Assessment pedestrian crossing safety using vehicle-pedestrian interaction data through two different approaches

Fixed videography (FV) vs In-Motion Videography (IMV)

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Assessment pedestrian crossing safety using vehicle-pedestrian interaction data through two different approaches: Fixed Videography (FV) vs In-motion videography (IMV)

Abstract

A significant portion of pedestrian accidents occurs in the outskirts areas due to the high vehicle speed and lack of safety facilities for pedestrians. Behavioral study on drivers and pedestrians is the key to better understand the causes of pedestrian accidents in order to develop safety models.

Despite numerous studies on pedestrian safety based on various roads, outskirt areas have not been considered. Hence, the present study focuses on evaluating the safety of pedestrian crossing in urban and outskirt areas and to determine the differences of drivers and pedestrians' behaviors between these areas through data based on fixed videography (FV) and in-motion videography (IMV). These approaches may lead to an exact analysis of the behavioral differences of road users behaviors from the perspective of pedestrians (FV data) and drivers (IMV data) in urban and outskirts roads. Accordingly, behavioral studies were conducted at urban and outskirts sites through FV as well as IMV using the behavior of 29 participants in the same roads in Babol city, Iran. The gap acceptance model using linear regression and pedestrian crossing probability model using logistic regression for both approaches showed similarity on results in both urban and outskirts roads. Furthermore, behaviors of pedestrians crossing and drivers' yielding on urban and outskirts roads were very similar. Vehicle speed, the distance of vehicle to pedestrian at the possible collision point, size of pedestrian groups, and waiting time before crossing were the most important behavioral differences of pedestrian for choosing a gap acceptance and probability of crossing on various sites through two different approaches. The inference of the models obtained in this study will lead to a better understanding of the behavior of road users for studies on advanced driving assistance systems (ADAS).

Keywords: Pedestrians behavior, videography, Drivers behavior, outskirts road, urban road

1. Introduction

According to the latest report by the World Health Organization (WHO) on the road safety, pedestrians are the most vulnerable group of road users who account for a significant share of road accidents (WHO, 2018). According to this report, an average of about 23% of the world's annual 1.35 million road fatalities involves pedestrians. On the other hand, the number of fatalities is not the same in different countries, with the middle-income countries accounting for about 80% of road fatalities despite a share of 59% of the total number of motor vehicles worldwide. Pedestrians' share of road accidents in different countries varies from 14% to 40% of total road accidents. For example, pedestrians account for about 27% of Europe's road fatalities, while only 14% of in East Asian countries. On the other hand, pedestrian fatalities in road accidents in the African continent are reported at around 40%, accounting for the highest rate of fatalities among continents. Pedestrian fatalities in the Oceania and Americas are reported at around 22, which is close to the average pedestrian fatalities around the world (23%) (WHO, 2018). The remarkable point about pedestrian accidents is that much of the pedestrian accidents occur in some particular areas (OECD, 2017; WHO, 2018). A sample of recent of International Road Assessment Programme (iRAP) assessments from 54 countries, covering 358,000 kilometres of rural and urban roads with over 700 billion vehicle kilometres of travel a year has highlighted that 88% of pedestrian travel is on one or two-star roads (WHO, 2018). According to this, one or two-star roads are referred to roads without any sidewalk or safe crossing while the minimum speed of vehicles is 60 kilometers per hour. The importance of this issue is that the excessive growth of the global population as well as the geographical/environmental characteristics have led to a saturation of population density in some cities. So in these cities, people are obliged to live in outskirt areas. Living in these areas and daily commuting to different urban areas are common around the world including in the northern part of Iran. What is important in this regard is the low level of safety on the roads that connect these outskirt areas to urban areas. To put it simply, considering that generally no safety measures are taken for the commuting of pedestrians on these roads, such roads are among the one-star roads, which, as reported by the WHO, are the most important pedestrian accident sites around the world (WHO, 2018). According to the Iranian Legal Medicine Organization report, pedestrian accident rate in the suburban roads are more than 2.5 times that of urban ones. A significant share of these fatalities is on the outskirt areas (Iranian Legal Medicine Organization, 2018). From among 3505 pedestrians killed in the accidents in 2018, more than 66% have been killed on suburban roads, with 74% of them being killed on outskirt roads connecting to urban areas (Iranian Legal Medicine Organization, 2018).

Therefore, although several studies have been carried out on pedestrian crossing safety to date, as far as we know, these studies have been on urban areas, and no studies have been carried out on pedestrian safety on outskirt area yet. Considering uneven statistics on pedestrian accidents in both urban and outskirt area, the present study is to investigate the pedestrian decision-making performance in choosing safe gaps on both areas. Therefore, two hypotheses investigated in the present study are: a) diversity of gaps chosen by pedestrians on urban and outskirts roads, and b) Similarity of the results of the data from FV (pedestrian' perspective) and IMV (driver's perspective). In addition, the research questions are:

- What are the parameters that influence the decision of crossing/not crossing of pedestrians in these two areas? Are these parameters different in these two areas?
- Is the gap chosen by pedestrians dependent on the behavior of the driver of the approaching car?

