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ABSTRACT

A study of pedestrians crossing behavior is conducted at an uncontrolled mid-block crosswalk in Istanbul, Turkey, to model the pedestrians waiting time, related to their behavior for making the crossing decision. This article focused on the issues encountered in the modeling of the operational behavior of pedestrians. The discrete choice framework is used because of its capacity to deal with individuals' choice behavior. Pedestrians waiting time is classified into three levels, including low, medium, and high levels based on the level of service of pedestrians waiting time. The pedestrians' behavior prediction has been improved by analyzing, taking into account three levels for pedestrian behavior.
Keyword: Pedestrian's waiting time; pedestrian's behavior; uncontrolled crosswalk; discrete choice model; crossing decision, level of pedestrians' waiting time

1. INTRODUCTION

In the metropolitan cities of developing countries, Pedestrians received low levels of priority. Especially, as the number of trips made by motorized vehicles increases, the risk of the involvement of pedestrians in accidents increases. Therefore, they are vulnerable users of the traffic system (Keegan and O'Mahony 2003; Tiwari et al. 2007; Ishaque and Noland 2008). In 2010, pedestrians accounted for 21.9% of 1850 fatalities on roadways in the UK, and 46% of 126 deaths in road accidents were pedestrians in London. Globally, 22% of road fatalities were pedestrians in 2010 (World Health Organization 2013). The pedestrian behavior is examined in different fields such as urban planning, architecture, land use, and even marketing (Okazaki and Matsushita 1993; Parker et al. 2003). The studies on pedestrian behavior are related to the analysis of perceptual, attitudinal, psychological and motivational factors; all of them are factors related to different attributes of human beings (Bernhoft and Carstensen 2008; Moyano Díaz 2002; Evans and Norman, 1998). Eventually, analyzing pedestrian behavior can help reduce the number of accidents that involve pedestrians in urban areas and increase their safety level (Lassarre et al. 2007). Studying the pedestrians waiting time, which is directly related to both the pedestrian decision for starting to cross and their safety while crossing the road, is a significant issue. Pedestrians detect the traffic; consider different factors, which affect their decision to cross the street. (Lee et al. 1984; Oudejans et al. 1996). In this article, the waiting time of pedestrians is analyzed by discrete choice analysis to determine the effect of different factors on pedestrians crossing behavior accurately. The study area is a mid-block crosswalk at an uncontrolled location.

This article consists of five chapters. The first chapter is the introduction, including motivation, objectives, and organization of the study. In Chapter 2, a literature study is presented. In Chapter 3, some information about the data, data collection approach, and analysis of data are presented. In Chapter 4, the estimated model, its results, and discussions about the results are presented. Finally, the conclusion part, including the summary of the findings, limitations, and some suggestions for future studies, is given in Chapter 5.

2. LİTERATURE REVIEW

In the literature, some studies have provided essential information about the effect of pedestrian demographic characteristics such as gender and age on the behavior while crossing the road. Oxley et al. (1997) focused on elderly pedestrians to understand whether elderly pedestrians, because of declines in their physical and perceptual abilities, are more vulnerable to crashes or not. The average kerb delays of young and elderly pedestrians were measured. Also, the gap acceptance of young and the elderly pedestrians on one-way and the two-way roads were found. The results of this study indicated that on one-way roads, the elderly pedestrian crossing behavior is similar to the young counterparts, and it is considerably safer than their crossing on the two-way roads. Moreover, the results showed that age-related perceptual deficits are an important factor in increasing the risk of involving in an accident.

In a study by Hamed (2001), pedestrian crossing behavior models at mid-block crosswalks on undivided and divided roads at Amman, Jordan, were estimated. It was revealed that the pedestrian waiting time has an impact on the number of attempts needed to cross the street successfully. Also, the results showed that pedestrians have different behaviors while crossing the road from one side to the middle part and from the middle section to the other side on undivided roads. On divided roads, male pedestrians are 1.35 times more likely to have less waiting time for crossing from one side to the refuge than females. Also, males are 3.105 times more likely to have less waiting time than females for crossing from the refuge to the other side of the street.

