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Crosswalk Utilization by Pedestrian: Perception versus Reality - Case Study of New Delhi

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ABSTRACT

Pedestrian safety at signalized intersections is a major cause of concern all over the world. Properly marked crosswalk enhances the safety of pedestrians as it is a well recognized crossing location by drivers. However a large number of accidents are reported at intersections predominantly due to the violation behavior of pedestrians. This study aims at understanding the crosswalk utilization behavior of pedestrians at urban signalized intersections. Data was collected through video recording and a questionnaire survey. Significant variables were identified and modelled using binomial logistic regression. Pedestrian personal level factors were found to significantly affect crosswalk compliance. Discrepancies were identified between perception and reality, suggesting that variation exists between what people say and what they practice in reality. The findings from this study suggest that a perception based study may not be as reliable as an observational study. The findings have both theoretical as well as practical implications and would certainly help the policy makers and designers in enhanced understanding of pedestrian behavior at urban signalized intersections.

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1. INTRODUCTION

Road accidents have become a major concern globally and particularly in emerging economies. Every year, approximately 1.35 million people die due to road accidents costing most countries about 3% of their GDP [1]. India being a developing country is no exception to this global predicament. To put into context India ranks second in terms of incidences of road accident fatalities globally [2]. The accident records from within the country report the occurrence rate of road accidents at 53 per hour and on an average 17 lives are lost per hour. The situation is alarming in million plus population Indian cities as these cities accounted for 11.5 % of the total fatalities. Delhi had the highest number of accidental death followed by Chennai in 2017 [3]. Pedestrians are the most vulnerable road users and ultimate sufferers of road accidents. Road accident fatalities involving pedestrians account for about 22% of the total fatalities worldwide [4]. Accident statistics from China report that pedestrian fatalities in traffic accidents are as high as 30% [5]. The share of fatal pedestrian road crashes in India was 13.8% in 2017 which is 3.4% more than the previous year whereas for Delhi it is almost 40% [3].

The probability of pedestrian crashes is high at intersections due to its typical nature in which a common space is shared among various road users. One recent study has highlighted that pedestrian crashes at intersections are associated with a higher probability of severe and fatal injuries [6]. Many of these accidents happen while crossing the road. In the past few years urban signalized and uncontrolled intersections in India have become accident hot-spots as more than 60% of pedestrian fatalities occurred there [3, 7]. Pedestrians violating the signal or not crossing the road along the designated crosswalks are considered as violation behaviors. Several studies have reported frequent violation behaviors by pedestrians as the leading cause of such accidents [8]. Compared to other road users, the behavior of pedestrians is quite unpredictable. They have

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higher freedom to choose their path and are bounded by fewer laws. Several studies have been performed to understand pedestrians' road crossing behavior at signalized intersections more specifically their violation behavior. Studies have reported several internal as well as external factors affecting pedestrians' crossing decisions at intersections.

Pedestrian personal attributes such as gender and age group were reported as significant factors affecting violation behavior. Male pedestrians have higher violation and risk taking tendencies than females. Contrary to this, female pedestrians are more sensitive to risk perception and provide less preference to cross the road during the red phase [9, 10]. In a study in China it was reported that males were found to comply more with traffic rules [11]. Females also consider waiting for more safer crossing opportunities [12]. Older pedestrians are found to be the most law-abiding whereas young adults have more frequent violation behavior [9, 11].

Researchers have also focused on other personal factors such as group size, effect of other pedestrians and crossing speed. Single or smaller groups of pedestrians have higher whereas larger group sizes have lower violation tendency [13]. Pedestrians are more likely to show unsafe behavior if they observe others doing the same. Further presence of children and other pedestrians who wait for the walk sign, increases the tendency to wait for pedestrian green signal [14, 15]. Pedestrians' crossing speed is a crucial parameter for designing pedestrian facilities. The HCM 2000 and the existing manual of the Indian Road Congress, suggests considering pedestrian walking speed as 1.2 m/s for design purposes [16, 17]. Pedestrian crossing speed is highly subjective to the pedestrian's demographic and crossing behavior. Higher crossing speed was reported for pedestrians with violation behavior, males and smaller groups as compared to their counter parts [8, 18, 19].