2. Literature review

Investigation of pedestrian behavioral parameters as well as traffic characteristics of pedestrian crossings plays an important role in identifying effective factors in pedestrian accidents. The effects of environmental and traffic characteristics, as well as other road users' behaviors have led to the complexity of the analysis of pedestrian crossing behaviors (Bichicchi et al., 2017; Etehad et al., 2015; Khattak & Tung, 2015; Ram & Chand, 2016; Sheykhfard & Haghighi, 2019; Wang et al., 2018).

So far, numerous studies have evalutated pedestrian safety using various methods. Most of the data used in these studies were obtained from accident database (Huang et al., 2018; Johnson et al., 2013; Khattak & Tung, 2015; Mohamed & Bromfield, 2017), questionnaires (Mwakalonge et al., 2015; Ram & Chand, 2016; Rolison et al., 2018) and field observations (Brosseau et al., 2013; Kadali & Vedagiri, 2013; Poó et al., 2018; Wang et al., 2018). Pedestrian safety simulation in driving simulators is another approach used by researchers to investigate pedestrian traffic safety (Erkuş & Özkan, 2019; Gómez et al., 2013; Obeid et al., 2017). In numerous studies on pedestrian behaviors, environmental factors such as road width and traffic volume (Granié et al., 2014), road light situation (Liu & Tung, 2014), or weather conditions such as rainfall (Bedeley et al., 2013), have been reported to affect pedestrians decisions to cross the road. Demographic characteristics of pedestrians such as gender and age (Sun & Benekohal, 2003; Yannis et al., 2013), as well as pedestrian risky behaviors like running on the road (Zhuang & Wu, 2011) can lead to changes in pedestrians' decisions when cross. On the other hand, the vehicle's speed and the distance to the pedestrian (Hunter et al., 2015), the type of vehicle (Serag, 2014) and the type of traffic control devices (Minhas et al., 2017) have been reported to affect the pedestrians' decision to cross the road.

2.1. Pedestrian viewpoint (Fixed videography)

The use of FV at pedestrian crossings has compensated for many of the limitations of traditional methods, such as the use of accident statistics or field observations by the research team. Today, making up for the lack of data in some areas, inaccurate data logging, and important variables of causative accident patterns are the most important advantages of using FV in pedestrian traffic safety research. Due to the importance of pedestrian traffic on various urban roads, extensive studies have been conducted by researchers to investigate the human, environmental and other possible variables of pedestrian accidents. In some of these studies the traffic variables such as vehicle type and pedestrian traffic volume (Qi & Guoguo, 2017), traffic control devices such as smart signs (Xu et al., 2018), environmental and geometrical variables such as weather conditions and pavement situation, number of lanes, or their widths (Bedeley et al., 2013; Kadali & Vedagiri, 2013; Ni et al., 2016) are the main variables affecting pedestrian traffic safety. However, in most studies, the human factors have been reported to be more important than others in the possibility of pedestrian accidents. According to these studies, the set of behaviors and actions of pedestrians and drivers plays a major role in increasing or decreasing the safety of pedestrian. In other words, pedestrians' decision to safely cross the road is highly connected with the gap acceptance by them, and in fact the safe gap selected can ultimately indicate their decision to cross the road. Several studies have shown that various parameters such as pedestrian crossing behaviors, i.e. zigzag movement (Zhang et al., 2017) or running (Zhuang & Wu, 2011), pedestrian physical condition (Salamati et al., 2013), pedestrian age (Liu & Tung, 2014; Sun & Benekohal, 2003), pedestrian gender (Yannis et al., 2013), accidents experience (Narváez et al., 2019), pedestrian group size (Hunter et al., 2015; Sheykhfard & Haghighi, 2018) have been investigated to analyze the selection of the safe or unsafe gap by pedestrians. In addition, some studies have recommended the more attention to the behaviors of pedestrians and drivers when encountering each other. Therefore, in recent years, the behavior of drivers has become a common research subject in the study of pedestrian traffic safety. Following are some of these studies.

2.2. Driver viewpoint (In motion videography)

Naturalistic Driving Studies (NDS) through IMV data were used to examine the behavior and action of drivers and other road users as they interact with each other. This is a new approach to current traffic investigation methods and provides information that is difficult or even impossible to obtain by other methods. In this realistic approach, user behavior is continuously studied in the natural environment of the road for a long time. Recording from the driver's perspective allows examining the driver's behavior during daily trips and identification and analysis of the relationship between the driver, the vehicle, road and other road users during different driving conditions (Sheykhfard & Haghighi, 2019; van Schagen et al., 2012). The term NDS presents a flexible approach to assess road users' behavior especially drivers. This approach helps researchers to better study driving behavior by monitoring the observance of the driving tasks and the road environment, as well as giving recommendations on what measures the driver should take before or near a collision (Venter, 2014). In NDS, vehicles are driven in real-life traffic conditions and are equipped with cameras and sensors that can record video and provide information on the driving, flow of traffic and the characteristics of environment before and at the time of occurrence of an interaction and traffic accidents. In recent years, studies have been conducted aimed at the pedestrian safety through the driver's perspective, the results of which indicate the effects of the drivers' behavior and action as well as the pedestrians' behavior on pedestrian traffic safety (Habibovic et al., 2013; Lin et al., 2018; Sheykhfard & Haghighi, 2018). The use of videography, especially through in-motion style, to examine the safety of pedestrians has led to a better understanding of the interactions of drivers, pedestrians and other road users in relation to each other. Studies in recent years have shown that driving errors in the form of inappropriate reactions when encountering the pedestrian can increase the potential for collision between them (Cafiso et al., 2017; Habibovic et al., 2013; Sheykhfard & Haghighi, 2018).