In the study by Oxley et al. (2005), a simulated road crossing task was used to study the effects of some factors on pedestrians crossing decisions related to the time gap. Pedestrian crossing decisions were analyzed, and the impact of the age, time gap, speed of vehicles, distance of the oncoming vehicle, and walking time is studied. Results showed that pedestrian crossing decision was mostly affected by the distance of the oncoming vehicle. Furthermore, elderly pedestrians did not choose the proper time gap compared to young pedestrians. These results presented the importance of the time gap in the pedestrian crossing choice behavior and the effect of age on choosing the time gap. The responses of the elderly participants were more affected by both the time gap and distance factors. For instance, when the distance is increased, the response rate rose from 44.4 m to 88.9 m and from 77 m to 155.6 m, and vehicle speed increased from 40 km/h to 80 km/h, despite time gaps being constant at 4 s and 7 s, respectively. However, response rates also increased when time gaps increased from 4 s to 7 s and stayed at asymptote. They found that even when old–old adults had adequate time to process the time gap of oncoming vehicles, but many of them, based on vehicle distance, made unsafe crossing decisions.

In a study by Ishaque and Noland (2008), pedestrian crossing behavior and their choice of speed at the micro-scale were focused. It was shown that pedestrian choice of speed was related to the risk of the specific situation, individual capabilities, and value of time. By making pavement surfaces smoother and safer for elderly pedestrians, their capability can be improved. The pedestrian capability interacts with the risk associated with traffic. When the risk of the accident reduces, the delay due to the risk avoidance will decrease, which leads to having less travel time. By increasing pedestrian signal cycle times and slowing traffic, older people tend to wait for long gaps in traffic. The pedestrian who has a higher value of time, have higher speeds, especially during peak hours. Moreover, the risk-taker pedestrians have a higher crossing speed than other pedestrians.

Bernhoft and Carstensen (2008) focused on comparing the behavior and preferences of elderly pedestrians with a group of people aged 40–49 in cities. It was found that elderly pedestrians appreciate pedestrian crossings and signalized intersections more than younger pedestrians. When the road is without the facilities, the elderly pedestrians feel that it is dangerous to cross the road. This behavior difference can be related to differences in physical abilities and health rather than to differences in age and gender. The proportion of the elderly pedestrians is more than the proportion of young pedestrians for cases of always deciding to walk up to a pedestrian crossing if they can see one, never crossing at a red light and never returning in a non-signalized crossing. Hence, elderly pedestrians have more cautious behavior.

In a study by Jamil et al. (2015), the pedestrian crossing choice models according to the road, traffic, and human factors were studied. The results showed that the pedestrian crossing choice was significantly affected by traffic flow and road type. Also, it was found that human factors have more effect than the mentioned factors. Three kinds of pedestrians were introduced, which were named risk-taking pedestrians, conservative pedestrians, and pedestrians for pleasure.

Jamil et al. (2015) worked on the uncontrolled marked crosswalk when the pedestrians crossed the road with changing directions and speeds that result in curved paths and higher chances of safety issues. They analyzed the pedestrians crossing patterns concerning entry/exit pairs, and also the turning points. It is found that avoiding collision with grouping pedestrian crossing together from the same or opposite direction, short or also fast distance, and avoiding traffic running straight on the lanes have the highest effect on the pedestrian crossing, and these results in curved paths.

Ferenchak (2016) focused on the relation between pedestrian behavior with motor vehicles. The data about pedestrians' characteristics were gathered from a mid-block crossing in Bangalore, Karnataka, India. By using logistic regression, it was found that the waiting time increases as the pedestrian gets elder. Moreover, elderly pedestrians have fewer conflicts with motor vehicles compared to younger pedestrians while crossing the road. Furthermore, it is found that males caused conflicts with motor vehicles two times more than females. Also, the waiting time for males was about half of the waiting time for females. The female and male samples were statistically different from one another concerning the waiting time. Also, males were less likely to use the crossing infrastructure than females properly. However, this relationship was not significant. Moreover, the probability of causing a conflict reduces as age increases. This relationship is statistically significant at a 99% confidence level as well.

