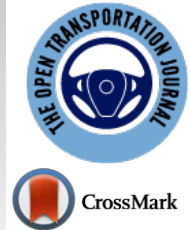




# The Open Transportation Journal

Content list available at: <https://opentransportationjournal.com>



## RESEARCH ARTICLE

### Pedestrian Compliance at Signalized Intersections along Major Arterials

Khaled Shaaban<sup>1,\*</sup>

<sup>1</sup>Department of Engineering, Utah Valley University, Orem, UT, United States

#### Abstract:

#### Background:

Pedestrian non-compliance at signalized crossings is unsafe and considered one of the causes of pedestrian crashes. The speed limit on most major urban roads is 60 km/hr or less. However, the speed on some urban roads is higher in some countries. In this case, the situation is more unsafe and increases the possibility of fatal injuries or fatalities in the case of a crash. Therefore, it is expected that the pedestrians will be more cautious on these roads.

#### Aim:

This study aims to explore pedestrian compliance at signalized intersections on major arterials with 80 km/hr speeds in Qatar.

#### Methods:

Video data were collected for pedestrian movements at multiple intersections.

#### Results:

The study reported a 68.1 percent compliance rate at the study locations. The results also revealed that 14.6 percent of the pedestrians crossed during the Flashing Don't Walk interval and 17.3 percent crossed during the Steady Don't Walk interval. These rates are considered high compared to other countries. Several variables that may influence pedestrians' behavior were investigated. Binary and ordinal logistic regression models were developed to describe the pedestrian crossing behavior as a function of these variables.

#### Conclusion:

Male and middle-age pedestrians were more likely to cross during these two intervals. The analysis showed that female pedestrians, elder pedestrians, pedestrians crossing in groups, pedestrians waiting before crossing, and pedestrians crossing against a flow of other pedestrians are more likely to comply and cross during the Walk interval compared to other groups. Several solutions were proposed in the study to increase compliance rates.

**Keywords:** Crossing compliance, Pedestrian behavior, Crosswalks, Traffic signal, Traffic safety, Signalized intersections.

#### Article History

Received: January 30, 2021

Revised: April 25, 2021

Accepted: May 30, 2021

## 1. INTRODUCTION

A high percentage of pedestrian crashes occur at signalized intersections [1, 2]. Many of these crashes are caused by pedestrian violations [3, 4]. Adding crosswalks at signalized intersections provides designated crossing locations for pedestrians and separates them from traffic. Previous research indicated that the presence of crosswalks increase pedestrian safety as well as crossing compliance when properly used as they reduce potentials for pedestrian crash occurrences [5, 6].

However, many pedestrians crossing at signalized intersections tend not to comply with pedestrian signals, especially at times when low vehicular traffic flows are observed.

Several studies investigated the influences of personal features on street-crossing behavior. Pedestrian characteristics such as gender and age have been shown to be important contributing factors to pedestrian violations. Many studies have reported that male pedestrians violate traffic rules more frequently than females and are more likely to cross in riskier situations [7 - 11]. One study showed opposing findings with male pedestrians observed to be more likely to comply with traffic rules on signalized crosswalks [12]. When it comes to

\* Address correspondence to this author at Department of Engineering, Utah Valley University, Orem, UT, United States; E-mail: [kshaaban@uvu.edu](mailto:kshaaban@uvu.edu)

age, previous studies showed that older pedestrians wait for a longer time than younger ones at crossing signals [7] and they also appear to be more inclined to comply with traffic laws [12 - 14]. In some cases, age failed to yield significant differences in offending crossing behaviors [9].

Compliance rates reported in the literature imply that pedestrian compliance varied from location to location, city to city, and neighborhood to neighborhood. Pedestrian characteristics, user preferences, and habits are expected to affect compliance rates. Therefore, the comparison of crossing compliance rates from one place to another may not be meaningful without knowing the local pedestrian characteristics. Limited studies investigated pedestrians' compliance behavior in Qatar and the surrounding region. This region includes Qatar, Oman, Bahrain, United Arab Emirates, Saudi Arabia, and Kuwait. This study aims to identify the compliance rate along major arterials in Qatar. The current study presents an extension of our previous work on pedestrian crossing speeds in Qatar [15].

