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MICRO SIMULATION OF THE ELDERLY POPULATION'S EFFECT ON IRAN'S PEDESTRIAN WALKING FLOW

ABSTRACT

From 1996 to 2006 Iran's population structure experienced considerable changes. During the mentioned period, the share of the population under 15 decreased from 39.6% to 28%. Considering this decrease, Iran's population was quickly guided to oldness which will have irreversible social and economic repercussions on the country's future progress. The main objective of this study is to estimate the effects of the elderly on the moving stream of other pedestrians on Iran's sidewalks, which is done for the first time in Iran using the Micro-Simulation method. The Micro-Simulation model of pedestrians is a computerized simulation procedure in which the moving behaviour of each pedestrian such as speed, path, and the direction is considered separately. According to the obtained results from this study, an increase in the percentage of the elderly population can lower the sidewalk's level of service. Also, the decrease of the average motion speed and the free walking space for wider paths is not necessarily less than that of narrow paths, in a way that by increasing the width of a sidewalk, pedestrians' total average speed and the average walking space decrease up to a specific width and then start to increase. This decrease on wider sidewalks is more than that in the narrower ones.

KEY WORDS

level of service, moving stream, sidewalk, average motion speed, free walking space

1. INTRODUCTION

The organization for Economic Co-operation and Development (OECD) predicts that in 2040 the population of the people above the age of 65 will reach 1.3 billion or 14% of the total population of the world [1]. Furthermore, Pauls [2] has announced that the population of the people above 65 in many countries was growing. From 1996 to 2006, Iran's population structure experienced considerable changes, and was quickly guided to oldness which will have irreversible social and economic repercussions on the country's future progress [3-5]. Considering three assumptions such as continuation of the family planning policy, fertility rate policy, and practicing the encourage-birth policy, the percentages of the elderly are predicted to be as shown in *Table 1* [5].

Walking is one of the transportation ways which can make a connection between an individual, the environment, and the society when other means of transportation, especially motorized vehicles are not available [6]. It is not only that walking is important for the public health, but it helps also the city environment to be alive [7-9]. Sidewalks are considered to be the most popular places among all the public places in a city, so a lot of attempts have been made to improve and manage them [10].

Ilango et al. [11] classified pedestrians in four groups according to their age: the children (0 to 15 years old), the young (15 to 30 years old), the middle-aged (30 to 60 years old), and the elderly (above 60). Walking speeds of individuals in free walking conditions depending on the mentioned ages, gender, health condition of the individual, and some other reasons such as purpose of the trip, time of the trip, and environmental and climate conditions are different [12-18]. According to Iran's sidewalk facility code No. 144 (Management and planning organization office of the deputy for technical affairs, Technical affairs and standards bureau, Ministry of roads and transportation research and Education centre), healthy people can change their walking speed from the low-speed

Table 1 - Percentages of the Elderly considering the three assumptions from 2011 to 2051 [5]

Year	Mean of three assumption amounts		First assumption (Family Planning Policy)		Second assumption (Fertility Rate Policy)		Third assumption (Encourage Birth Policy)	
	Male	Female	Male	Female	Male	Female	Male	Female
2011	2.60	2.50	2.6	2.5	2.6	2.5	2.6	2.5
2021	2.80	3.10	2.8	3.1	2.8	3.1	2.8	3.1
2031	4.50	4.93	5.7	6.2	3.9	4.3	3.9	4.3
2041	4.47	4.90	3.4	3.7	5	5.5	5	5.5
2051	6.70	7.30	6.7	7.3	6.7	7.3	6.7	7.3

walking limit of 0.6-0.9 m/s to high-speed walking limit of 1.5-1.8 m/s [19].

According to previous studies [20-23], males walk 5% to 7% faster than females. Also, the young walk 6% to 8% faster than the middle-aged and 18% to 24% faster than the elderly.

In studies conducted in Iran, the speed of pedestrians above 65 has not been measured correctly yet [24], so in order to obtain the walking speed of this age group, a field research including 3,924 pedestrians with 287 ones above 65 in 6 districts of Tehran (Capital city of Iran) was conducted by the authors. Results show that the average walking speed of the male elderly is 1.03 m/s with a standard deviation of 0.11 m/s, and the average walking speed of the female elderly is 0.98 m/s with a standard deviation of 0.24 m/s.

Two important factors can play a very essential role in organizing and designing sidewalk facilities. These two factors are the pedestrians' behaviour and their moving characteristics. According to the investigations done by the authors, no specific research has been conducted in Iran on sidewalk capacity analyzing procedures. Studying pedestrians started from the 1960s [25], and in general, Fruin [26] first defined different levels of service for sidewalks. Due to some obvious area differences, environmental conditions, purpose of walking, bodily characteristics of different people, and also facilities of the sidewalks, sidewalk traffic flow characteristics and pedestrians' behaviour not only depend on the location and the capacity of the sidewalk, but also on the area of the investigation.