Zhou et al. (2017) studied the pedestrians' group behavior to develop a collision avoidance model for two pedestrian groups to explore how they avoid each other and effectively show the social connections between them, giving new insight into the evacuation of social groups.

Fricker et al. (2019), indicated the difference between one-way and two-way uncontrolled crosswalks. They figured out that in the two-way operations, the willingness of drivers to slow down or stop for pedestrians is higher than that of in one-way operation. Also, in a two-way operation, the driver is less likely to care about whether there is a close follower behind or about an adjacent vehicle when a pedestrian–motorist interaction occurs. In a two-way operation, the effects of interaction between vehicles are less than one-way operations, which leads the drivers to react more to the interacted pedestrian. Also, in two-way operations, environmental characteristics factors become significant to a driver's decision to slow down.

3. DATA

In this study, the data are collected from an uncontrolled crosswalk on Aytar Street in Istanbul-Turkey, shown in Figure 1. The data are gathered by recording pedestrians crossing behavior on the crosswalk for 12 hours on a typical working day. Aytar Street is a one-way street that has two lanes, and the width of the street is 8 m. The parking is prohibited on both sides of the street. However, there are sometimes vehicles parked illegally.

Figure 1: Crosswalk on Aytar Street in Istanbul-Turkey.

As traffic video data dominate traffic sensing (Ke et al. 2017), camera records are used in this study, and the characteristics of the pedestrians and traffic at the uncontrolled crosswalk are observed to analyze pedestrian crossing behavior. We indicate the pedestrians' characteristics, including gender, age, using the mobile phone while waiting for crossing the street, the number of pedestrians who start waiting at the same time, pedestrians with kids and/or carrying something are observed. Here, age is distinguished for being elderly or not through appearance.

The second group of observations is about pedestrian/traffic interaction. For this group, the gap at the crossing, waiting time, and average headway of rejected vehicles are observed. The gap is measured at a section on the crosswalk. It is the time between the last vehicle before (back bumper), and the first vehicle (front bumper) after the pedestrian crosses the street. Also, the pedestrians waiting time is measured, which is started when the pedestrian approaches the pavement until the pedestrian sets foot on the street to cross it. The average headway of rejected vehicles by the pedestrian to cross is found, which is between 1.25s to 5.01s, and when the pedestrians waiting time is 0, the average headway of rejected vehicles is assumed to be equal to 0 in the dataset. The term "headway" is defined as the time between the front bumper of one vehicle and the front bumper of the next (Hutchinson 2008). The number of rejected vehicles by pedestrians for crossing the street is observed, which is between 1 to 16 vehicles, and for the pedestrians with zero waiting time, the number of rejected vehicles for them is assumed to be equal to 0 in the dataset. The final set of observations is about traffic attributes. The observations include illegal parking at the crosswalk, the cases if the driver approaching yield to stop or reduce speed or change course.

Table 1 presents the averages of the gap, the waiting time, average headway of rejected vehicles, the number of rejected vehicles, and the number of pedestrians start waiting at the same time (PWS).

Table 1. The average of each Factor.

Factor	Average
PWS	1.39
Gap (s)	6.22
Waiting Time (s)	6.41
Average headway of rejected vehicles (s)	1.45
Number of rejected vehicles	1.47

The average headway of rejected vehicles in Table 1 is observed to take values as high as 5.01 s while the maximum PWS is four. The pedestrians at the crosswalk reject at least one vehicle (wait for at least one vehicle) before crossing. Moreover, the crosswalk and traffic conditions seem to make pedestrians wait relatively longer since average PWS is about one.

Table 2 shows the number and percentage of pedestrians for each group of categories, including gender, age, using the phone, approaching driver yielding, PWS, and crossing for the first time.

Table 2. Number and percentage of pedestrians in each pedestrians group.

Factor	Group	#	Percentage
Gender	Male	359	58.09
	Female	259	41.91
Age	Young	584	94.5
	Elderly	34	5.50
Using phone	Using	38	6.15
	Not using	580	93.85
Driver yielding	Yes	276	44.66
	No	342	55.34
Crossing at the first attempt	Yes	354	57
	No	264	43
PWS	Alone	434	70.23
	2	136	22.01
	3	36	5.82
	4	12	1.94

Table 3 and Table 4 presents the average pedestrians’ gap, waiting time, and average headway of rejected vehicles for each pedestrian group and pedestrian characteristics, respectively.