To summarize, the use of FV and IMV data in recent years has significantly compensated some of the limitations of using previous methods. Applying these data provided a significant opportunity for researchers to study pedestrian safety from different perspectives in relation to influential factors such as human, environment, vehicle, and road. Despite numerous studies based on various scenarios on pedestrian safety through FV (Ābele et al., 2018; Hunter et al., 2015; Minhas et al., 2017b; Salamati et al., 2013; Serag, 2014) and IMV (Alferova et al., 2017; Antić et al., 2016; Habibovic et al., 2013; Lin et al., 2018; Sheykhfard & Haghighi, 2018; Sheykhfard & Haghighi, 2020), to the best of our knowledge, no studies have been conducted on pedestrian safety on the outskirts areas connecting to the urban areas. However, according to statistics (Iranian Legal Medicine Organization, 2018; Organisation for Economic Co-operation and Development (OECD) Staff et al., 2017; WHO, 2018), a significant portion of pedestrian accidents annually occur on these routes. Therefore, the present study is to evaluate the safety of pedestrian crossing in urban and outskirt areas and to determine the differences of drivers and pedestrians' behavior between them, both from the pedestrian's perspective (FV) and from the driver's perspective (IMV).

3. Methodology and materials

3.1. Study sites

Due to its unique geographical and climatic conditions, there is scattered population in Mazandaran province in northern Iran (area of about 24000 km^2 and a population of over 3 million). For this reason, various outskirts areas have been built around the cities so that daily commute from outskirts to urban areas has become a habit in ~~these~~ this province. According to Iranian Legal Medicine Organization report, Mazandaran is one of the three provinces with the highest number of road accidents in Iran (Iranian Legal Medicine Organization, 2018). Also, about 700 people are killed on different roads in Mazandaran province annually, with pedestrians accounting to about 28% of the fatalities. About half of these fatalities are related to the urban and outskirts roads of Babol city. The present study is to investigate different routes of urban and outskirts roads in this city in order to evaluate pedestrian safety. Therefore, four urban and outskirts roads (two sites per each area) were selected as the study sites through FV. These sites were chosen due to the high number of traffic accidents as well as the high volume of pedestrian traffic based on the province legal medicine organization statistics. Some characteristics of these roads are given in Table 1.

Table1

Geometric and traffic characteristics of outskirts and urban roads

Characteristics	Unmarked Crosswalks	Marked Crosswalks
Crossing type	Uncontrolled crossing	Uncontrolled crossing
Posted speed limit	60km/hr.	40km/hr.
Total of lanes	4+ median	3+ median
Lane width	4m	3.75m
Direction of traffic	Two-way	Two-way

3.2. Data collection

3.2.1 FV data

At each urban and outskirts areas, videography was made by installing a fixed camera on the highest building overlooking the roads. At each site, video was recorded via the camera Panasonic HC-V180 Camcorder (30 frames per second) at three 1-hour intervals. Therefore, video was recorded from 7:30 to 8:30 in the morning, 12:30 to 13:30 in the afternoon and 18:30 to 19:30 in the evening. Meanwhile, recording was done in July 2019 and the weather was clear and sunny during recording. Fig 1 shows pictures of some of these sites.

Fig. 1. FV in study sites (Left: Outskirt road; Right: Urban road)

3.2.2. IMV data

NDS studies were carried out by installing cameras in the cars of the participants. A total of 29 participants (15 male drivers, 14 female drivers; 18-65 years old) participated in current study in the city of Babol, Iran (Fig 2). In order to avoid the possible impact of the study on their driving behavior, information regarding the objective of the research was not provided to the participants. On average, the NDS was examined about 30 minutes for each participant. IMV was conducted via The CARPA-120 Dual Dash cam Video Resolution 640 x 480; Recording Frame Rate of 30 fps) during August 2019. Also, the variables extracted from the FV and IMV records are listed in Table 2.