In most cases, traffic engineers adopt some models which are used to analyze the vehicle traffic to determine the levels of service of the streams in pedestrians [13, 27, 28]. The typical type of the above mentioned modelling is using linear regression to measure the crossing stream of pedestrians [26, 29]. Weidmann in 1993 used the double S-bended model to model the traffic of sidewalks [30]. Studying pedestrians' behaviour can be done in different ways. According to previous studies, there are three general methods in this field: field observation and study method [31, 32], subjective method [33, 34], and simulation method [35-37]. The new method with which the traffic capacity of Iran's sidewalks is investigated is the Micro-Simulation method. Different software programs have been organized for this method all over the world. The software program which is used in this paper to investigate the effects of the population ratio of the elderly on the sidewalk streams is Micro-PedSim [38].

Currently, Iran is a young country with a ratio of the elderly pedestrians of 5.2% of the total population, but their presence in front of entertainment centres, retirement centres, and schools shows the eligibility of the presented study. Additionally, the adopted procedure in this paper can be used to investigate the effects of pedestrians from other age groups on the crossing stream and emergency situations.

2. MICRO-SIMULATION OF SIDEWALKS

In the past, pedestrians were mostly modelled using the Macro method. One of the fundamental problems associated with this method was to use the average speed for the whole pedestrian stream on the sidewalk without considering the details of each person's moving characteristics. Observing pedestrians' motion shows their mutual effect on each other; in such a way that their decisions to change their speed, overtake each other, move at constant speed (in dense conditions), and change their paths to avoid colliding with other pedestrians are different considering all the available situations on the sidewalk. Some of the pedestrians walk individually, and some of them walk in groups. In the past, all of the above mentioned patterns of behaviour were modelled as flow-speed-density equations using the Macro method [13, 39]. Using the Macro method would always result in the principle that more pedestrians needed more walking space while imposing some specific changes in individuals' paths, and although the total walking space decreases, the moving flow improves. In general, the Micro method considers more accurate details and assumptions in comparison with the Macro method. The Micro-Simulation model of pedestrians is a computerized simulation procedure with which the moving behaviour of each pedestrian, such as speed, path, and the direction is considered separately.

This kind of simulation is a suitable means for designing public transportation systems [40-42], de-

Table 2 - Comparison of microscopic pedestrian simulation models

Model	Presented by	In	Phenomena explaining	Values of the variables	Higher programming orientation	Parameter calibration
Benefit-Cost cellular	Gipps and Marksjo [45]	1985	Queuing	Arbitrary Scoring	Cellular based	By inspection
Cellular Automata	Blue, V.J. and Adler [46]	1999	Macroscopic	Binary	Heuristic	Compare Fundamental Diagram
Queuing Network	Lovas [47], Thompson and Marchant [48,49] Watts [50]	1987-1995	Queuing, Evacuation	Physical Meaning	Queuing model	By inspection
Magnetic Force	Okazaki [51, 52] Matsushita [53, 54] Yamamoto [55].	1979-1991	Queuing, way-finding in maze	Physical Meaning	Heuristic	By inspection
Social Force	Helbing [56] Molnar [57], Schweitzer and Vicsek [58]	1991-1999	Queuing, self organization	Physical Meaning	Mathematical	By inspection

signing public spaces and optimizing people's walking spaces [43], and designing places which in critical situations of people density can cause incidents [44]. Different models have been created for the Micro simulation method [45-58]. *Table 2* compares five well-known models which are used to simulate pedestrians.

Variables of Benefit-Cost cellular model are mostly arbitrary while Magnetic and Social Force models cover different variables in various environmental and physical conditions. The Magnetic model is extended as an innovative method while the Social Force model, because of its more accurate mathematical nature, is the most suitable method to explain the pedestrians' moving behaviour.

Micro simulation model of pedestrians has two different parts: motivation to move forward (from the origin to the destination), and considering a pedestrian's repulsive force to avoid other pedestrians or an external obstacle. Helbing et al. [56] extended the equations of the Social Force model as follows:

$$m\frac{d\vec{v}_i(t)}{dt} = \underbrace{m\frac{v_0\vec{e}_i - \vec{v}_i(t) + \vec{\xi}_i(t)}{\tau}}_{(1)} + \underbrace{+\sum_{j(\neq i)} \vec{f}_{ij}(\vec{x}_i(t), \vec{x}_j(t)) + \vec{f}_b(\vec{x}_i(t))}_{(2)} \qquad (1)$$

where $d\vec{v}_i(t)/dt$ is the moving acceleration of a pedestrian with the mass of m. The first section in the right side of the equation represents the motivation force of the individuals to move from the origin to the destination, and the second part is the sum of the repulsive forces of pedestrians toward each other or toward an external obstacle.

Because of the high capability of the Micro simulation method to define different effective factors in analyzing sidewalks, this method has extendedly been used recently. The software program which is used in this paper to investigate the effects of the population ratio of the elderly on the sidewalk streams is Micro-PedSim [38]. The main criterion in analyzing the input data and comparing them with the collected data is the same as the level of services which is defined in Iran's sidewalk facility code No. 144 for the moving stream of a sidewalk [19].

3. METHODOLOGY

In order to estimate the effect of the elderly population on the moving stream of other pedestrians on sidewalks, the Micro-simulation method has been used, and for this simulation, the Micro-PedSim 1.3 software, which was developed in 2002 by Teknomo [38], has been chosen. In order to validate this software program, 12 sidewalks with almost the same conditions (width, slope, paving, side obstacles, trade centres) in six different districts of Tehran during three 5-minute periods (in the morning, at noon, and in the evening) were filmed. These footages were recorded on 1st to 6th of October 2011. Among all of the footages with the total duration of 180 minutes, three one-minute ranges were selected at random. These three time ranges were studied, and the average values of the parameters such as speed and their density were used together with the extracted values from the Micro simulation to validate the software.