Table 3. The average pedestrians' gap, waiting time, and average headway of rejected vehicles for each pedestrian group.

Factor	Group	Gap (s)	Waiting time (s)	Average headway of rejected vehicles (s)
Gender	Male	6.16	5.57	1.26
	Female	6.31	7.57	1.71
Age	Young	6.19	6.18	1.41
	Elderly	6.78	10.42	2.11
Using phone	Using	6.41	8.36	1.48
	Not using	6.21	6.28	1.45
Driver yielding	Yes	6.38	6.60	1.49
	No	6.08	6.26	1.42
PWS	Alone	1.35	6.93	1.50
	2	1.16	5.71	1.45
	3	1.10	2.55	0.99
	4	1.27	7.21	1.08

As it is seen in Table 3, males wait shorter and have less average headway of rejected vehicles compared to the females while they also reject at least one vehicle on average. Moreover, elderly pedestrians' waiting time and average headway of rejected vehicles are higher than young pedestrians. Also, the pedestrians who use the mobile phone while waiting for crossing the street have higher waiting time and average headway of rejected vehicles than who do not use it. Furthermore, when a driver is approaching to stop or reduce speed, the pedestrians’ waiting time and the average headway of rejected vehicles are higher. The PWS range in the dataset is between 1 (pedestrian start waiting alone) and 4, and the minimum and maximum waiting time are when PWS is 3 and 4, respectively. However, the minimum and maximum average headway of rejected vehicles are when PWS is 3 and 1 (pedestrian start waiting alone), respectively.

Table 4. The average pedestrians’ gap, waiting time, and average headway of rejected vehicles for each pedestrian characteristics.

Pedestrian category	Group	Gap (s)	Waiting time (s)	Average headway of rejected vehicles (s)
Young	Male	6.10	5.08	1.19
	Female	6.32	7.66	1.71
Elder	Male	7.03	12.47	2.31
	Female	6.17	5.50	1.63

Table 4 shows that the elderly male's average headway of rejected vehicles and waiting time is more than the elderly females. Also, the young males have shorter waiting time and average headway of rejected vehicles than the young females.

3.1 Comparision of Two Populations With Mann-Whitney U Test

The Mann-Whitney U test is a nonparametric test of the null hypothesis that two samples come from the same population against an alternative hypothesis that two samples are from different populations. In order to calculate the U statistic (U_{sta}); first, all the data must be ranked together, ignoring which group they belong to it. Then each group ranks must be added up (T_1, T_2) and U_{sta} will be calculated with Equation 1 (Bury 1999):

$$
{}_{sta} = \begin{cases} {}_{1} = (n_1 \times n_2) + \left(n_1 \times \dfrac{n_1 + 1}{2}\right) - T_1 \\ {}_{1} = (n_1 \times n_2) + \left(n_2 \times \dfrac{n_2 + 1}{2}\right) - T_2 \end{cases} \tag{1}
$$

Where:

n_1 and n_2: Number of data in the first and second groups, respectively.

T_1 and T_2: Sum of the ranks in the first and second groups, respectively.

After calculating the U_{sta}, the value of Z_{sta} can be calculated by Equation 2 (Bury 1999), and for testing the null hypothesis, it must be compared to the critical Z value ($Z_{critical}$) obtained from the Z table for the assumed level of significance, which is 0.05 for this study.

$$
{}_{sta} \rightarrow Z_{sta} \Rightarrow Z_{sta} = \frac{{}_{sta} - \mu_u}{\sigma_u} \tag{2}
$$

$$
\sigma_u = \sqrt{\frac{n_1 \times n_2 \times (n_1 + n_2 + 1)}{12}} \quad , \quad \mu_u = \frac{n_1 \times n_2}{2}
$$

Table 5. Results of the Mann-Whitney U test for the waiting time of pedestrians.