## 2. METHODS

The common speed limit on major urban roads is 60 km/hr or less [16]. However, the speed on most major urban roads in Qatar is 80 km/hr. In this case, the situation is more unsafe and increases the possibility of fatal injuries or fatalities in the case of a crash. Three similar intersections along major arterials in the city of Doha were chosen for this study. The selected intersections were typical in size, as illustrated in Fig. (1). All intersections were also located in the same area. When possible, various crossing options should be evaluated in the same environment. This approach is preferred for more meaningful comparisons since the effects of pedestrian characteristics can be isolated from the crosswalk and geometric features of pedestrian paths and roadways. Previous research pointed out the impact of the environment on pedestrian behavior [17 - 20]. For example, the layout of the crosswalk including type, length, and width can affect pedestrian compliance [17, 18]. Therefore, by selecting almost identical sites, the analysis is focused mainly on human factors. The video data were collected for a total of 24 hours at each location.

The extracted data included 1,423 pedestrians. Our

previous work showed that the observed 15<sup>th</sup> percentile speed in this region (1.03 m/s) [15] was marginally lower than the speed recommended in the Manual on Uniform Traffic Control Devices (MUTCD) (1.07 m/s) [21] and the National Cooperative Highway Research Program (NCHRP) Report 562 (1.13 m/s) [22]. Different characteristics were obtained from the data, such as gender, age group, type of clothing, carrying bags, using a mobile phone, and waiting time. The age group of the pedestrians was simplified to three types: children, middle-age, and elders to reduce the possibility of error [23, 24]. The type of clothing was used to identify the residents that wear a traditional type of cloth called "thoub" for male and "abbayah" female. The presence of other pedestrians on the road while crossing was included in the analysis in the form of two variables. The first variable, flow with, indicates that other pedestrians are crossing in the same direction at the same time. The second variable, flow against, indicates that other pedestrians are crossing from the opposite direction of the selected pedestrian at the same time of crossing.

## 3. RESULTS

### 3.1. Pedestrian Behavior

The pedestrian crossing behavior was classified into three cases; began crossing during the "Walk" time, crossing during "Flashing Don't Walk" (FDW), and crossing during the "Steady Don't Walk" (SDW) time. Most of the pedestrians (68.1%) were observed crossing during the Walk interval. A low percentage (14.6%) were observed crossing during the FDW interval, and during the SDW interval (17.3%). The majority of all pedestrians (89.0%) crossed when no vehicles were present. The data showed a low number of female pedestrians (9.4%), children (0.2%), pedestrians with traditional clothes (1.8%), and pedestrians using their phones while crossing (2.5%). These percentages are typical for the city of Doha [25, 26]. Furthermore, 25.7% of all pedestrians did not wait before crossing. A reasonable percentage of pedestrians were observed crossing with a flow against (35.6%), crossing with a flow in the same direction (24.2%), and carrying bags (16.4%). Fig. (2) shows the pedestrian characteristics for the Walk, FDW, and SDW cases for the different variables. Due to the limited number of children observed (three pedestrians), this data is not included in the age chart.



Fig. (1). Aerial view of the study locations.