In order to investigate various types of sidewalks, three different sidewalks with narrow, medium, and wide widths were simulated. Also, to simplify the model, it was assumed that all pedestrians move only in one direction. Then, for calibrating the created models (before simulating the main models which included the elderly pedestrians as well), firstly, all of the pedestrian's characteristics were entered into the software program. Next, the results were compared to the maximum and minimum allowed average speed and walking space presented in reference 19. Considering previous studies, in addition to the calibrated model, three models with 10%, 20%, and 30% presence of the elderly on sidewalks were considered for each model. Afterward, having simulated the models, the obtained average of the speed and walking space from the simulation were compared to the results obtained by calibration (100% pedestrians were assumed not to be the elderly), and the results have been extracted as the average speed and the walking space corresponding to the average unit flow rate of the pedestrians.

4. VALIDATION OF THE MICRO-PedSim SOFTWARE

The Micro-PedSim software is an innovative means to study the moving behaviour of pedestrians through micro simulating the pedestrians. This software has the capability of simulating and observing the microscopic behaviour associated with pedestrians. None of the presented models to simulate pedestrians' behaviour has been validated based on actual moving information. There is no statistical guarantee that the defined parameters for the software are reliable for the area being studied by the authors, so for practical purposes, there is need to validate the available parameters in the software considering the moving behaviour of the statistical society under study, *Figure 1*.

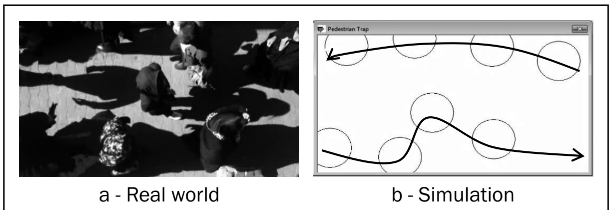


Figure 1 - Pedestrians' behaviour on a sidewalk

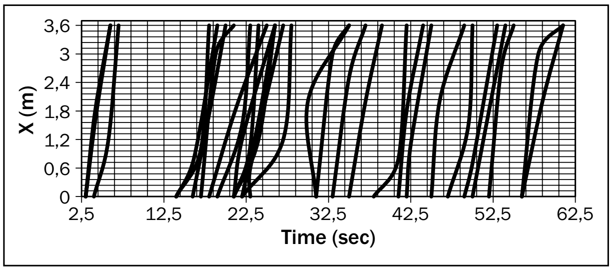


Figure 2 - Temporal–spatial curves of pedestrians diagram related to one of the random 60-second ranges of pedestrians' motion in the studied sections

This procedure has been pursued using the collected data of pedestrians' moving behaviour extracted from the recorded films with Avi format. Temporal–spatial curves of pedestrian diagram related to one of the random 60-second ranges of pedestrians' motion in the studied sections are presented in *Figure 2*.

The average of the data (speed and density) obtained from the field study in three different takes from one section was calculated in different 60-second ranges, Figures 3 and 4.

Then, these values were compared to the results obtained from the Micro-PedSim simulation software. The distribution for both the speed and density parameters obtained from the field observation and simulation are shown in Figures 5 and 6. The coefficient of correlation of the speed parameter is 0.6766, *Figure* 6a, and the amount of that of the density parameter is 0.7068, *Figure* 6b.

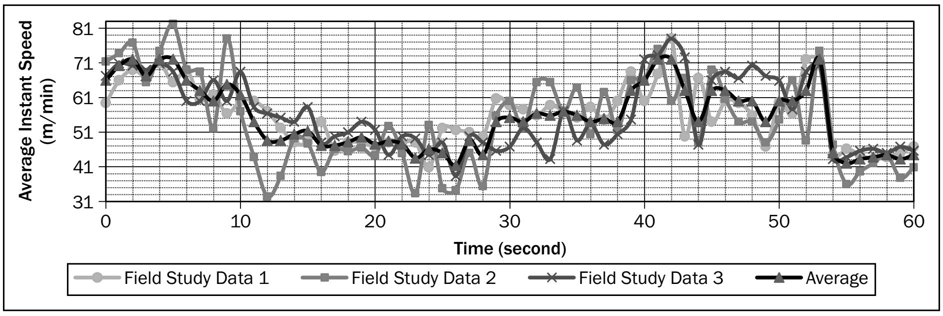


Figure 3 - Speed profile of the real world data

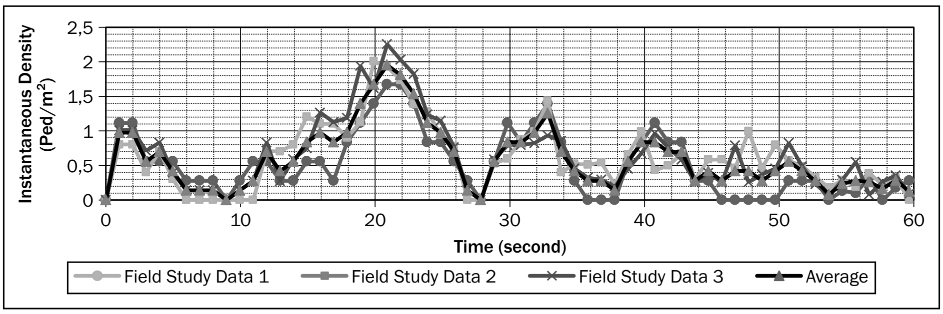


Figure 4 - Density profile of the real world data
(If density = 0 Ped/m^2, it indicates that there are no pedestrians on sidewalks)