Characteristic	Groups	Z_{sta}	$Z_{critical}$	Decision
Gender	Male Female	-3.84	±1.96	Not same population
Using phone	Using Not using	-0.33	±1.96	Same population
Age	Elderly young	-2.18	±1.96	Not the same population
Presence of illegally parked vehicle	Yes No	-0.25	±1.96	Same population
Crossing diagonally	Yes No	-1.25	±1.96	Same population
Carrying something	Yes No	-1.28	±1.96	Same population
Driver yielding	Yes No	-0.72	±1.96	Same population

The two different groups for each characteristic do not come from the same population if their Z_{sta} does not include in the range of the $Z_{critical}$; otherwise, they come from the same population and cannot be separated as two different groups. The results of the Mann-Whitney U test at a 5% level of significance are shown in Table 5. The results given in Table 5 indicate that males and females for gender characteristics do not come from the same population because Z_{sta} does not include in the range of the $Z_{critical}$. Also, pedestrians who are the elderly pedestrian or young, do not come from the same population. The other groups in each characteristic come from the same population because their Z_{sta} included in the range of the $Z_{critical}$, showing that it cannot be considered as two separate groups. Hence, gender can be considered as two groups, including males and females. Moreover, age can be classified into two groups which are the elderly pedestrian and young pedestrian.

4. ESTIMATED MODEL

In this study, the multinomial logit model is used to analyze pedestrian behavior. The curbside waiting times of the pedestrian are classified into three levels. To use a discrete choice model, the waiting time, which is continuous data, is turned into discrete data. The data is classified into three levels by determining threshold values for each of them. If another model such as regression model was used, a waiting time model could not be responded to analyze the discrete levels of waiting time to find the actual pedestrian behavior in different situations for each level of waiting time as the regression model can be used to estimate only the value of the waiting time.

In this study, three levels are considered for the waiting time of pedestrians are low, medium, and high levels of waiting time, and they are determined based on the level of service (LOS) of pedestrians waiting time (Nemeth et al. 2014). Table 6 shows the waiting time ranges at each level of waiting time. In this study, level A is considered for low level with waiting time from 0 s to 5 s, the level B is medium level for waiting time from 5 s to 10 s, and the remaining levels which are C, D, E, and F are assumed as high level that includes waiting time which is equal to or higher than 10 s.

In the dataset of this study, the minimum and maximum of the pedestrians waiting times are 0 s and 67.05 s, respectively.

Table 7 shows the data analysis of the relationship between some of the pedestrians' characteristics with being at each level of waiting time.

Considering the different categorizations of the sample, for the low level, the highest percentage of waiting time is recorded for young males, at the medium level is for the elderly females, and at the high level is for the elderly males.

Table 8 displays the average of waiting time, average headway of rejected vehicles, gap, number of rejected vehicles, and PWS at each level of waiting time.

Tables 8 shows that the average gap at the medium level of waiting time is less than the low and high level. The PWS at the medium level is more than the low and high levels.

The characteristics include six variables, while five of them are independent, and one is the dependent variable. In this study, the independent variables are being male, and the elderly variable as dummies, the PWS variable, the number of rejected vehicles variable and average headway of the rejected vehicles variable as continuous variables. The dependent variable is the pedestrian's waiting time. The male and the elderly variables are assumed as the dummy variable, as shown in Table 9.

Table 6. Waiting time ranges at each level of waiting time, based on the LOS of pedestrians waiting time.

Level of waiting time	LOS	Comments	Waiting time ranges (s)	Level number
Low	A	Usually no conflicting traffic	0-5	1
Medium	B	Occasionally some delay due to conflicting traffic	5-10	2
High	C	Delay noticeable to pedestrians, but not inconveniencing	10-20	3
	D	Delay noticeable and irritating, increased likelihood of risk-taking	20-30	
	E	Delay approaches tolerance level, risk-taking behavior likely	30-45	
	F	Delay exceeds tolerance level, high likelihood of pedestrian risk-taking	≥ 45	

Table 7. Percentage of various pedestrians' characteristics at each level of waiting time.