An important location specific factor that notably affects the safe crossing behavior of pedestrians, is the presence of properly marked crosswalks at signalized intersections. The safety potential is great at properly marked zebra crossings as a majority of crossings occur at these locations. An early study in Scandinavian countries reported that the absence of crosswalks significantly increases the pedestrian dangerous behaviors [20]. Signalized intersections with properly marked crosswalks are very attractive and well identified site by pedestrians to cross the road and help to channelize pedestrian traffic [21]. In a study conducted in Delhi it was found that zebra crossing is preferred as it is perceived to be safe [22]. Pedestrians decision is also influenced by many factors such as comfort level, convenience to cross and safety [23].

The appalling data indicates the unfortunate state of road safety, predominantly the plight of the most vulnerable road users in emerging economies. Pedestrian behavior is stochastic and modelling their behavior is often a challenging task. The behavior of pedestrians, especially in developing countries is different from that of other countries. While several attempts have been made to study pedestrian behavior in developed countries. It requires more attention and understanding in developing countries such as India. Studies have focussed mainly on "reactive approach" (crash data analysis) rather than "proactive approach" (perception and behavior analysis) to assess pedestrian safety at signalized intersections. In light of the above discussions the primary aim of this study is to understand pedestrians' crosswalk utilization behavior at urban signalized intersections. Further this study aims at analyzing the discrepancy between pedestrians' perception and reality for crosswalk utilization.

2. METHODOLOGY

The major steps involved in this study are: (1) site selection (2) data collection- video recording and questionnaire survey (3) data extraction and compilation (4) analysis and results.

2. 1. Site Selection Reconnaissance survey of several signalized intersections in New Delhi was performed initially and two intersections were finalized considering various physical, vehicular and pedestrian factors. Site 1 is 4-legged and has mixed land use patterns consisting of college, offices, commercial establishment and open spaces. Site 2 is 3-legged and predominantly industrial area with few residential dwellings. Both sites have substantial pedestrian and vehicular traffic and are spatially well apart. Site pictures are shown in Figure 1.

2. 2. Data Collection Video recording technique was used to record pedestrian road crossing behaviour [24]. Data such as pedestrian's crosswalk compliance, gender, age group, group size and technological distractions were successfully captured. Data was collected on week days with normal weather conditions. Two or more cameras were installed as per the site conditions to cover the entire section of the study sites. The field of view and height of the cameras were adjusted to cover the ends of the carriageway including sidewalks and medians, crosswalks with a few meters distance on both sides and signal phases. Video recordings were carried out during morning (9-10 AM) and evening (5-6 PM) hours without disturbing the normal traffic flow. The placements of cameras were not noticed by the pedestrians thus their naturalistic and actual behaviours were recorded. Further to compare the actual behavior of pedestrians

(a)

(b)

Figure 1. (a) Broad View of Site 1 (b) Broad View of Site 2

with their perceived behavior, a response based face to face questionnaire survey was also conducted simultaneously along with video recordings. The moment pedestrians crossed the road; volunteers approached and requested them to participate in the survey. A comprehensive questionnaire was prepared by studying previous relevant literature. Data was collected by using printed as well as Google forms. The questions were clearly explained to respondents and their responses were recorded. Question related to their crosswalk compliance behavior was asked. Respondents' gender, age, education and employment status were also obtained.

The observed pedestrians and questionnaire respondents belong to the same population (study sites) and both the samples were collected at study locations simultaneously. In total 552 pedestrians were observed out of which, 309 pedestrians participated in the survey resulting in a response rate of about 56%. The difference in the sample size of video data and questionnaire exits because all of the observed pedestrians were not willing to participate in the questionnaire survey. Some of the previous studies have adopted a similar methodology [11, 25].