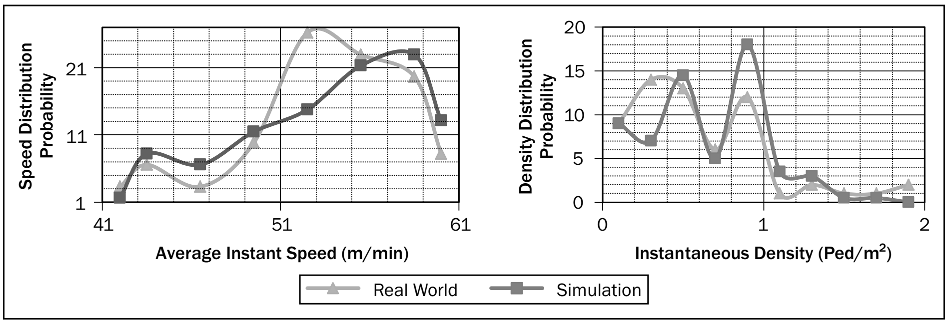
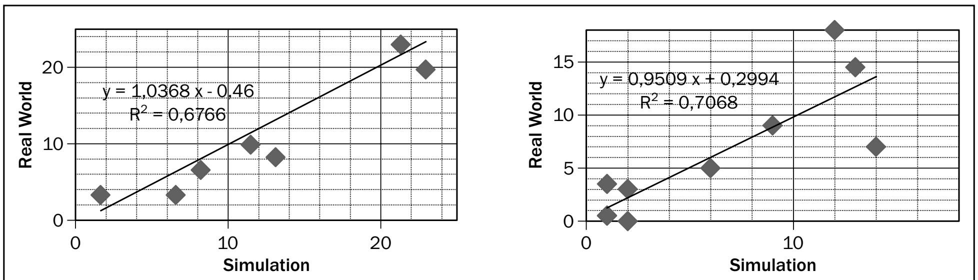


Figure 5 - Probability of speed and density distribution



a - Speed *b - Density*

Figure 6 - Validation of the probability of speed and density distribution

5. MICRO SIMULATING THE EFFECT OF THE RISING PERCENTAGE OF THE ELDERLY ON SIDEWALKS

Studies have not determined a specific border between the homogeneous and non-homogeneous traffic of pedestrians on sidewalks yet. For example, the effect of some students' or an elderly person's motion on the traffic stream becoming non-homogeneous is unclear. Some studies [13] have determined this border limit to be 20% for the elderly; in such a way that if this percentage of the elderly pedestrians is available in the moving stream of typical pedestrians, the traffic flow on sidewalks cannot be considered homogeneous. Pheasant et al. [59] in 2006 showed that if 30% of the total pedestrians are elderly people, the existing traffic stream on the sidewalk will be non-homogeneous. Despite all of these attempts, there is no unique criterion to determine the accurate ratio of the elderly necessary to make the traffic stream of the sidewalk non-homogeneous.

HCM [13] suggests that if 20% of the total pedestrians are elderly people, the design walking speed should be considered to be 1.2 m/s, and if the percentage of the elderly people exceeds 20, the walking speed should be considered 1 m/s. By micro simulation, the authors have obtained the effects of different percentages of the elderly pedestrians' presence on sidewalks on the changes of the total average speed of the sidewalks. As shown in *Figure 7*, the average moving speed of the pedestrians on sidewalks decreases exponentially with the increase in the percentage of the elderly people's presence on sidewalks. The change of the diagram's slope when the presence percentage of the elderly people reaches 20 is obvious. The mentioned procedure confirms the studies conducted by Teknomo in 2002 [37].

In order to estimate the presence of the elderly on sidewalks, three different types of sidewalks with the same specific length were chosen; three sidewalks with the lengths of 10 m and three different widths of 1.5 m, 3 m, and 4.5 m. In addition, with the purpose of simplifying the models, it is assumed that all the pedestrians are walking in the same direction

In this paper, in order to simulate the proposed models, both the motions of the typical and the elderly pedestrians have been considered. Two important features available in the Micro-PedSim software are the ability to change the size of a desired pedestrian's body and their walking speed. The distribution of the walking speed for typical and elderly pedestrians is done according to Iran's sidewalk facility code No. 144 [19] and the author's field studies, respectively. For modelling, the flow rate per unit width (person per minute per metre) is used as input data, and the average speed and the walking space corresponding to the input data are extracted for the future comparisons.

