0.180	1.08	0.83	0.41	2.22
	Out of crosswalk	614	1.07	0.184	1.06	0.78	0.62	1.74
Women with regular Islamic dressing	Through crosswalk	428	1.03	0.151	1.01	0.78	0.64	1.54
	Out of crosswalk	267	1.02	0.176	1.02	0.74	0.65	1.82
Women with Islamic veils dressing	Through crosswalk	153	0.99	0.148	0.97	0.74	0.64	1.50
	Out of crosswalk	48	0.94	0.127	0.95	0.70	0.57	1.18
Group movements	Through crosswalk	514	0.97	0.136	0.95	0.74	0.62	1.54
	Out of crosswalk	395	0.92	0.169	0.91	0.66	0.52	1.54

TABLE 3. The results of pedestrian's crossing with the impact of vehicles interferences at un-signalized intersections

Classification	Type of movement	Number of people	Mean speed	Standard deviation	Median	V_{15}	Lowest speed observed	Highest speed observed
Males	Through crosswalk	192	1.13	0.198	1.12	0.84	0.70	1.82
	Out of crosswalk	250	1.15	0.138	1.14	0.88	0.83	1.74
Women with regular Islamic dressing	Through crosswalk	133	1.04	0.129	1.05	0.80	0.67	1.33
	Out of crosswalk	167	1.05	0.136	1.04	0.82	0.77	1.41
Women dressing in Islamic veils	Through crosswalk	25	0.99	0.125	1.00	0.74	0.75	1.29
	Out of crosswalk	35	0.94	0.095	0.92	0.76	0.71	1.26
Group movements	Through crosswalk	162	0.99	0.109	0.98	0.76	0.80	1.25
	Out of crosswalk	452	0.99	0.107	0.99	0.75	0.75	1.33

Then, using the stopwatch, the time for all pedestrians crossing the intersection (8489 pedestrian) were obtained and by dividing the distance traveled by the crossing duration, the speeds of movement of persons (S) were provided. Then, using the relation ($\nu=\rho\times S$) proposed by the HCM (2000, 2010) [17, 18], the density for each minute was calculated. At the end, the graphs of density-flow rate, speed-flow rate and speed-density were drawn by the data obtained for all the intersections in conditions of crossing through crosswalk or out of crosswalk (Figures 1 to 6).

Finally, the mathematical relationships between variables were calculated using regression analysis and its formula is visible on the graph. The amount of R

(Pearson correlation coefficient) shows the compatibility of the forecast graph with real data. As can be seen in the graph, the highest relationship between the variables is observed in the density-flowrate graphs.

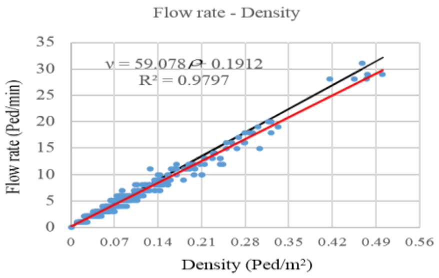

Figure 1. The relationship between flow rate and density when crossing out of crosswalk (all intersections)

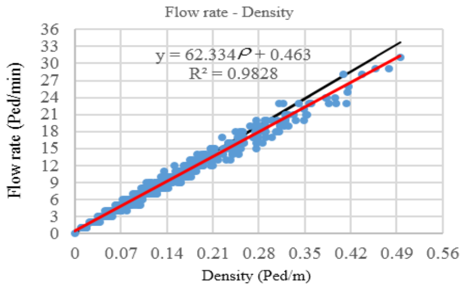

Figure 2. The relationship between flow rate and density when crossing crosswalk (all intersections)

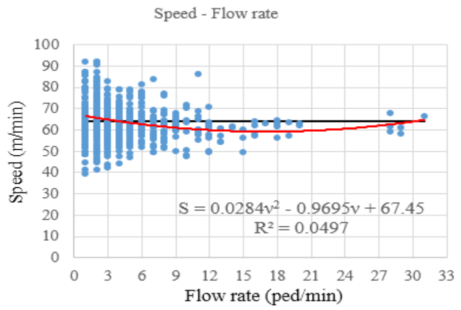

Figure 3. The relationship between speed and flow rate when crossing out of crosswalk (all intersections)