2. 3. Data Extraction The data from video recordings were extracted manually using AVS Video Editor Software. Recordings were played in ultra slow motion and frame by frame images were watched to extract the required data. In total, 552 pedestrian data were extracted with complete information. Data were coded and entered into excel sheets for further analysis. Gender is categorized into "Male (0) and Female (1)". Since the exact age of a pedestrian cannot be found from video, it is estimated by grouping them into "Young (0), Middle (1) and Old age (2) groups". Group size is defined as pedestrian crossing alone "Single (0), Pair (1) and More than two (2)". Technological distraction is defined as "Yes (1)", if a person was clearly observed using mobile, talking over the phone and using head phones or else "No (0)". Pedestrian crosswalk compliance behavior (CCB) is "Yes (1)" if s/he crosses the road using a strip of road which includes crosswalk plus the area up to a distance of 0.5 m on either side of the crosswalk. A distance of 0.5m on either side of the crosswalk was included in CCB to include those pedestrians who cross in large groups and some of them are not exactly on the crosswalk but very close to it [11]. Crossing the road at any other location other than this strip would be considered as crosswalk non compliance, "No (0)". CCB at study sites is shown in Figure 2.

The data from the questionnaire form were extracted, coded and entered into an excel sheet. Incomplete or erroneous responses were excluded from further analysis. A total of 309 responses with complete information were successfully recorded. Gender and age group were coded similarly. Pedestrian education levels were collected into four categories- "Uneducated or Nil (0), Primary school (1), Secondary school (2) and Graduate and above (3)". Employment status consists of five categories- "Unemployed (0), Job (1), Self Employed (2), Student (3) and Home Maker (4)". To assess the utilization of crosswalk question, "Where do you generally cross the road at signalized intersection?" was asked. The response categories were "At any convenient location at intersection (0), Away from intersection (1), Crosswalks (2) and between vehicles stopped at signal (3)".

(a)

(b)

(c)

(d)

Figure 2. (a) CCB-Yes Site 1 (b) CCB-Yes Site 2 (c) CCB-No Site 1 (d) CCB-No Site 2

2. 4. Analysis and Modeling Initially descriptive statistics are performed for the variables from video data to have a brief inference of sample distribution. Concise information about pedestrian characteristics and behaviour related to crosswalk compliance is obtained. To identify significant variables, Chi-square hypothesis test is performed to ascertain significant association between categorical variables using IBM SPSS Statistics 22. If p-value is less than 0.05 then it supports the alternate hypothesis that significant difference exists within groups in terms of crosswalk compliance. Finally, pedestrian CCB model is developed using statistically significant variables. A pedestrian has only two choices while crossing the road, whether or not to cross the road using crosswalk. Therefore, a binary logistic regression model is used to predict binary responses from categorical predictor variables [26].

The probability of selecting an alternative (compliance/non compliance) is based on a linear combination function (utility function) expressed as follows:

$$U_i = \beta_0 + \beta_1 x_{1,i} + \beta_2 x_{2,i} + \beta_3 x_{3,i} + \ldots . \beta_N x_{N,i} \quad (1)$$

$$P(i) = \frac{e^{U_i}}{1+ e^{U_i}} \quad (2)$$

where U_i = the utility of choosing alternative i, i = the alternative (compliance/non compliance), N = number of independent variables, β_0 = model constant, and β_N = coefficients of predictor variables, x= predictor variables that determine the probability of outcome of alternatives and $P(i)$= probability of pedestrian compliance. Descriptive analysis is performed for questionnaire data as well. Crosswalk utilization of respondents is compared with gender, age group, education level and employment status. Finally, the results between perception and observation were compared.