Fig. 2. IMV of one of the participants

Table2
Variables

Code	Variables	Definition and calculation
R.G	*Rolling Gap*	*Crossing on a zigzag motion by pedestrian*
Group	*Group*	*Whether the pedestrians cross the group or alone; Group: 1, Alone: 0*
W.T	*Waiting time*	*Time that each pedestrian waits to accept a gap*
H.T.C	*How to cross*	*Running: 1; Walking: 0*
Gender	*Gender*	*Male: 1; Female: 0*
Choice	*Choice*	*Whether pedestrians start crossing immediately; Cross: 1; Wait: 0*
D	*Distracted*	*Whether pedestrian is distracted by a secondary task while crossing (using phones, eating, luggage etc.) Yes: 1,*
ATT	*Attention*	*No: 0*
V.T	*Vehicle type*	*Looking towards the approaching vehicle; Yes: 1, No: 0*
S_P	S_P	*Vehicle type*
S_v	S_v	*Pedestrian speed*
X_P	X_P	*Vehicle speed*
X_v	X_v	*The distance from the pedestrian to the potential collision point*
T.C	*Time to cross*	*The distance from the vehicle to the potential collision point*
S.M	*Safety margin*	*The time takes for a pedestrian to cross the road*
Gap	*Gap acceptance*	*The time interval between passage a pedestrian from a point on the road until the next vehicle reaches that point*
		Time difference between the moment the pedestrian is ready to cross the road until the vehicle reaches the collision possible point
P.crossing	*Pedestrian crossing*	*Whether pedestrian could cross or not ; Yes: 1; No: 0*

3.3. Methods

In this study, linear regression and logistic regression models were used for analysing gap acceptance behavior and possibility of crossing behaviour of pedestrians, respectively. In the first step, the linear regression model through SPSS (v.24) software were was used to determine the factors affecting gap acceptance behavior. In linear regression, the value of one variable (the dependent variable such as y) are estimated from the values of two or more other variables (independent variables such as x_1, x_2 ,x_3, ..., x_k). This is done by generating a linear equation as follows:

$$Y = b_0 + b_1 x_1 + b_2 x_2 + b_3 x_3 + \cdots + b_k x_k \quad (1)$$

Where, the parameters b_1,b_2,…, b_k are the regression coefficients, and the intercept (b_0) is the regression constant. To prevent correlation between independent variables and its negative effect on dependent variable, Pearson correlation test was used for continuous variables and Chi-square test was used for discrete variables. In the initial model, all variables (except the variables that were correlated with each other) were studied, then the variables that had little effect on the dependent variable (acceptance gap) (significance level greater than 5%) were excluded from the model. In the next step, the remaining variables from the previous step (highly effective variables) were re-analyzed and, the final model was determined. Then, logistic regression was used to examine the correlation between pedestrian crossing probability and the independent variables. In the initial logistic regression model, all variables (except for correlated variables) were analyzed by SPSS software. So, the variables that had little effect on the model depent variable (accepted or rejected gap) (sig> 0.05) were excluded from the model. In the next step, modeling was performed again with the remaining variables and the model was determined with the best fit and the coefficients of the independent variables and their constant values were calculated. Therefore, the probability that the pedestrian crossing the road is obtained by the Eq. (2). Finally, influential variables along with their impact coefficients in the final model were determined.

$$\Pr(Y_i = 1 \mid x) = \frac{e^{\mathrm{logit}(p)}}{1+e^{\mathrm{logit}(p)}} \quad (2)$$

$$\mathrm{logit}(p) = \ln(\frac{p}{1-p}) = \alpha + \beta_1 x_{1,i} + \beta_2 x_{2,i} + \cdots + \beta_k x_{k,i} \quad , \quad i=1, 2,\ldots, n$$

4. Results and discussion

4.1. Descriptive statistics

4.1.1. FV data

Investigating films from FV using Tracker Software showed that there have been 298 accepted gap (cross) and 108 rejected gap (not to cross) in the to the outskirts areas. Also, in the urban areas, 616 gap were accepted and 114 were rejected by pedestrians. Observing IMV data also showed that in the outskirts areas, there were 231 accepted and 87 rejected gaps. There were 176 accepted and 69 rejected gaps on the urban areas. Table 3 shows the descriptive statistics for each site. In addition, the variables considered for the gap acceptance behavior modeling and the crossing probability model are provided in Table 2. According to Table 3, pedestrians are almost 1.7 times more likely to reject the gap in the outskirts than urban areas. Comparing 108 rejected gaps against 298 accepted ones in the outskirts areas indicates that about 27% of attempts in crossing the roads have failed. On the other hand, on urban routes, 16% of pedestrians failed in their first attempt to cross the road. The results also showed that pedestrian women behaved more cautiously than pedestrian men and attempted to use larger gaps to cross the road. Investigating the videos showed that in the same conditions (distance to approaching vehicle and vehicle speed), female pedestrians use gaps 3 and 2 times as more as men in the outskirts and urban areas, respectively. The number of pedestrians waiting to cross the road was another factor that led to the difference in the number of gaps accepted and rejected by pedestrians. As can be seen in Table 2, with the increase in the number of pedestrians waiting on the outskirts and urban roads, the number of gaps accepted by the pedestrians increased. Aggressive behaviors such as running on the outskirts roads were observed more than 2.5 times higher than that on the urban roads while accepting the gap by the pedestrians, indicating a high crossing risk on the outskirts roads. Viewing the films also showed that when accepting the gap, about 21% and 38% of pedestrians lost their attention to road especially to approaching vehicle via an internal or external distraction factor, respectively. Using mobile phones, talking to other pedestrians and also carrying luggage, like backpacks, accounted for 69, 22 and 9% of pedestrian distractions in the outskirts areas, respectively. In urban areas, use of mobile phones (61%), advertises of shops and advertising digital billboards (18%), talking to pedestrians (7%), and carrying luggage like backpacks (14%) were the causes of pedestrian distraction. The type of vehicles passing on the outskirts also caused varied numbers of gaps. Analyzing of videos showed that under the same conditions (distance to approaching vehicle and the vehicle’s speed) the probability of accepting the gap by the pedestrians lowered with approaching heavy vehicle by about 43% relative to light vehicles. On the other hand, video analysis showed that pedestrians who looked at the approaching vehicles when crossing were more likely to cross than those ignoring the approaching vehicle, even if their chosen gap is smaller. Pedestrian crossings on outskirts roads were significantly different than pedestrian crossings on the urban roads, such that the probability of risky behaviors, like the zigzag movement, during acceptance of the gap by pedestrians was twice as high in outskirts roads as the urban roads.