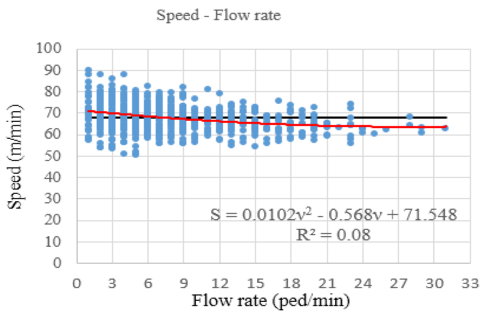

Figure 4. The relationship between speed and flow rate when crossing crosswalk (all intersections)

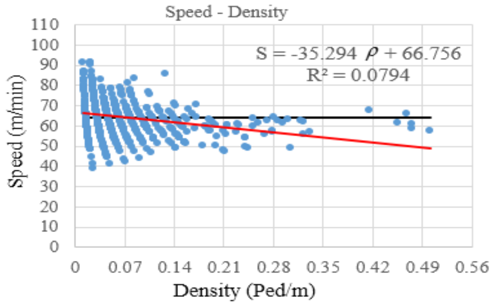

Figure 5. The relationship between speed and density when crossing out of crosswalk (all intersections)

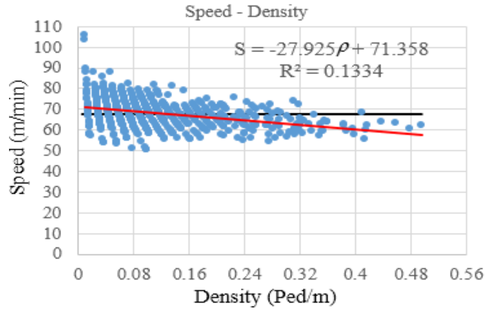

Figure 6. The relationship between speed and density when crossing crosswalk (all intersections)

As shown in Figures 1 to 6, the highest relationship between the variables is observed in density-flow rate graphs.

To see the relationship between speed, density and volume for all pedestrians (n=8489) that were evaluated in this study, the equations for all intersections were plotted. The results of all pedestrians crossing the intersections through crosswalks were obtained as Equations (9) to (11):

$\nu = 62.334\rho + 0.463$ $R^2 = 0.9828$ (9)

$S = 0.0102\nu^2 - 0.568\nu + 71.548$ $R^2 = 0.08$ (10)

$S = -27.925\rho + 71.358$ $R^2 = 0.1334$ (11)

The results of the pedestrians crossing out of crosswalks at all intersections are as Equations (12) to (14):

$\nu = 59.078\rho + 0.1912$ $R^2 = 0.9797$ (12)

$S = 0.0284\nu^2 - 0.9695\nu + 67.45$ $R^2 = 0.0497$ (13)

$S = -35.294\rho + 66.756$ $R^2 = 0.0794$ (14)

where, ν is the flow rate, S denotes pedestrians speed and ρ is their density.

Due to extensive data, collected from quiet to busy time, Figures 3 to 6 are parabolic. This is due to the changes in the speed of pedestrians in different conditions of saturated, half-saturated and unsaturated. Thus, in these graphs, the peak value of the parabola can be considered on the mean speed. The mean speed is shown with solid lines in graphs 3 to 6. Due to the low scattering data from the mean speed, the pedestrians speed for Rasht can be considered constant and regardless of the density.

According to Equations (9) and (12), the flow rate and density values with a high correlation coefficient follow the same linear equation of $\nu = \rho \times S$. Replacing the mean value, the constant S=67.97 m/min for crossing through crosswalk and constant S=64.15 m/min for crossing out of crosswalk, this relationship is transformed into Equations (15) and (16):

$$\nu = 64.15 \times \rho \tag{15}$$

$$\nu = 67.97 \times \rho \tag{16}$$

The thick solid lines in Figures 1 and 2, show these equations, respectively.

Comparing Equations (9) and (12) to (15) and (16), it is shown that the basic assumption of 1 univariate linear relationship between flow rate and density is correct and with a little neglect, we assign the mean rate for all values of densities and obtain the flow rate according to that.