3. RESULTS AND DISCUSSION

3. 1. Obsevational Study The descriptive statistic of video data is shown in Figure 3. The sample has a major share of male and young pedestrians. Concerning group size, most of the pedestrians crossed the road alone followed by pairs and larger groups. Small percentages (5.62%) of pedestrians were found to be technologically distracted while crossing the road. Overall only 28.8% were observed to show crosswalk compliance behavior. The CCB at sites 1 and 2 were found to be 27.56% and 29.76%, respectively. Such low CCB can be due to the fact that, either the pedestrians fail to realize the importance of zebra or the wrong placement of zebra crossings [27]. Further chi-square test shows that statistically significant differences exist among gender (p= 0.037), age group (p=0.003), group size (p=0.048) and distracted pedestrian (p=0.029) with regards to CCB.

To have a comprehensive understanding of factors affecting pedestrian's crosswalk utilization, regression model is developed. Binary logistic regression model is developed to predict CCB using gender, age group, group size and technological distraction as explanatory variables. From the total data 80% of the sample is used for model development and the remaining 20% for model validation. The BL model outcomes are shown in Table 1. The model accuracy is found to be 70.7% and 73.1% for training and validation data, respectively. Hosmer and Lemeshow test which is used to assess the predictive performance of the model, is found to be insignificant (p=0.807) suggesting that that model has considerable predictive capability [28].

From the model results it can be inferred that gender is positively but weakly associated with CCB. Odds ratio or Exp(B) is slightly more than 1 suggesting that the odds of crosswalk compliance is a rather high for females as compared to males. The result is in line with previous findings [9, 10] but contradicts the result

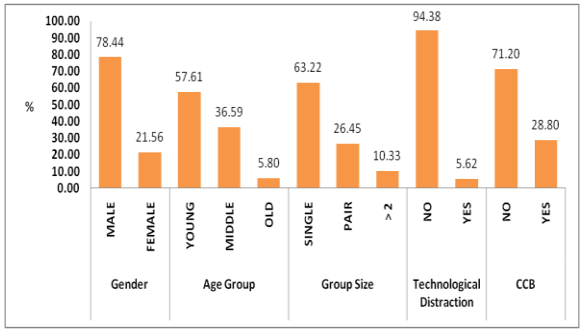

Figure 3. Descriptive Statistics from Video Data

TABLE 1. BL Model Outcomes for CCB

Variables	B	Std. Error	Exp(B)	p-value
Constant	-0.989	0.180	0.372	0.000
Gender	0.008	0.256	1.008	0.037
Age Group	0.181	0.175	1.198	0.003
Group Size	0.127	0.161	1.135	0.048
Technological Distraction	-1.068	0.630	0.344	0.029
Model Summary				
Sample	Training - 444 ; Validation - 108			
Log Likelihood			531.077	
Cox & Snell Pseudo R^2	0.013			
Nagelkerke Pseudo R^2	0.019			
Hosmer and Lemeshow Test χ^2			3.760 (p-value = 0.807)	
Model Accuracy			Training - 70.7% ; Validation - 73.1%	

obtained in China where males showed more compliance behavior [11]. Males have more risk-taking tendencies and have a negative attitude towards rules and regulations whereas females are more sensitive to risk perception and prefer compliance behavior. The result is also contradictory to previous results where gender failed to yield any significant association with compliance behavior [25].

Pedestrian's age group is positively and moderately related to crosswalk utilization at signalized intersection. Odds ratio is found to be 1.198 which means that the odds of compliance are less for younger pedestrians as compared to middle or old age. The compliance rate of old age pedestrians is about 5% more than middle age. Overall elderly pedestrians are the most compliant and young adults are the least. The results complement the past studies where similar behavior was observed [11]. The above findings conclude that old age pedestrians are associated with an increased level of compliance and law abidance. Older pedestrians suffer from reduced mobility, sensory and cognitive skills and thus prefer to cross slowly only when safer crossing opportunities are available. The presence of properly marked crosswalk enhances the safety perception of elderly pedestrians as it is a well recognised crossing location by drivers. Various other studies failed to establish any significant relation between pedestrians' age and crossing behavior [13, 18].