Passengers' characteristics		Low level (%)	Medium level (%)	High level (%)
Gender	Male	65.74	16.15	18.11
	Female	51.35	21.24	27.41
Age	Elderly	44.12	29.41	26.47
	Young	60.62	17.64	21.75
Male	Elderly	41.66	29.17	29.17
	Young	67.46	15.23	17.31
Female	Elderly	50.00	30.00	20.00
	Young	51.41	20.88	27.71

Table 8. Average of the gap and waiting time, average headway of rejected vehicles, number of rejected vehicles, and PWS at each level of waiting time.

Level of waiting time	Ranges of the waiting time (s)	The percentage share of waiting time	Average waiting time (s)	Average Gap (s)	Average headway of rejected vehicles (s)	Number of rejected vehicles	PWS
Low	0-5	59.71	1.37	6.57	0.33	0.11	1.42
Medium	5-10	18.28	7.08	4.98	2.61	1.31	1.48
High	≥ 10	22.01	19.52	6.31	3.52	5.27	1.26

Table 9. Dummy coding for dummy variables.

Dummy variables	Dummy coding	
	0	1
Gender	Female	Male
Age	Young	elderly

Table 10 shows the correlation between variables. As shown in Table 10, the correlation between waiting time and gap is found positive, which is not logical. Hence, it is decided not to include this variable in the model. However, the correlation matrix indicates that other independent variables are appropriate to be used in the model.

Table 10. Existed correlation between the variables.

Variables	Gender	Age	PWS	Average headway	Number of rejected gap	Gap	Waiting time
Gender	1						-0.11
Age	0.6	1					0.11
PWS	-0.01	0.02	1				-0.09
Average headway of rejected vehicles	-0.12	0.09	-0.06	1			0.65
Number of rejected vehicles	-0.1	0.06	-0.1	0.61	1		0.93
Gap	-0.02	0.03	0.01	-0.09	0.06	1	0.02

4.1 Utility Equations

The high level of waiting time is selected as the reference alternative for all independent variables and constants. Hence, all the analysis and comments are relative to the high level. In this study, to have a better explanation of results obtained for the coefficient of independent variables, all variables and constants are assumed as alternative-specific. The utility equation for each level is presented in Equation (3).

$$\begin{gathered}
\text{The utility of the low level:}\\
\text{Utility low} = \text{constant1} + \beta 1 \times \text{male} + \beta 2 \times \text{elderly} + \beta 3 \times \text{PWS} \\
+ \beta 4 \times \text{number of rejected vehicles} + \beta 5 \\
\times \text{average headway of rejected vehicles} \\
\text{The utility of medium level:}\\
\text{Utility medium} = \text{constant2} + \beta 6 \times \text{male} + \beta 7 \times \text{elderly} + \beta 8 \times \\
\text{PWS} + \beta 9 \times \text{number of rejected vehicles} + \beta 10 \times \\
\text{average headway of rejected vehicles} \\
\text{The utility of high level:}\\
\text{Utility high} = 0
\end{gathered} \tag{3}$$

As it is seen in Equation (3), the utility functions of low and medium levels have five independent variables with a constant. As a result, there are 10 alternative-specific variables and two alternative-specific constants in the model.

4.2 Results of The Estimated Model

Table 11 shows the coefficients and their T-statistics of the estimated model. In Table 11, the coefficients, which are statistically significant at 90% level, are in bold, and the comparison level is the high level of waiting time, and all coefficients are in comparison to it. The results of the model show that males and the elderly variables are insignificant at both low and medium levels. These variables do not have statistical effects on waiting time in the model, but they might logically have impacts on waiting time. On the other hand, the PWS, the number of rejected vehicles, and the average headway of the rejected vehicle variables are statistically significant at the 90% level at both low and medium levels. As is seen in Table 11, the coefficient sign of male variable is positive at both low and medium levels as expected. It means the probability of waiting time at a high level is less for males compared to females. In the literature, similarly, the waiting time for females is found to be more than the males to cross (Harrell, 1990 Tiwari et al. 2007; Ferenchak 2016). One of the reasons is mentioned to be the higher walking speed of males (Tarawneh 2001). Moreover, males generally make more risky crossing decisions than females and accept shorter gaps (Oxley et al. 1997; Moyano Díaz 2002; Holland and Hill 2010).