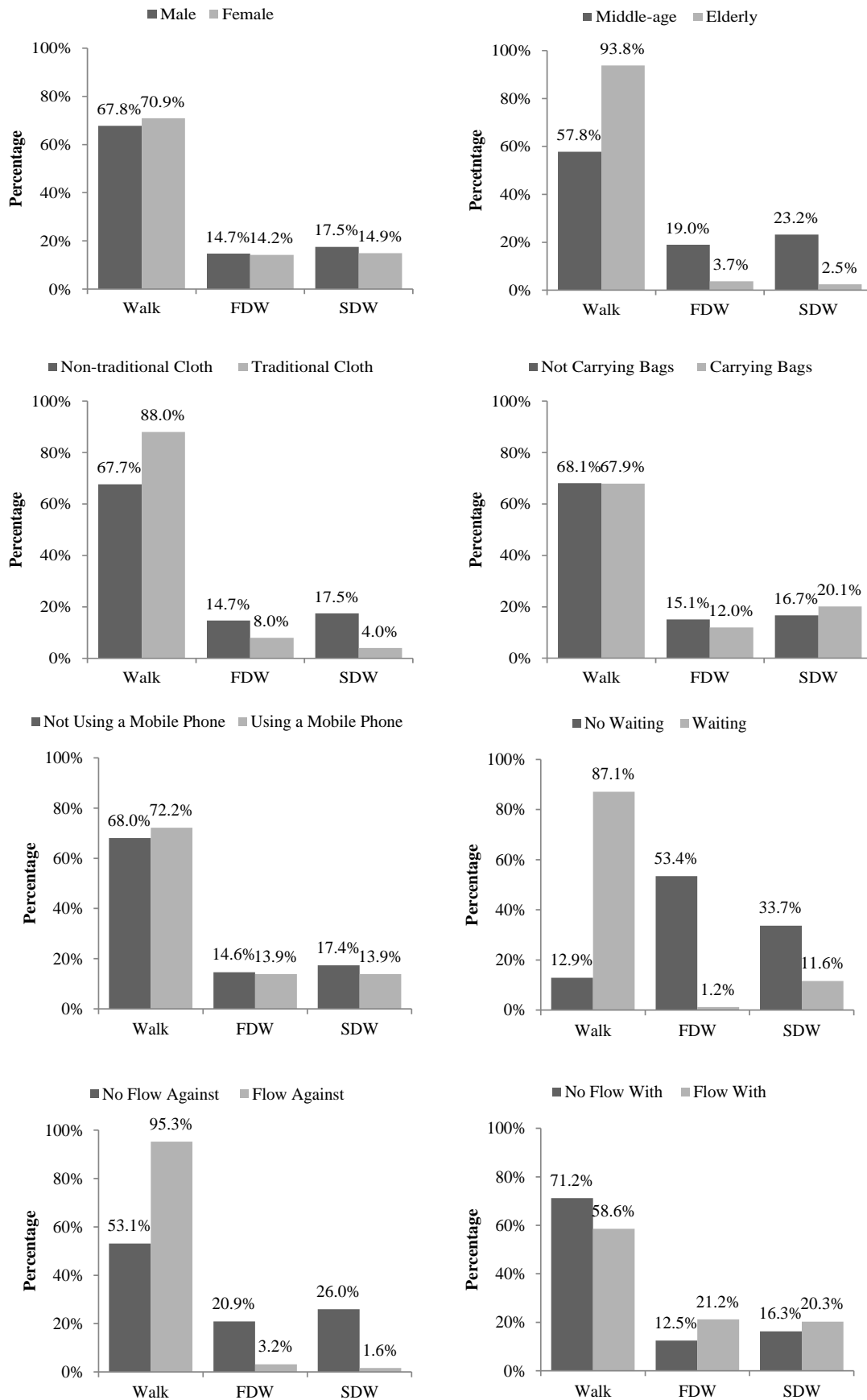


Fig. (2). Pedestrian characteristics for the walk, FDW, and SDW cases.

### 3.2. Logistic Regression

In this study, logistic regression models were used to explain the crossing behavior of pedestrians. The first binary model was used to differentiate pedestrians' behavior during the Walk interval from other behaviors (either FDW or SDW intervals). The ordinal model was used to differentiate between Walk, FDW, and SDW. Due to the limited observations of children, this data was excluded from the logistic regression analysis resulting in 1,420 pedestrians.

### 3.3. Binary Logistic Describing Walk vs FDW/SDW

Binary logistic regression is an appropriate statistical technique when the independent variable is binary. It represents two groups of interest, with values of 0 and 1. The procedure for estimating the coefficients is a maximum likelihood, and the goal is to find the best linear combination of independent variables to maximize the likelihood of obtaining the observed outcome frequencies [27, 28]. Binary logistic regression takes the following form (Eq. 1):

$$\Pr(y_i) = \frac{e^{U_i}}{1+e^{U_i}}, \tag{1}$$

where  $\Pr(y_i)$  is the probability of observation  $i$  being a success. The term  $U_i$  is a utility function that is related to the independent (explanatory) variables in the following linear form (Eq. 2):

$$U_i = \beta_0 + \sum_j \beta_j x_{ij}, \tag{2}$$

where  $\beta_j$  are coefficients to be estimated and  $x_{ij}$  are observed explanatory variables associated with observation  $i$ .