Table3

Descriptive statistics

Variables		Gap							
		FV				IMV			
		Outskirt roads		Urban roads		Outskirt roads		Urban roads	
		Accepted (298)	Rejected (108)	Accepted (616)	Rejected (114)	Accepted (231)	Rejected (87)	Accepted (176)	Rejected (69)
Gender	Male	181	29	357	38	138	49	119	39
	Female	117	79	259	76	93	28	57	30
Number of pedestrians	1	159	68	319	63	132	38	79	38
	2	69	22	164	30	59	23	51	18
	3	35	11	74	11	21	15	20	11
	4	22	5	49	7	17	8	18	1
	5 and more	13	2	26	3	2	3	8	1
Run	Yes	213	-	167	-	179	-	42	-
	No	85	-	449	-	52	-	134	-
Distracted by internal/external factor	Yes	63	37	234	46	42	50	51	42
	No	235	71	382	68	189	37	125	27
Type of vehicle	Light	209	63	616	114	231	87	176	69
	Heavy	89	45	-	-	-	-	-	-
Attention to approaching vehicle	Yes	266	91	499	101	198	64	157	59
	No	32	17	117	13	33	23	19	10
Crossing path	Perpendicular	64	-	223	-	77	-	93	-
	Oblique	98	-	289	-	49	-	50	-
	Rolling	136	-	104	-	105	-	33	-

4.1.2. IMV data

Data extracted from the videos recorded inside the car show that there is a pattern almost similar to the variables discussed in the previous section. In this approach, the likelihood of rejected gap by the pedestrians was also higher on outskirts roads (1.26 times) than the urban ones, which can be attributed to the high speed of the vehicles as one of the factors. It was also found that pedestrian women use larger gaps than men, indicating their higher conservativeness when crossing the roads. The distracting behaviors in this approach were also factors that influenced pedestrian acceptance or rejection of the gap. It was also observed that pedestrians are more inclined to cross the urban roads in direct and oblique paths, which can be attributed to the narrowness of the roads. On the outskirts areas, due to the wideness of the road, the pedestrians attempted to cross the road in a zigzag movement path, which in most cases accompanies running. It is predictable that doing so by the pedestrians will increase the potential for accidents.

4.2. Pedestrian gap acceptable behavior

4.2.1. Modelling

Table 4 show acceptance gap models through these two data collection approaches in both urban and outskirts areas. As shown in Table 4, the variables affecting the gap coefficients have different effects on the dependent variable (acceptance gap). It is important to note that at both areas, the models obtained through FV and IMV videography data are mostly similar. This result indicates that although a different approach has been considered in the present study, the results are very similar. It should be noted that based on the values of the Bi column of the coefficients table, it cannot be concluded that the variable with a higher coefficient (regardless of its sign) has a greater effect on the dependent variable, because the measurement units of variables in this column are different. Therefore, the standardized beta coefficients column (regardless of its sign) is used to compare the effects of the variables. Beta represents the rate of change in the dependent variable as per the change as big as a standard deviation in the independent variable. According to the Kolmogorov-Smirnov (KS) test value (more than 0.05; 95% significance level) for models through both data collection in case studies; a) outskirt road by FV (0.316), b) outskirt road by IMV (0.392), c) urban road by FV (0.418) and d) urban road by IMV (0.473), it can be concluded that the distribution of the dependent variable (acceptance gap) is normal. In addition, about 87% of the acceptance gap in the outskirts roads is explained by the effective variables identified on models in outskirt road by FV and outskirt road by IMV which is about 90% in urban road by FV and urban road by IMV (urban roads). The values of the Durbin-Watson test for outskirt road by FV (2.057), outskirt road by IMV (1.935), urban road by FV (1.855), and urban road by IMV (1.711) indicate the independence of errors from each other, considering that their values are limited to the interval 1.5 to 2.5. Ultimately, the final model is fit considering the values of different tests.