As in previous studies [13] this study also has a similar conclusion regarding the effect of group size on compliance behavior. As compared to individual pedestrians the crosswalk compliance is more for larger groups. Single pedestrian has higher noncompliance than that of a platoon due to freedom from platoon and directional effects [18]. The more the pedestrians wait at an intersection the more number of pedestrians join them and the larger the group size the less likely is the violation behavior. Such behavior can be explained based on conformity psychology. Similar conformity tendency behavior has been reported in many studies [14, 29]. The CCB for pedestrians crossing in pairs is found to be the highest as compared to others.

Technological distraction includes talking and texting on mobile and listening to music while crossing. The model result suggests that it is negatively and strongly associated with CCB. The CCB for non-distracted pedestrians is 30.3% whereas for distracted pedestrians it is only 12%. So technological distraction is associated with reduction in CCB and is in line with past findings [30]. Use of mobile phones causes cognitive distractions thereby reducing safety [31]. Mobile phone usage is also intimately related to the crossing performance of pedestrians. Text distraction is associated with least crossing performance and most impairment followed by talking and listening to music while crossing [32]. Technological distraction is significantly associated with situational awareness. Pedestrians using mobile phones are less likely to look left-right before and during crossing [9].

3. 2. Questionnaire Survey Study The descriptive statistic of questionnaire survey data is shown in Figure 4. The distribution of respondents with respect to gender and age is similar to observational data. The sample consists of a large proportion of male and young respondents. In terms of education level and employment status the sample has a mixed distribution. It can be observed that a large share of respondents is secondary school educated and job holders. About 52.7% of respondents said to use the crosswalk to cross the road at signalized intersections and a fourth of respondents cross at any convenient location.

The variation in road crossing behavior concerning gender, age, education level and employment status are shown in Figure 5. Within gender an equal proportion of male and female respondents use crosswalk to cross the road at signalized intersection. As compared to males more females choose convenient location to cross the road, suggesting that females prefer more comfort and convenience. Crosswalk utilization is the most for young followed by middle and elderly respondents. On the contrary significant number of old age respondents cross road at any convenient location. Old pedestrians suffer from lack of mobility, so they might face hardship in walking an additional distance to crosswalk locations; hence prefer to cross the road as per their comfort and

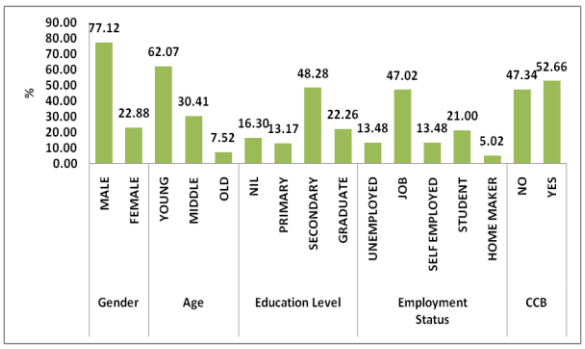

Figure 4. Descriptive Statistics from Questionnaire Survey

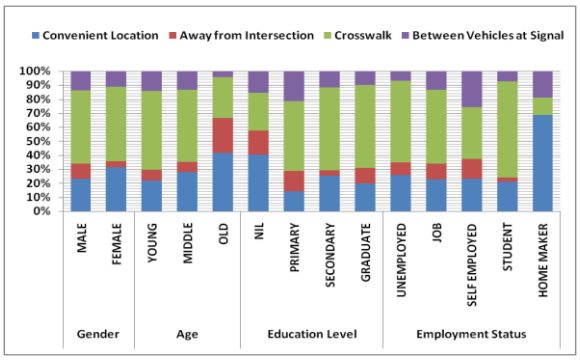

Figure 5. Road Crossing Behaviors for Gender, Age, Education and Employment

convenience. Education is found to have a significant effect on crosswalk compliance as higher education level is associated with an increase in crosswalk compliance. The result is similar to the results obtained in Mumbai [33]. In terms of employment status most crosswalk compliance is reported from students and least from home makers. Students are well aware of the safety implications of crosswalks whereas home maker might not be frequent visitors at signalized intersection and are not much aware hence cross the road at any convenient location.