The first model considered two outcomes: a pedestrian crossing during the Walk interval (success) or any other behavior (failure). The other outcomes included both FDW or SDW intervals. The final model presented in Table 1 lists the model estimation and the odds ratio for the independent variables. In this model, the following baseline conditions are assumed for the independent variables: male, middle-age,

traditional clothing, not carrying bags, not using a phone, not crossing in a group, did not wait before crossing, no flow against, and no flow with. The model showed that the odds of female pedestrians crossing the road during the Walk interval is 1.8 times higher than the odds of male pedestrians. The model also indicated that the odds that an elder pedestrian crossing the road during the Walk interval is 3.8 times higher than the odds of the middle-age pedestrians. The odds of pedestrians crossing in groups during the Walk interval is 2.8 times the odds of a pedestrian crossing alone. Compared to pedestrians not waiting, pedestrians waiting before crossing are 32 times more likely to cross during the Walk interval. Pedestrians crossing against flow are 11.1 times more likely to cross during the Walk interval. Finally, pedestrians crossing with flow are 2.1 times less likely to cross during the Walk interval.

### Ordinal Logistic Model Describing Walk vs. FDW vs. SDW

The second model considered all potential stopping outcomes: Walk, FDW, or SDW. Failure to consider the differences could lead to an inaccurate understanding of the impacts of explanatory variables on the pedestrian's behavior. To fully capture these effects, ordinal logistic regression was estimated and compared to the binary logistic regression model previously described. Ordinal logistic regression is applied to categorical responses with an ordered structure; e.g., not successful, somewhat successful, and successful. In general, the ordinal logistic regression model takes the following form (Eq. 3):

$$\ln(\theta_k) = \beta_k + \sum_j \beta_j x_{ij}, \tag{3}$$

where  $\theta_k$  represents the proportional odds of an equal or smaller response occurring ( $\Pr(y_i \leq k)$ ) compared to a larger response occurring ( $\Pr(y_i > k)$ ) defined as follows (Eq. 4):

$$\theta_k = \frac{\Pr(y_i \leq k)}{\Pr(y_i > k)}. \tag{4}$$

For a categorical response variable with  $K$  outcomes,  $K - 1$  proportional odds ratios (i.e., intercepts/constants) are needed to define the model since  $\Pr(y_i > K) = 0$ .

Table 1. Parameter estimates for the binary logistic regression.

	Estimate	Standard Error	Wald	df	p-value	Odds Ratio Exp(B)	95% Confidence Interval	
							Lower	Upper
Constant	-5.399	0.758	50.790	1	<0.001	0.005	-	-
Group [Yes] vs [No]*	1.056	0.288	13.445	1	<0.001	2.876	1.635	5.058
Waiting [Yes] vs [No]*	3.492	0.202	299.145	1	<0.001	32.841	22.109	48.781
Flow Against [Yes] vs [No]*	2.411	0.347	48.398	1	<0.001	11.141	5.649	21.973
Age [Elder] vs [Middle-age]*	1.344	0.387	12.095	1	0.001	3.835	1.798	8.182
Flow With [Yes] vs [No]*	-0.765	0.287	7.110	1	0.008	0.466	0.265	0.817
Gender [Female] vs [Male]*	0.578	0.287	4.057	1	0.044	1.782	1.016	3.128
Phone Use [Yes] vs [No]	0.935	0.531	3.106	1	0.078	2.548	0.900	7.210
Clothing [Non-traditional] vs [Traditional]	0.138	0.927	0.022	1	0.881	1.149	0.187	7.060
Carrying Bags [Yes] vs [No]	-0.022	0.217	0.010	1	0.919	0.978	0.640	1.496