Table4

Estimation linear regression model results of effective factors

Code	Road type	Approach	Unstandardized (Bi)	Standardized beta	(t-value)	Sig
Constant	Outskirt	FV	-0.408	-1.025	2.005	0.000
		IMV	-1.394	-3.881	3.115	0.004
	Urban	FV	-3.313	-0.045	3.672	0.002
		IMV	-0.237	-0.091	4.815	0.003
Gender	Outskirt	FV	6.176	1.320	3.216	0.004
		IMV	8.164	0.918	6.705	0.009
	Urban	FV	-	-	-	-
		IMV	-	-	-	-
V.T	Outskirt	FV	4.058	0.497	4.809	0.000
		IMV	-	-	-	-
	Urban	FV	-	-	-	-
		IMV	-	-	-	-
S_v	Outskirt	FV	13.059	0.041	8.002	0.010
		IMV	19.216	0.082	5.061	0.000
	Urban	FV	8.492	0.116	6.662	0.015
		IMV	7.059	0.107	5.608	0.010
X_v	Outskirt	FV	8.467	0.018	6.431	0.005
		IMV	14.149	0.044	4.008	0.000
	Urban	FV	10.025	0.102	2.065	0.003
		IMV	9.803	0.099	3.094	0.006
T.C	Outskirt	FV	1.618	0.731	5.547	0.005
		IMV	3.398	0.485	6.043	0.002
	Urban	FV	3.255	0.158	7.035	0.009
		IMV	2.299	0.197	6.726	0.010
Group	Outskirt	FV	-	-	-	-
		IMV	-	-	-	-
	Urban	FV	1.141	0.716	3.363	0.023
		IMV	1.865	0.828	3.524	0.017
Choice	Outskirt	FV	-	-	-	-
		IMV	-	-	-	-
	Urban	FV	-7.695	-1.690	-2.047	0.034
		IMV	-5.967	-1.484	-2.906	0.029

Analysis of the significant coefficients for each of the variables shown in the Table 4 indicates that in the outskirts roads, the gender and crossing time variables have the most impact on the acceptance gap. According to the results, pedestrian women tend to use larger gap to cross the road than pedestrian men, which can be attributed to their conservative behavior. Passengers who needed more time to cross tried to avoid smaller gap. Another influencing factor was the type of vehicle, and pedestrians choose larger gap when facing larger vehicles. Although the speed and acceleration of these vehicles are lower than that of cars, and therefore under similar conditions, pedestrians are more likely to cross safely when faced with heavy vehicles. But because of the dimensions of these vehicles, pedestrians prefer to use larger gap. The speed and distance of the vehicle were other variables that the pedestrians used to choose the gap. On the urban roads, the effective variables identified by IMV data analysis were the same as those identified by the analysis of data from FV data, with two differences. First, due to the use of cameras inside the cars, it was not possible to assess the impact of the type of vehicle. The ban on heavy vehicles on certain roads due to specific geometrical features led to the fact that, in the present study, we could not investigate the impact of vehicle type on acceptance gaps by means of IMV. The second difference is about the effectiveness of variables that are based on the results of FV data analysis, although gender and time to cross are still the most important variables for crossing, but compared to the results of IMV data analysis, they have a lesser effect on gap selected. On the other hand, the effect of the distance between the vehicle and the pedestrian was almost similar to that of the FV analysis approach. The speed of the vehicle also had a relatively greater effect on the acceptance gap in the IMV data analysis than FV ones.

Acceptance gap model for pedestrians on urban roads not only is influenced by variables such as vehicle speed, distance between vehicle and pedestrian and time required to cross the road (these variables were effective in the model of outskirts roads), but also it showed significant differences with pedestrian group size and choice variables. Data analysis showed that with the increase in the number of pedestrians waiting to cross the road, the probability of choosing larger gap increased. Therefore, it seems likely that the probability of accident for the pedestrians moving in groups decreases due to choosing larger gap. On the other hand, the negative coefficient of choice variable indicates that pedestrians who choose to immediately cross the road (not waiting before moving) use smaller gap, which may increase the likelihood of the pedestrian-vehicle collision under dangerous conditions (high speed cars or slow pedestrians' speed in short distance between them). In summary, the acceptance gap models for urban roads are mostly similar in fixed and in-motion videography data, which is also the case with the obtained models of outskirts roads.