According to the authors' studies, there is no specific difference between typical and elderly pedestrian body thickness and width. Also, Buchmueller and Weidmann's studies [12] confirm this issue. As result, according to *Figure 8*, suggested by Iran's sidewalk facility code No. 144 [19], the thicknesses and widths of two pedestrians in two-dimensional models are consid-

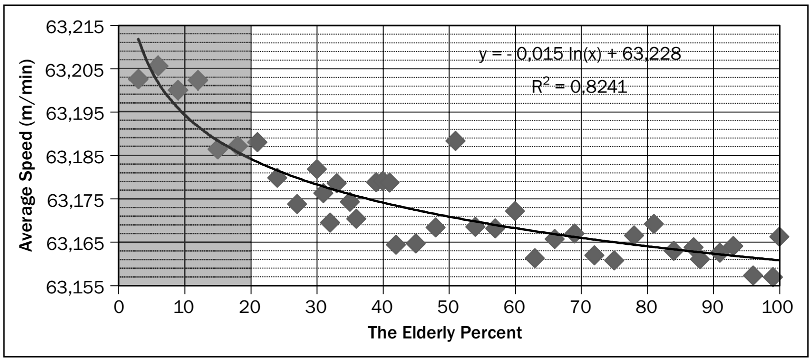


Figure 7 - Average moving speed of the pedestrians on sidewalks versus percentage of the elderly people's presence on sidewalks

ered to be 43 cm and 140 cm, respectively. Because of the fact that the pedestrians are simulated as circular areas in the software, according to Equation 2, the diameters of these circles are considered to be 62 cm.

$$A_1 = A_2 \rightarrow 43 \times 70 = \frac{\pi D^2}{4} \rightarrow D \approx 62\,\text{cm} \quad (2)$$

where A_1 is the occupied area of the sidewalk by a pedestrian suggested by Iran's sidewalk facility code No. 144; A_2 is the occupied area of the sidewalk by a pedestrian according to the software assumptions; and D is the diameter of the simulated pedestrian as a circle in the software.

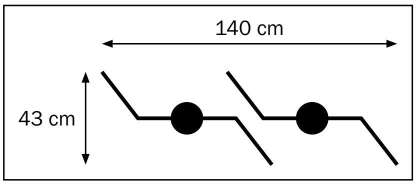


Figure 8 - Thicknesses and widths of two pedestrians in two-dimensional models [19]

The unit flow rate used in these simulations is as the defined ranges in *Table 3*. The results obtained from simulations will be compared to the average speed and walking space ranges corresponding to the unit flow rate of the pedestrians. In order to extract these values, *Table 3* is used.

5.1 Calibrating the initial created models

In order to calibrate the created models (before creating the main models including the elderly pedestrians), first, the characteristics of all the pedestrians were entered into the software as the average unit flow rate for a typical pedestrian. Then, the results were compared to the allowed average speeds and maximum and minimum walking spaces presented in *Table 3*. Tables 5 and 6 separately represent the averages of speed and walking space of pedestrians for each level of service resulting from the calibrated model.

According to *Figure 9* and *Table 7*, pedestrians' speed in the calibrated model in levels of services A,

Table 3 - Proposed criteria of pedestrian's levels of service for Iran's sidewalks [19]

Level of Service	Pedestrian Space (m^2/ped)	Expected Flows and Speeds		
		Average Speed (m/min)	Unit Flow Rate (ped/m/min)	V/c
A	≥ 6	≥ 76	≤ 13	≤ 0.18
B	≥ 4	≥ 74	≤ 19	≤ 0.27
C	≥ 2.6	≥ 71	≤ 27	≤ 0.4
D	≥ 1.6	≥ 65	≤ 41	≤ 0.6
E	≥ 0.6	≥ 40	≤ 68	≤ 1
F	< 0.6	< 40	Various	

Table 4 - Unit flow rate used in simulation (ped/m/min)

	Level of Service A	Level of Service B	Level of Service C	Level of Service D	Level of Service E
Table 3 Low	0	14	20	28	42
Model 1 (1.5m width)	6	16	23	34	55
Model 2 (3.0m width)	6	16	23	34	55
Model 3 (4.5m width)	6	16	23	34	55
Table 3 High	13	19	27	41	68

Table 5 - Average walking speed for models versus Table 3 ranges, (m/min)

	Level of Service A	Level of Service B	Level of Service C	Level of Service D	Level of Service E
Average Speed	76	74	71	65	40
Model 1 (1.5 m width)	79.56	76.32	74.7	72.3	64.14
Model 2 (3.0 m width)	78.96	75.42	73.74	71.1	60.9
Model 3 (4.5 m width)	77.52	73.98	72.12	70.68	60.83

Table 6 - Average walking space for models versus Table 3 ranges, (m2/ped)

	Level of Service A	Level of Service B	Level of Service C	Level of Service D	Level of Service E
Table 3 Low	6	4	2.6	1.6	0.6
Model 1 (1.5 m width)	8.82	4.14	3.25	1.79	1.52
Model 2 (3.0 m width)	10.45	5.82	3.09	2.43	1.54
Model 3 (4.5 m width)	11.08	4.25	3.42	2.32	1.59
Table 3 High	-	6	4	2.6	1.6

B, C, and D has good similarity to the allowed ranges in *Table 3*, but for the level of service E, due to imposing denser conditions, there are differences in comparison to the average speed of *Table 3*. These differences for the first, the second, and the third calibrated models are 60.35%, 52.25%, and 52.08%, respectively.