\* It refers to significance at 5 percent level

**Table 2. Parameter estimates for the ordinal logistic regression.**

-	-	Estimate	Standard Error	Wald	df	p-value	95% Confidence Interval	
-	-	-	-	-	-	-	Lower	Upper
Threshold	Compliance=Walk	4.028	0.972	17.162	1	<0.001	2.122	5.933
	Compliance=FDW	5.237	0.977	28.724	1	<0.001	3.322	7.152
Location	[Group=No]*	0.853	0.237	12.953	1	<0.001	0.388	1.317
	[Group=Yes]	0 <sup>a</sup>	-	-	0	-	-	-
	[Ped Waiting=No]*	2.225	0.149	224.235	1	<0.001	1.934	2.517
	[Ped Waiting=Yes]	0 <sup>a</sup>	-	-	0	-	-	-
	[Flow Against=No]*	2.093	0.328	40.684	1	<0.001	1.450	2.736
	[Flow Against=Yes]	0 <sup>a</sup>	-	-	0	-	-	-
	[Age=Middle-age]*	-0.716	0.354	4.101	1	0.043	-1.410	-0.023
	[Age=Elder]	0 <sup>a</sup>	-	-	0	-	-	-
	[Flow With=No]*	-0.452	0.231	3.804	1	0.051	-0.905	0.002
	[Flow With=Yes]	0 <sup>a</sup>	-	-	0	-	-	-
	[Gender=Male]*	0.400	0.233	2.966	1	0.085	-0.055	0.856
	[Gender=Female]	0 <sup>a</sup>	-	-	0	-	-	-
	[Ped Phone Use=No]	0.718	0.432	2.760	1	0.097	-0.129	1.565
	[Ped Phone Use=Yes]	0 <sup>a</sup>	-	-	0	-	-	-
	[Clothing=Non-traditional]	0.122	0.844	0.021	1	0.885	-1.531	1.776
	[Clothing=Traditional]	0 <sup>a</sup>	-	-	0	-	-	-
	[Carrying Bags=No]	0.029	0.180	0.026	1	0.873	-0.323	0.381
	[Carrying Bags=Yes]	0 <sup>a</sup>	-	-	0	-	-	-

\* It refers to significance at 5 percent level

<sup>a</sup> Set as reference variable

The ordinal model covered all possible outcomes: Walk, FDW, or SDW, as shown in Table 2. The following baseline conditions are assumed: female, elder, traditional clothing, carrying bags while crossing, using phone while crossing, crossing in a group, waiting before crossing, walking with flow, and walking against flow. Interestingly, the trends revealed by the ordinal logistic regression model were similar to those provided by the simpler binary logistic regression. Males were found to be more likely to cross during the FDW and SDW intervals compared to females. Similarly, pedestrians with non-traditional clothing were found to be more likely to cross during the FDW and SDW intervals compared to pedestrians with traditional clothing. Pedestrians waiting before crossing were more likely to cross during the Walk interval. The ordinal logistic regression model also revealed that pedestrians crossing with the flow were more likely to cross during the FDW and SDW intervals, on the contrary of the pedestrians crossing against the flow. The clothing type, carrying bags, and using a phone while crossing variables were not found to influence crossing behavior in a statistically significant way.

## CONCLUSION

The purpose of this study was to investigate pedestrians' compliance at signalized intersections along major arterials in Qatar. This study is one of the first efforts to study pedestrians' compliance in this region and provides insight into the factors related to crossing behavior. All main roads at the studied intersections had a speed of 80 km/hr. A 68.1 percent compliance rate was observed at the different locations. This percentage is considered less than the compliance rate in

several countries in other regions. For example, a study at multiple intersections in New York found that the lowest compliance was 79.7 percent [29]. Another study in Ohio reported that the pedestrian crossing compliance rate was 85.4 percent [30]. A study in Beijing reported 70 percent and 57 percent compliance rates at two locations [31].

The study also revealed that pedestrians who crossed during the FDW and SDW intervals were 14.6 percent and 17.3 percent out of the total sample. It should be noted that the possibility of a pedestrian crash is much higher while crossing during the SDW interval [3]. Males and pedestrians with non-traditional clothing were found to be more likely to cross during the FDW and SDW intervals compared to females and pedestrians with traditional clothing. Moreover, pedestrians waiting before crossing were more likely to cross during the Walk interval and pedestrians crossing with other pedestrians crossing in the same direction were more likely to cross during the FDW and SDW intervals. A reason can be that pedestrians feel safer taking the risk of crossing as a group during the FDW and SDW intervals.

The current study makes a significant contribution in pedestrians' behavior literature, as it sheds light on pedestrians' compliance levels in Qatar, a country in the Arabian Gulf region. The low compliance identified in the study can be alarming for Qatar and different countries with similar characteristics in the Arabian Gulf region, including Oman, Bahrain, United Arab Emirates, Saudi Arabia, and Kuwait. Public agencies and transportation authorities in Qatar and other countries in the region should develop different strategies to achieve higher compliance.

One solution that is not currently implemented in Qatar is the use of pedestrian countdown timers (PCT). PCT provides additional information to the pedestrians by providing information regarding the amount of remaining time to complete the crossing movement, which improves their comprehension of the FDW signal. Previous research found that the PCT is easier to understand as compared to the conventional FDW signal [32]. This resulted in pedestrians taking more informed decisions regarding their crossing- either to start or stop and wait until the pedestrian Walk interval. Once implemented, their effectiveness should be investigated in the future.