5. CONCLUSION

The purpose of this study was to understand the behavior of pedestrians crossing the intersection. With studies conducted, many pedestrian behavioral characteristics were identified:

- The intersections with traffic lights, pedestrians crossing the street show such a behavior that prevents the speed reduction by population growth. Observations showed that in some cases when pedestrians in crowd are waiting for the people in front to cross the street through crosswalks, they change their path to an area out of the crosswalk to escape from the crowd and cross the street fast. At intersections without traffic lights, it is observed that accumulation of the population is less than intersections with traffic lights due to scattering of crossing out of crosswalks. For this reason, the effect of flow rate and density on the speed in these intersections will be far less. Obviously in the relationship between flow rate and density, with increasing flow rate and the number of pedestrians crossing, the density will increase. Therefore, it was concluded that in the city of Rasht, flow rate and density have no great influence on the speed of crossing, but the density increases with increasing flow rate.
- Relations of speed, density and flow rate also showed that in pedestrians crossing through intersections, the flow rate and density are strongly dependent on each other, but the two variables do not have a great impact on the speed of pedestrians. In other words, with crowd increase, the pedestrians look for ways to escape and cross fast through intersection. For pedestrians, there is a relationship between the flow rate and density with a high correlation coefficient in crossing though crosswalk ($R^2 = 0.99$) and out of crosswalk ($R^2 = 0.99$), but the relationship between speed and flow rate is not significant (in crossing through crosswalk $R^2 = 0.29$ and out of crosswalk $R^2 = 0.24$). Also, there is no significant relationship between speed and density (in crossing through crosswalk $R^2 = 0.36$ and out of crosswalk $R^2 = 0.28$).

6. REFERENCES

1. Gehl, J. and Gemzoe, L., Winning back public space, in Sustainable transport. 2003.97-106.
2. Papadimitriou, E., Theofilatos, A. and Yannis, G., "Patterns of pedestrian attitudes, perceptions and behaviour in europe", ***Safety Science***, Vol. 53, (2013), 114-122.
3. Ayati, E., "Rural road traffic accidents in iran", ***International Journal of Engineering***, Vol. 2, No. 3&488.
4. Hamed, M.M., "Analysis of pedestrians’ behavior at pedestrian crossings", ***Safety Science***, Vol. 38, No. 1, (2001), 63-82.
5. Boles, W., "The effect of density, sex, and group size upon pedestrian walking velocity", ***Man-environment Systems***, Vol., No., (1981).
6. Hughes, R.L., "A continuum theory for the flow of pedestrians", ***Transportation Research Part B: Methodological***, Vol. 36, No. 6, (2002), 507-535.
7. Helbing, D., Johansson, A. and Al-Abideen, H.Z., "Dynamics of crowd disasters: An empirical study", ***Physical Review E***, Vol. 75, No. 4, (2007), 046109.
8. Liu, W., Zhou, H. and He, Q., "Modeling pedestrians flow on stairways in shanghai metro transfer station", in Intelligent Computation Technology and Automation (ICICTA), 2008 International Conference on, IEEE. Vol. 2, (2008), 263-267.
9. Chen, X., Ye, J. and Jian, N., "Relationships and characteristics of pedestrian traffic flow in confined passageways", ***Transportation Research Record: Journal of the Transportation Research Board***, No. 2198, (2010), 32-40.
10. Plaue, M., Chen, M., Bärwolff, G. and Schwandt, H., "Trajectory extraction and density analysis of intersecting pedestrian flows from video recordings", ***Photogrammetric Image Analysis***, (2011), 285-296.
11. Plaue, M., Bärwolff, G. and Schwandt, H., On measuring pedestrian density and flow fields in dense as well as sparse crowds, in Pedestrian and evacuation dynamics, (2012). Springer.411-424.
12. Tang, S., Kwak, D. and Kitahara, T., "Study on pedestrian's speed and density under the mid-low density: Comparison of pedestrian behavior on the station square between chiba, japan and shanghai, china".
13. Shafabakhsh, G., Mohammadi, M. and Mirzanamadi, R., "Analysis of pedestrians' walking speed in iran's sidewalks

(considering the elderly)", ***Text Road Publication, Journal of Basic and Applied Scientific Research***, (2013), 172-182.