From *Figure 10* and *Table 7*, the average walking space for pedestrians for the first calibrated model in levels of services A and C has good similarity with the allowed ranges in *Table 3*, but in level of service B because of more free traffic conditions, and in levels of service D and E due to the imposing denser conditions, there are some differences in comparison to

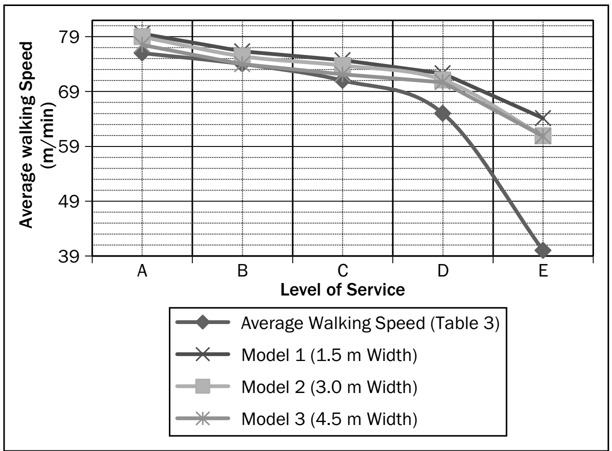


Figure 9 - Average walking speed for models versus Table 3 ranges (m/min)

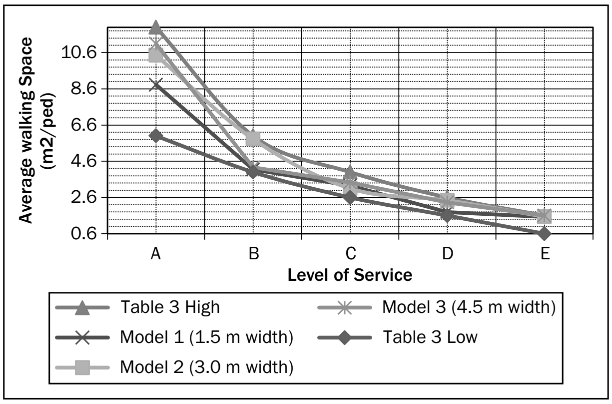


Figure 10 - Average walking space for models versus Table 3 ranges (m^2/ped)

the minimum and maximum average of the allowed ranges in *Table 3*. These differences for the first calibrated model in levels of services B, D, and E are 17.2%, 14.76%, and 38.18%, respectively. Also, for the second calibrated model in levels of services A, B, D, and E, the differences are 16.1%, 16.4%, 15.71% and 40%, respectively. And for the third calibrated model in levels of services A, B, D, and E, the differences are 23.1%, 15%, 10.47%, and 44.54%, respectively.

The results of the simulation are obtained as the average speed and walking space corresponding to the average unit flow rate of the pedestrians entered into the software. The unit flow rate of the pedestrians used in the simulations was entered into the software as the average defined ranges in *Table 3*. While com-

Table 7 - Difference percentages of the obtained values of the calibrated models and Table 3 ranges for average walking speed (m/min) and average walking space (m^2/ped)

	Level of Service A		Level of Service B		Level of Service C		Level of Service D		Level of Service E	
	Speed	Space	Speed	Space	Speed	Space	Speed	Space	Speed	Space
Model 1 (1.5 m width)	4.68	2	3.14	17.2	4.79	1.51	11.23	14.76	60.35	38.18
Model 2 (3.0 m width)	3.89	16.1	1.92	16.4	3.86	6.36	9.38	15.71	52.25	40
Model 3 (4.5 m width)	2.00	23.1	0.03	15	1.58	3.63	8.74	10.47	52.08	44.54

paring the results of the simulation, also the averages of the speed and walking space ranges corresponding to the average unit flow rate of the pedestrians were used. The results of all the three simulations are analyzed in the following sections.

5.2 Results of the first model (sidewalk with the width of 1.5 m)

The averages of the speed and the walking space obtained from the first model simulation are compared to the results of the calibrated model, in which all of the pedestrians are assumed to be non-elderly people. *Figure 11* shows the effect of elderly people's presence ratio on decreasing the pedestrian's speed. As can be observed, the average speed corresponding to the average imposed unit flow rate decreases as the traffic of the elderly increases. Also, in comparison to the traffic on the sidewalk with fewer pedestrians, as the number of the pedestrians increases, the average speed decreases more. For the 14-percent elderly population of Iran in 2051 in low flow condition (level of service A), a 4.47-percent decrease in pedestrian speed is predicted while this decrease for high flow condition (level of service E) is about 7.02%.

Figure 12 shows the effect of the elderly people's presence on the walking space of the sidewalks. As can be seen the walking space corresponding to the average unit flow rate of pedestrians decreases as the traffic of the elderly increases. Also, in comparison to the traffic with fewer pedestrians, as the number of the elderly people increases, the walking space decreases more. For the 14-percent elderly population of Iran in 2051 in low flow condition in level of service B, a decrease of 35.02% in the walking space of the pedestrians is predicted while this decrease for high flow condition (level of service D) is about 12.58%.

5.3 Results of the second model (sidewalk with the width of 3 m)

By increasing the pedestrians' unit flow rate, the average walking space decreases, *Figure 13*. In this model, the sidewalk has been widened, so it is expected that by the moving width getting wider, the average speed and the average walking space of the pedestrians will increase. As result of the increase in the walking space the low speed of the elderly does not interfere with the traffic of other pedestrians.