4.3. Pedestrian crossing behavior

The positive coefficients of the variables indicate their direct impact on the increased crossing probability of pedestrian, and the negative coefficients indicate that any increase in the value of a variable can lead to a lower crossing probability of the pedestrian. It is therefore understood that variables such as distance between the vehicle and the pedestrian, group size of pedestrians waiting to cross, as well as waiting time when selecting an acceptance gap will increase the likelihood of pedestrians crossing. Similarly, it can be concluded that the increase in the speed of vehicles will reduce the crossing probability of pedestrians. Table 5 shows that the coefficients and variables identified for the same road using FV and IMV data are almost identical. Also, the higher the coefficient of a variable (regardless of its positive or negative sign), the greater its effect on the target variable (the crossing probability). Therefore, the group size of pedestrians at the start of movement is one of the most important factors affecting the crossing likelihood which also increases the safety. For example Table 5 shows that, using video-based data, the crossing probability of pedestrians is shown to be 6.43 times higher if they choose to cross the road as a group ($\mathrm{Odd} = \mathrm{e}^{\beta} = \mathrm{e}^{1.862} = 6.43$). On the other hand, the distance between the vehicle and the pedestrian was another important factor that increased the crossing probability of pedestrians. Also, the values obtained for the Nagelkerke R square coefficients for models were between 0.69 and 0.73, indicating that the independent variables of these models have good explanatory power regarding the variance and variations of the dependent variable of the crossing probability. The fitting of the models was also evaluated by the Hosmer-Lemeshow test. This test shows the correspondence between the numbers of observed and expected cases for the two classes of crossing or non-crossing, with a significance level greater than 5% (sig> 0.05) indicating that there is a good fit for the obtained models.

Table5
Estimation binary logit model results of effective factors

Model	Code	Approach	(Bi)	(t-value)	Sig
Outskirt road	Constant	FV	0.089	3.152	0.015
		IMV	0.126	4.835	0.013
	S_v	FV	-0.132	-5.942	0.000
		IMV	-0.108	-6.186	0.005
	X_v	FV	0.552	3.144	0.031
		IMV	0.716	3.679	0.019
	Group	FV	1.862	3.223	0.006
		IMV	1.428	3.629	0.008
	W.T	FV	0.417	2.992	0.042
		IMV	0.588	3.002	0.035
Urban road	Constant	FV	0.008	2.964	0.026
		IMV	0.035	3.045	0.005
	S_v	FV	-0.095	-5.468	0.002
		IMV	-0.045	-4.982	0.004
	X_v	FV	0.325	4.145	0.020
		IMV	0.314	4.512	0.028
	Group	FV	0.689	4.152	0.000
		IMV	0.476	6.181	0.000
	W.T	FV	0.236	3.943	0.039
		IMV	0.211	4.003	0.038

Fig.3 shows the status of pedestrians crossing or not crossing in the outskirts and road urban roads. FV and IMV-based data are shown concerning the two variables of vehicle speed and vehicle-to-pedestrian distance. Regard to both plots, Fig.3 shows that there is very similar pattern of pedestrians' crossing status based on both FV and IMV data. On urban roads, the likelihood of pedestrians crossing (filled blue circle) is increased when the approaching vehicle speed is low.