14. Rastogi, R. and Chandra, S., "Pedestrian flow characteristics for different pedestrian facilities and situations", European Transport\Trasporti Europei, Vol. 53, Paper n 6, (2013).
15. Bargegol, I., Gilani, V.N.M. and Jamshidpour, F., "Modeling pedestrian flow at central business district" ***Jurnal UMP Social Sciences and Technology Managemen***t, Vol. 3, (2015), 223-229.
16. Center, I.S., "Official results of census of populations and houses of iran", (2011).
17. Manual, H.C., "Transportation research board", National Research Council, Washington, ***DC***, Vol. 113, (2000).
18. Manual, H.C., "Transportation research board of the national academies, 2010", (2010).

Relationship between Pedestrians' Speed, Density and Flow Rate of Crossings through Urban Intersections (Case Study: Rasht Metropolis)

RESEARCH NOTE

I. Bargegol[a], V. Najafi Moghaddam Gilani[b], F. Jamshidpour[c]

[a] *Department of Civil Engineering, Faculty of Engineering University of Guilan, Rasht, Iran*
[b] *Highway and Transportation Engineering, Faculty of Engineering, University of Guilan, Iran*
[c] *Transportation Engineering, Managing Director of Transport and Traffic, Rasht Metropolitan Municipality, Rasht, Iran*

PAPER INFO

Paper history:
Received 17 June 2017
Received in revised form 18 August 2017
Accepted 08 September 2017

Keywords:
Pedestrian
Crosswalk
Intersection
Speed
Density
Flow Rate

چکیده

سفرهای درون‌شهری به شکل‌های مختلف، با وسایل نقلیه یا به‌صورت پیاده انجام می‌شود، لیکن در تمامی سفرها بخشی از سفر ناگزیر به‌صورت پیاده انجام می‌گیرد. از آنجا که تقاطع‌ها به‌عنوان گره‌های ترافیکی عامل تعیین‌کننده‌ی ظرفیت شبکه حمل‌ونقل می‌باشند ، هرگونه اختلال در آن‌ها باعث کاهش شدید ظرفیت شبکه می‌شود. متأسفانه در ایران توجه به رفتار ترافیکی عابران پیاده کمتر موردتوجه قرار گرفته است و این درحالیست که این قسمت از بخش‌های بسیار مهم و اثرگذار مهندسی ترافیک است و در برخی موارد عابران پیاده دلیل اصلی افزایش تأخیر کاربران راه می‌باشند، لذا مهم‌ترین اقدام قبل از هر چیز شناخت ویژگی‌های عابران است. شناخت مواردی از قبیل سرعت، حجم و چگالی عابران پیاده امری ضروری جهت کنترل جریان ترافیک و میزان تأخیر است و می‌تواند به طراحی بهتر امکانات مرتبط با عابران منتهی شود. مواردی که در این پژوهش مورد مطالعه قرار می‌گیرند عبارتند از: رابطه میان سرعت، چگالی و نرخ جریان عابران پیاده در عبور از عرض خیابان. در این پژوهش با تصویربرداری از چهار تقاطع به مدت ۱۵ ساعت در کلانشهر رشت اقدام به جمع آوری اطلاعات گردید و تعداد ۸۴۸۹ عابر عبوری مورد بررسی قرار گرفتند. دو تقاطع مورد بررسی چراغدار و دو تقاطع دیگر بدون چراغ بودند. سپس با تعیین متغیرهای سرعت، چگالی و حجم عابران پیاده و با روش رگرسیون خطی و غیرخطی و یافتن ضریب همبستگی بین متغیرها، روابط بین سرعت، چگالی و حجم عابران پیاده بدست آورده شدند. نتایج نشان داد برای عابران پیاده، بین نرخ جریان و چگالی یک رابطه با ضریب همبستگی بالا در عبور از خط‌کشی (R^2=۰/۹۹) و در عبور از محل‌های غیر خط‌کشی (R^2=۰/۹۹) برقرار است، اما ارتباط بین متغیرهای سرعت و نرخ جریان معنادار نبود (در عبور از خط‌کشی R^2=۰/۲۹ و در عبور از محل‌های غیر خط‌کشی R^2=۰/۲۴)، همچنین سرعت و چگالی نیز ارتباط معناداری با یکدیگر ندارند (در عبور از خط‌کشی R^2=۰/۳۶ و در عبور از محل‌های غیر خط‌کشی R^2=۰/۲۸).

***doi**: 10.5829/ije.2017.30.12c.01*