Figure 14 represents the details related to the decrease of the average speed of pedestrians while the elderly people's presence of 10%, 20%, and 30% are assumed. Like the first model, as the moving traffic on the sidewalk becomes denser, the pedestrian's average speed decreases. In this situation, the sidewalk is twice wider in comparison to the first model, but the speed reductions have changed less than 10% in comparison to the calibrated model. This can be due

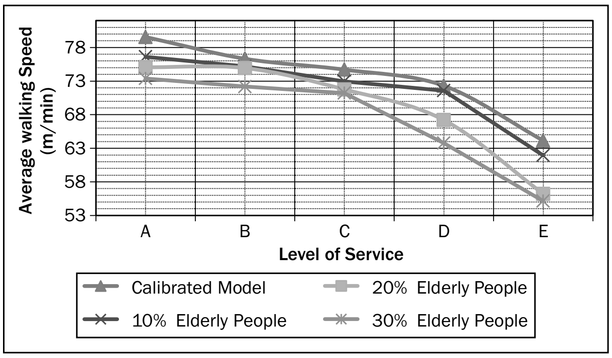


Figure 11- Effect of elderly people's presence ratio on decreasing pedestrian speed in Model 1

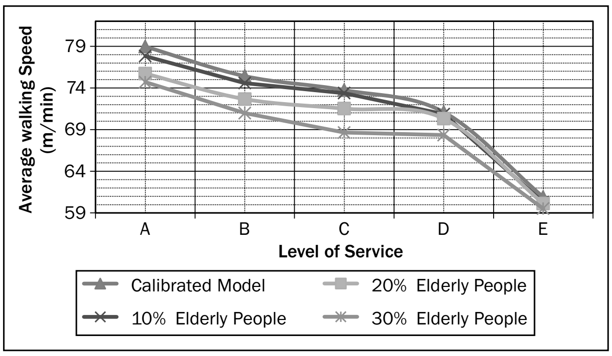


Figure 13- Effect of elderly people's presence ratio on decreasing the pedestrian speed in Model 2

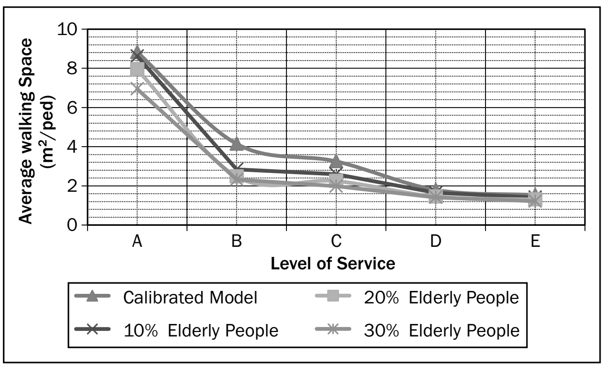


Figure 12 - Effect of elderly people's presence ratio on decreasing pedestrian walking space in Model 1

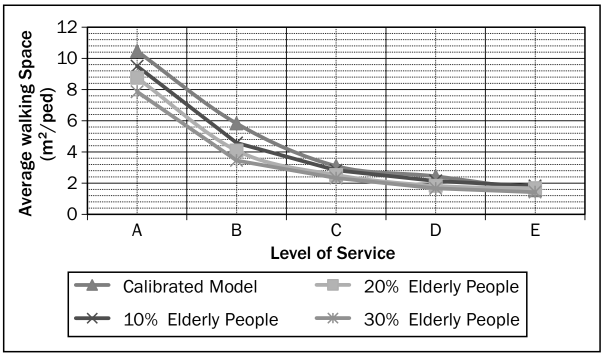


Figure 14 - Effect of elderly people's presence ratio on decreasing the pedestrian walking space in Model 2

to more pressure from the typical pedestrians on the elderly ones in order to increase their walking speed. The average speed difference in level of service A is about 2.51% and in level of service E it is nearly 1.11%.

The simulation results show that in higher flow conditions the decrease in the walking space is less than that of the lower flow condition. This decrease percentage in level of service B is about 24.74% and in level of service D it is nearly 17.18%.

5.4 Results of the third model (sidewalk with the width of 4.5 m)

Figure 15 represents the details related to the decrease of the average speed of pedestrians while elderly people's presence of 10%, 20%, and 30% is assumed. Like the first and the second model, as pedestrian traffic on the sidewalk becomes denser, the average walking speed decreases. The difference of the average speed in level of service A is about 2.79% and in level of service E it is nearly 5.65%.

As the traffic rate of the pedestrians increases, the average walking space decreases, *Figure 16*. In the third model the sidewalk is wider than in other models (4.5 m). Simulation results show that in higher flow condition and denser traffic the decrease of the walking space is more than that of the lower flow condition. This decrease percentage in level of service B is about 7.11% and in level of service D it is nearly 9.28%.