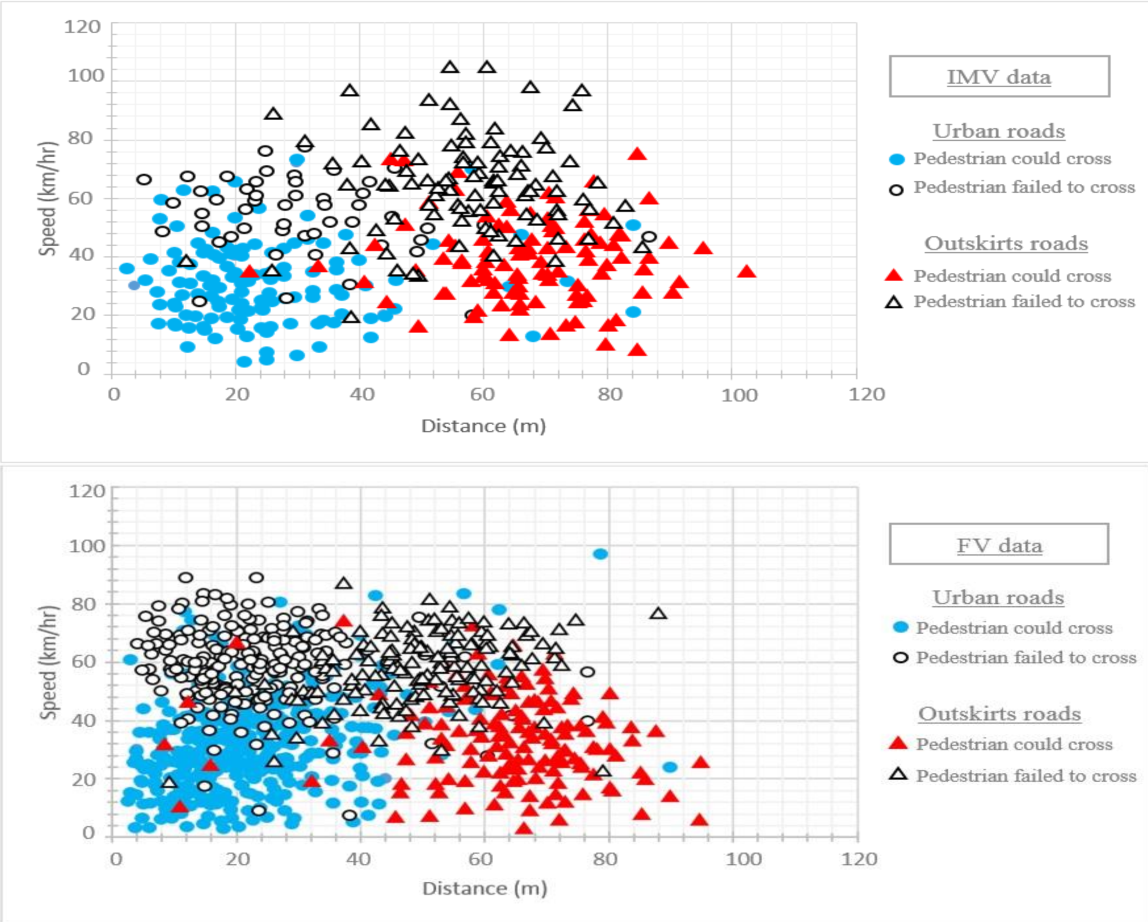

Fig. 3. Plots of pedestrian crossing conditon (Up: IMV data; Down: FV data)

Also, the probability of conditons in which pedestrians failed to cross (empty circle) increased as the car speeds up at a constant distance. The reasons for this include drivers' unwillingness to change their driving behavior, who are not willing to yield encountering pedestrians to allow them to cross the road. On the other hand, at the same speed, pedestrians on the outskirts roads were able to cross (filled red triangle) only when the distantace between approching car and them wasn't short. Simply put, pedestrians are more likely to cross the outskirts roads (filled red triangle) than on urban roads (filled blue circle) only if there is a longer distance between cars and pedestrians. Otherwise, at a constant distance and speed, pedestrians are more likely to cross on urban roads than on outskirts roads, which may be related to reasons such as road width, or more willingness of drivers to yield to pedestrian through various actions. Furthermore, on outskirts roads, pedestrians at short distances to cars were more likely to wait on the side of the road (empty triangle) to use a bigger gap size to cross. In this case (short distances), if the approaching vehicle speed is hig, the pedestrians decisions to wait on the side of the road increased.

5. Conclusions and further research

New approaches such as FV and IMV data for better detailed analyzing road user behavior have compensated some of the limitations of using previous methods. Considering remarkable portion of pedestrian accident occur on the outskirts areas connecting to the urban areas, the current study attempts to evaluate the safety of pedestrians crossing on both urban and outskirts areas through two different approaches. Data collection based on FV and IMV on the roads provided valuable information on the behavior of road users at different times and distance on roads. In the first step, data were analyzed to determine the pedestrian acceptance gap behaviour model through the linear regression model. FV and IMV data were analyzed for each of the urban and outskirts roads.The findings showed the similarity of results using these two different approaches. Based on result of linear regression models the drivers and pedestrians exhibited relatively similar behavior on both outskirts and urban routes. Also, the results showed that the variables of pedestrian gender, pedestrian willingness to cross without waiting on the side of the roads, inclination of pedestrians to move in groups, and time required to cross the road can be described as pedestrian behaviors that lead to different decisions when crossing the road. On the other hand, the distance between the vehicle and the pedestrian as well as the speed of the approaching vehicle are other influential factors in choosing an accepted gap by pedestrian. In second step, the pedestrian crossing behavior model on both types of studied areas showed similar affects on variables such as vehicle speed, distance of vehicle and pedestrian, pedestrian group size, and waiting time on the both case study area. A similar behavior pattern was observed for pedestrians crossing in the outskirts and urban roads. However, pedestrians on the outskirts roads perform more cautious behavior to cross than in the urban ones. The modeling results also showed that the IMV and FV data are mostly similar to one another and can be deduced that drivers' behavior in NDS studies was not different from their normal behavior. In general, the findings of the present study are very important in two forms. First, using FV and IMV approaches evaluated the issue of pedestrian safety from the perspectives of drivers and pedestrians. Meanwhile, previous studies on road user behavior have always been addressed from a separate perspective. Accordingly, the results of the present study expose a better understanding of the nature of the interaction between the driver and pedestrians. Second, in this study the pedestrian safety was examined on the outskirts areas, meanwhile, this subject had not been addressed through driver or pedestrian behaviors on previous studies up to now. Based on the result, the behavior of road users in both urban and outskirt areas indicates the same behavior in different situations, although slight changes were performed in some of road users' decisions regarding different conditions.

It is anticipated that the results of such study will lead to a better understanding of the behavioral and performance differences of drivers and pedestrians on the urban and outskirts routes when encountering each other. In other words, considering that the use of advanced driver assistance systems (ADAS) is increasing rapidly (Acerra et al., 2019; Bianchi Piccinini et al., 2014; Dumitru et al., 2018; Ghasemi et al., 2020; Schnelle et al., 2018; Varotto et al., 2018), accurate identification of pedestrian behaviors in different urban and outskirts routes can be a positive step in adapting ADAS to enhance pedestrian safety in different areas, including outskirts areas. Taking into account the models presented, future research in this field can focus on the role of Advanced Driver Assistance System (ADAS) to assess the vehicle-pedestrian conflict probability. Studies with such perspectives are expected to lead to a more comprehensive assessment of the role of ADAS in enhancing pedestrian safety on the roads.

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