Table 11. The estimation results for waiting time levels.

Variables	Coefficient	T-statistic
Low level		
Gender (Being male)	0.653	1.371
Age (Being elderly)	-0.109	-0.117
PWS	**0.728**	**1.920**
Average headway of rejected vehicles	**-0.996**	**-3.645**
Number of rejected vehicles	**-3.314**	**-7.239**
Constant	**7.063**	**6.252**
Medium level		
Gender (being male)	0.253	0.629
Age (being elderly)	0.409	0.533
PWS	**0.893**	**2.779**
Average headway of rejected vehicles	**-0.673**	**-2.775**
Number of rejected vehicles	**-1.447**	**-7.335**
Constant	**4.411**	**4.132**
Details		
Number of observations	618	
LL_{Base}	-588.170	
$LL_{estimated}$	-235.674	
ρ^2	0.6	
-2LL	704.992	

The coefficient sign of the elderly variable is negative at a low level. It shows that the probability of waiting time at a high level is higher than the likelihood of waiting time at a low level. However, the coefficient sign of the elderly variable is positive at the medium level, which indicates that the probability of waiting time for being at the medium level for the elderly is higher than the likelihood of being at a high level. As it is mentioned in the past studies, the elderly pedestrians need more time to decide to cross the street compared to the young pedestrians (Harrell 1990; Oxley et al. 1997; Hamed 2001; Moyano Díaz 2002; Li and Tsukaguchi 2005; Holland and Hill 2007; Rosenbloom et al. 2008; Holland and Hill 2010; Li 2013; Ferenchak 2016).

The PWS variable has a positive coefficient sign at both low and medium levels of waiting time, showing that as much as the PWS increases, the likelihood of waiting time at a high level is decreased.

The sign of the coefficient of the number of rejected variables is negative at both low and medium levels. Therefore, the higher the number of rejected variables by the pedestrians, the higher the probability of waiting time at a high level.

In this study, the average headway range of the rejected vehicles is between 1.25 s and 5.01 s. This variable has a negative sign at both low and medium levels. It is determined that in the mentioned range, as much as the average headway of the rejected vehicles is higher for the pedestrian, the probability of pedestrians waiting time at the high level is higher compared to the probability of waiting time at the low and medium levels.

5. CONCLUSİONS

In this study, a discrete choice model with five independent variables for three levels of pedestrians waiting time is estimated to have a better understanding of pedestrians crossing behavior and offer an alternative to other existing pedestrian behavior models. The results show that if the PWS at the curbside increases, the probability of waiting at both low and medium levels is more than the probability of being at the high levels. Moreover, the higher the number of rejected vehicles by pedestrians, the higher the probability of waiting time at high levels compared to the low and medium levels. The probability of waiting time at a high level is less for males compared to females. The likelihood of waiting time at a high level is more than the probability of waiting time at a low level for elderly pedestrians. Also, the probability of waiting time at the medium level for the elderly is higher than the likelihood of waiting time at a high level. Furthermore, when the average headway of rejected vehicles (its range in this study is from 1.25s to 5.01s and 0 for pedestrians whose waiting time is 0) is higher for the pedestrian, the probability of waiting time at the high level is higher compared to the low and medium levels. The understanding of these issues will increase the sensitivity and awareness of engineers and transport planners. This framework provides a useful guide for future pedestrian models to improve future safety.

One of the limitations of this study is not using an ordered response model, as there is an ordered outcome (waiting time from low to high). Also, considering the development in the field of econometric modeling, the used model is a traditional one. Hence, In future studies, other methods such as the ordered logit model can be used because of the ordered nature of waiting time. The nested logit model can also be used with two composite alternatives. Besides, some other models such as the multi-state semi-Markov model and also the random parameters multinomial logit models with heterogeneity in parameter means and variances can be estimated to better track unobserved heterogeneity compared to models with fixed means and variances. Moreover, the analysis might be expected to include other locations with different flow characteristics, the number of the lane, etc. Furthermore, additional independent variables that affect waiting time that is not considered in this study can be used in future studies such as speed and type of the upcoming vehicle.

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