6. CONCLUSION

The main objective of this simulation is to predict the effects of the increasing elderly population in Iran (as a developing country) on other pedestrian flows in the future. As it is obvious from Figures 11-16 the increase of the elderly population can lower the levels of service of sidewalks. Especially according to Iran's sidewalk facility code No. 144, most sidewalks in Iran are built with levels of service C, and D, so the elderly people's presence on sidewalks can transfer their levels of service from C to D, and even E, or from D to E. For example, according to *Figure 15*, if the sidewalk is designed without considering the elderly people's presence, and if the ratio of the elderly people to all the pedestrians is 0.3, then the level of service C will be transferred to lower levels (between D and E).

The effects of the elderly people's presence on other pedestrian traffic were investigated in this study. The increasing elderly people's ratio resulted in lower average speed and walking space of the pedestrians for a specific unit flow rate. The decrease of the average walking space with only 10% of elderly population is negligible in lower flow condition such as E, but at higher levels of service such as A, B, and C with higher share of elderly people's population, this decrease is more noticeable. Also, the decrease in the average speed and walking space on wider sidewalks is not necessarily lower than on narrow sidewalks. According to the results obtained in Section 5, by increasing the width of a sidewalk, this change in the total average of pedestrian parameters decreases till it reaches a specific width, and then it starts to increase. This increase has more values for wider sidewalks. The reason of this event can be the pressure of the typical pedestrians on the elderly ones to increase their speed on narrow sidewalks. As the sidewalk becomes wider, this pressure decreases, so the effect of elderly people's presence becomes more apparent. As the sidewalk becomes even wider, the typical pedestrians can easily overtake the elderly pedestrians.

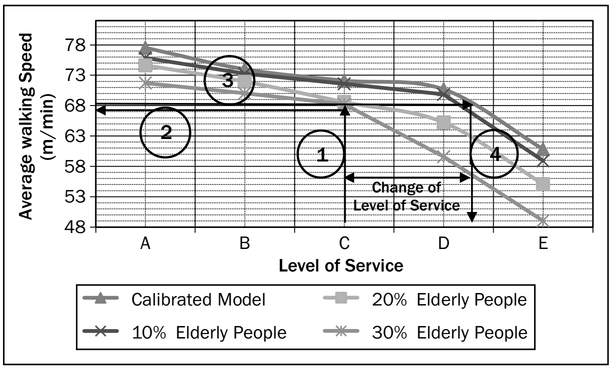


Figure 15 - Effect of elderly people's presence ratio on decreasing the pedestrian speed in Model 3

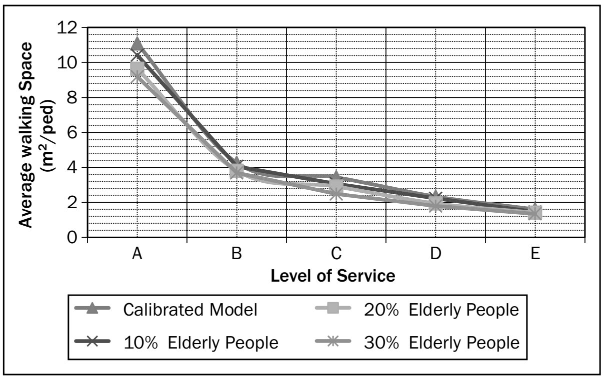


Figure 16 - Effect of elderly people's presence ratio on decreasing the pedestrian walking space in Model 3

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خلاصه

میکرو شبیه سازی اثر سالخوردگی در جریان حرکتی عابرین پیاده کشور ایران

در فاصله سال‌هاي 1375 تا 1385، هرم سني جمعيت ايران تحولات ساختاري قابل ملاحظه‌اي را تجربه كرده است. طي مدت ياد شده، سهم جمعيت كمتر از 15 سال كشور از 39/6 درصد به حدود 28 درصد كاهش يافته است. با چنين كاهشي، جمعيت ايران به سرعت به سمت سالخوردگي سوق يافته كه اين امر پيامدهاي سنگين اجتماعي و اقتصادي را به توسعه آينده كشور تحميل خواهد كرد. هدف اصلی مطالعه‌پیشرو تخمین اثر جمعیت افراد سالخورده در جریان حرکتی سایر عابرین پیاده در پیاده‌روهای شهر تهران برای اولین بار در ایران با استفاده از روش شبیه سازی میکرو است. مدل میکرو شبیه سازی عابرین پیاده یک روش شبیه سازی رایانه مبنا است که رفتار حرکتی تک تک عابرین از جمله سرعت، مسیر و جهت حرکت هر عابر را به صورت مجزا در نظر می‌گیرد. طبق نتایج به دست آمده از این تحقیق افزایش جمعیت مسن مي‌تواند کیفت سرویس دهی پیاده‌روها را به سطح سرویس‌های پایین‌تر انتقال دهد، همچنین کاهش میانگین سرعت حرکت و فضاي آزاد پیاده روی براي مسیرهای عریض‌تر لزوماً کمتر از مسیرهاي باريك نیست، به طوری که با افزایش عرض پیاده‌رو تغییرات میانگین سرعت کل عابرین و متوسط فضای حرکتی ابتدا تا عرض مشخصی کاهش و سپس شروع به افزایش می‌نماید. این افزایش در حدی است که برای پیاده‌روهای پهن‌تر بیشتر از پیاده‌روهای باریکتر می‌باشد.

كلمات كليدي

سطح سرویس، جریان حرکتی، پیاده‌رو، سرعت متوسط حرکتی، فضای آزاد پیاده‌روی

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