Also, lower-speed roads are directly related to a lower risk of pedestrian-vehicle collision and injuries [33]. Therefore, consideration should be given to reducing speed limits to 60 km/hr or less in urban areas. Moreover, some studies found that a high percentage of pedestrians do not understand the FDW indication [34, 35]. Testing the knowledge of the pedestrians and identifying proper countermeasures to increase the knowledge and educate pedestrians should be investigated in the future. Finally, low levels of enforcement for pedestrian violations exist in this region [36]. Therefore, more strict enforcement should be implemented at signalized intersections.

A number of limitations with the current study should be noted. The study focused on one type of crosswalk to focus on pedestrian characteristics and eliminate any other factors. Some studies pointed to the effect of the environment on pedestrian behavior and injuries [20, 37]. Thus, it is important to study different types of crosswalks and different environmental settings to identify the types of facilities pedestrians favor and the attitudes of pedestrians towards such facilities. In addition, studying additional intersections to cover a larger sample of females and children can provide more information regarding these two groups. However, the low number of female and children pedestrians is common in Qatar, as indicated by previous studies [38 - 40]. Furthermore, several outstanding questions remain regarding the reasons for different pedestrians' behaviors at signalized intersections. Therefore, future research should examine if pedestrians are more likely to make deliberate violations *versus* errors at crossings, confirm whether violations are consistent across different groups, and identify factors to increase the likelihood of compliance. These goals can be achieved by conducting a questionnaire survey with a representative sample of the population.

#### CONSENT FOR PUBLICATION

Not applicable.

#### AVAILABILITY OF DATA AND MATERIALS

Not applicable.

#### FUNDING

None.

#### CONFLICT OF INTEREST

The author declares no conflict of interest, financial or otherwise.

#### ACKNOWLEDGEMENTS

Declared none.

#### REFERENCES

- [1] C. Lee, and M. Abdel-Aty, "Comprehensive analysis of vehicle-pedestrian crashes at intersections in Florida", *Accid. Anal. Prev.*, vol. 37, no. 4, pp. 775-786, 2005. [http://dx.doi.org/10.1016/j.aap.2005.03.019] [PMID: 15869737]
- [2] S.S. Pulugurtha, and V.R. Sambhara, "Pedestrian crash estimation models for signalized intersections", *Accid. Anal. Prev.*, vol. 43, no. 1, pp. 439-446, 2011. [http://dx.doi.org/10.1016/j.aap.2010.09.014] [PMID: 21094342]
- [3] M.J. King, D. Soole, and A. Ghafourian, "Illegal pedestrian crossing at signalised intersections: Incidence and relative risk", *Accid. Anal. Prev.*, vol. 41, no. 3, pp. 485-490, 2009. [http://dx.doi.org/10.1016/j.aap.2009.01.008] [PMID: 19393797]
- [4] P. Onelcin, and Y. Alver, "Illegal crossing behavior of pedestrians at signalized intersections: Factors affecting the gap acceptance", *Transp. Res., Part F Traffic Psychol. Behav.*, vol. 31, pp. 124-132, 2015. [http://dx.doi.org/10.1016/j.trf.2015.04.007]
- [5] J.N. Ivan, P.E. Garder, and S.S. Zajac, *Finding strategies to improve pedestrian safety in rural areas.*, University of Connecticut: Massachusetts, United States, 2001. [http://dx.doi.org/10.1037/e439672008-001]
- [6] R.A. Retting, M.S. Nitzburg, C.M. Farmer, and R.L. Knoblauch, "Field evaluation of two methods for restricting right turn on red to promote pedestrian safety", *ITE J.*, vol. 72, no. 1, pp. 32-36, 2002.
- [7] H. Guo, Z. Gao, X. Yang, and X. Jiang, "Modeling pedestrian violation behavior at signalized crosswalks in China: A hazards-based duration approach", *Traffic Inj. Prev.*, vol. 12, no. 1, pp. 96-103, 2011. [http://dx.doi.org/10.1080/15389588.2010.518652] [PMID: 21259179]
- [8] M.M. Hamed, "Analysis of pedestrians' behavior at pedestrian crossings", *Saf. Sci.*, vol. 38, no. 1, pp. 63-82, 2001. [http://dx.doi.org/10.1016/S0925-7535(00)00058-8]
- [9] T. Rosenbloom, "Crossing at a red light: Behaviour of individuals and groups", *Transp. Res., Part F Traffic Psychol. Behav.*, vol. 12, no. 5, pp. 389-394, 2009. [http://dx.doi.org/10.1016/j.trf.2009.05.002]
- [10] G. Tiwari, S. Bangdiwala, A. Saraswat, and S. Gaurav, "Survival analysis: Pedestrian risk exposure at signalized intersections", *Transp. Res., Part F Traffic Psychol. Behav.*, vol. 10, no. 2, pp. 77-89, 2007. [http://dx.doi.org/10.1016/j.trf.2006.06.002]
- [11] A. Tom, and M-A. Granić, "Gender differences in pedestrian rule compliance and visual search at signalized and unsignalized crossroads", *Accid. Anal. Prev.*, vol. 43, no. 5, pp. 1794-1801, 2011. [http://dx.doi.org/10.1016/j.aap.2011.04.012] [PMID: 21658507]
- [12] G. Ren, Z. Zhou, W. Wang, Y. Zhang, and W. Wang, "Crossing behaviors of pedestrians at signalized intersections: Observational study and survey in China", *Transp. Res. Rec.*, vol. 2264, no. 1, pp. 65-73, 2011. [http://dx.doi.org/10.3141/2264-08]
- [13] M-A. Granić, M. Pannetier, and L. Guého, "Developing a self-reporting method to measure pedestrian behaviors at all ages", *Accid. Anal. Prev.*, vol. 50, pp. 830-839, 2013. [http://dx.doi.org/10.1016/j.aap.2012.07.009] [PMID: 22836115]
- [14] T. Rosenbloom, D. Nemrodov, and H. Barkan, "For heaven's sake follow the rules: pedestrians' behavior in an ultra-orthodox and a non-orthodox city", *Transp. Res., Part F Traffic Psychol. Behav.*, vol. 7, no. 6, pp. 395-404, 2004. [http://dx.doi.org/10.1016/j.trf.2004.10.004]
- [15] K. Shaaban, "Analysis of pedestrian crossing speeds at signalized intersections in qatar", *Arab. J. Sci. Eng.*, vol. 44, no. 5, pp. 4467-4476, 2019. [http://dx.doi.org/10.1007/s13369-018-3460-3]
- [16] G. Forbes, T. Gardner, H.W. McGee, and R. Srinivasan, "Methods and practices for setting speed limits: An informational report", In: *Office of Safety*, Federal Highway Administration.: United States., 2012.
- [17] J. Supernak, V. Verma, and I. Supernak, "Pedestrian countdown signals: what impact on safe crossing?", *Open J. Civil Eng.*, vol. 3, no. 03, p. 39, 2013. [http://dx.doi.org/10.4236/ojce.2013.33B007]
- [18] Y. Yang, and J. Sun, "Study on pedestrian red-time crossing behavior: integrated field observation and questionnaire data", *Transp. Res. Rec.*, vol. 2393, no. 1, pp. 117-124, 2013. [http://dx.doi.org/10.3141/2393-13]

- [19] P. Gärder, "Pedestrian safety at traffic signals: A study carried out with the help of a traffic conflicts technique", *Accid. Anal. Prev.*, vol. 21, no. 5, pp. 435-444, 1989.  
[[http://dx.doi.org/10.1016/0001-4575\(89\)90004-3](http://dx.doi.org/10.1016/0001-4575(89)90004-3)] [PMID: 2619853]
- [20] O. Keegan, and M. O'Mahony, "Modifying pedestrian behaviour", *Transp. Res. Part A Policy Pract.*, vol. 37, no. 10, pp. 889-901, 2003.  
[[http://dx.doi.org/10.1016/S0965-8564\(03\)00061-2](http://dx.doi.org/10.1016/S0965-8564(03)00061-2)]
- [21] C. Traffic, *Manual on Uniform Traffic Control Devices.*, MUTCD, 2009.
- [22] K. Fitzpatrick, *Improving pedestrian safety at unsignalized crossings (no. TCRP Report 112).*, 2006.
- [23] Y.I. Demiroz, P. Onelcin, and Y. Alver, "Illegal road crossing behavior of pedestrians at overpass locations: Factors affecting gap acceptance, crossing times and overpass use", *Accid. Anal. Prev.*, vol. 80, pp. 220-228, 2015.  
[<http://dx.doi.org/10.1016/j.aap.2015.04.018>] [PMID: 25916663]
- [24] Y. Alver, and P. Onelcin, "Gap acceptance of pedestrians at overpass locations", *Transp. Res., Part F Traffic Psychol. Behav.*, vol. 56, pp. 436-443, 2018.  
[<http://dx.doi.org/10.1016/j.trf.2018.05.010>]
- [25] K. Shaaban, D. Muley, and D. Elnashar, "Temporal variation in walking behavior: An empirical study", *Case studies on transport policy*, vol. 5, no. 4, pp. 671-680, 2017.
- [26] K. Shaaban, and D. Muley, "Investigation of weather impacts on pedestrian volumes", *Transp. Res. Procedia*, vol. 14, pp. 115-122, 2016.  
[<http://dx.doi.org/10.1016/j.trpro.2016.05.047>]
- [27] P. McCullagh, and J.A. Nelder, *Generalized linear models.*, CRC press, 1989.  
[<http://dx.doi.org/10.1007/978-1-4899-3242-6>]
- [28] A. Agresti, and M. Kateri, *Categorical data analysis Int Ency Stat Scii.*, Berlin, Heidelberg: Springer, 2014.
- [29] H.J. Park, S. Li, W. Yu, W. Yang, W. Alhajyaseen, and M. Iryo-Asano, "Pedestrian crossing behavior and compliance at signalized intersections", *17th International Conference Road Safety On Five Continents (RS5C 2016), Rio de Janeiro, Brazil, 17-19 May 2016.*, 2016
- [30] N.M. Roupail, "Midblock crosswalks: A user compliance and preference study", *Transp. Res. Rec.*, no. 959, pp. 41-47, 1984.
- [31] Y. Tanaboriboon, and Q. Jing, "Chinese pedestrians and their walking characteristics: Case study in Beijing", *Transp. Res. Rec.*, pp. 16-16, 1994.
- [32] K.W. Kim, Y. Kim, and H.Y. Seo, "An evaluation of pedestrian countdown signals", *KSCE J. Civ. Eng.*, vol. 6, no. 4, pp. 533-537, 2002.  
[<http://dx.doi.org/10.1007/BF02842006>]
- [33] C.G. Prato, S. Kaplan, A. Patrier, and T.K. Rasmussen, "Considering built environment and spatial correlation in modeling pedestrian injury severity", *Traffic Inj. Prev.*, vol. 19, no. 1, pp. 88-93, 2018.  
[<http://dx.doi.org/10.1080/15389588.2017.1329535>] [PMID: 28534647]
- [34] J.E. Tidwell, and D.P. Doyle, "Driver and pedestrian comprehension of pedestrian law and traffic control devices", *Transp. Res. Rec.*, no. 1502, pp. 119-128, 1995.
- [35] J.P. Singer, and N. Lerner, *Countdown Pedestrian Signals: A comparison of alternative pedestrian change interval displays.*, Westat, 2005.
- [36] K. Shaaban, "Assessment of drivers' perceptions of various police enforcement strategies and associated penalties and rewards", *J. Adv Trans*, vol. 2017, p. 14, 2017. Art no. 5169176.  
[<http://dx.doi.org/10.1155/2017/5169176>]
- [37] G.M. Abdella, and K. Shaaban, "Modeling the impact of weather conditions on pedestrian injury counts using lasso-based poisson model", *Arab. J. Sci. Eng.*, pp. 1-12, 2020.
- [38] K. Shaaban, "Why don't people ride bicycles in high-income developing countries, and can bike-sharing be the solution? the case of qatar", *Sustainability*, vol. 12, no. 4, p. 1693, 2020.  
[<http://dx.doi.org/10.3390/su12041693>]
- [39] K. Shaaban, and K. Abdur-Rouf, "Assessing walking and cycling around schools", *Sustainability*, vol. 12, no. 24, p. 10607, 2020.  
[<http://dx.doi.org/10.3390/su122410607>]
- [40] K. Shaaban, and K. Abdelwarith, "Pedestrian attribute analysis using agent-based modeling", *Appl. Sci. (Basel)*, vol. 10, no. 14, p. 4882, 2020.  
[<http://dx.doi.org/10.3390/app10144882>]