3. 3. Perception versus Reality In view of above outcomes no significant correlation is found between perception and reality. There exists a gap between what people say and what they actually practice. Since only three variables (gender, age and crosswalk compliance) are common in video and questionnaire data, so a comparison is made considering these variables. During the observational survey only 28.8% of pedestrians used the crosswalk, whereas 52.7% of respondents revealed using a crosswalk at signalized intersections. Crosswalk compliance regarding gender and age from perception and reality data is shown in Table 2. Crosswalk compliance rate for males and females is similar in perception as well as reality. But overall both males and females reported to be more compliant while in reality it is not so. In respect to age group large differences are

TABLE 2. Crosswalk Compliance: Reality versus Perception

Variable	Category	Crosswalk Compliance (%)	
		Observation	Perception
Gender	Male	29.14	52.44
	Female	29.79	53.42
Age	Young	27.38	56.06
	Middle	31.10	51.55
	Old	35.71	29.17

observed between perception and reality. Younger pedestrians were observed to be the least crosswalk compliant whereas they reported toward a much higher side. On the contrary old age pedestrians were observed to be most compliant but they reported to be less compliant. Overall, it is concluded that in all cases except for old age, pedestrians responded to be more crosswalk compliant than they practice.

The discrepancy between perceptions and reality could be explained as follows. Pedestrian movements were recorded without making them aware; thus, showing their actual behavior. On the contrary questionnaire survey was conducted face to face with pedestrians. Although pedestrians were aware that none of their personal details are collected and it is purely for academic research, still some might feel that the information might be used against them. Pedestrians' responses might also be affected by their mood. Further it is a common human psychology to portray oneself as good, in front of others.

Although perception based approach for assessment of pedestrian safety at signalized intersections is a crucial proactive approach, it suffers from certain limitations. Differences might exist between actual and perceived risks [34, 35]. A lot of variations exist between what people say and what they actually do [27]. In addition, it should be noted that although pedestrian perceptions are important, they may not highly correlate with actual safety considerations. Finally, it suffers from social attraction bias where respondents give favourable responses which might not reflect their actual behavior or feelings. In light of the above discussions, perception based study might not portray the reality, resulting in misleading conclusions. So, it is recommended that additional analysis to be performed to establish a relationship between perceived and actual behaviors.

4. CONCLUSIONS

The present study aimed to analyze pedestrian crosswalk compliance behavior at urban signalized intersections. Data was collected using video recordings and a response based questionnaire survey.

Significant variables were analyzed and modelled using the binary logistic regression technique. Finally differences between reality and perception were assessed. Based on the above findings the following important conclusions are made:

- Female, elderly and larger groups have higher odds whereas technologically distracted pedestrians have lower odds of crosswalk compliance.
- Higher level of education is associated with an increase in crosswalk compliance behavior.
- Large differences exist between what people say and what they actually practice. So perception based study should not be solely used for decision making as it might have misleading outcomes.

Based on the valuable findings, the present study has practical as well as theoretical applications. This study has added useful insights about pedestrian behavior in the existing state of art. It highlighted the fact that even though marked crosswalks are safer locations to cross the road, but failed to attract the pedestrians to use them. The low CCB suggests that pedestrians are not much aware of the importance of crossing the road at designated crosswalks. Further proper placement of crosswalks might significantly increase crosswalk compliance. So to increase the CCB and ultimately increase pedestrian safety at intersections, pedestrian facilities should be suitably designed particularly catering to the needs of elderly pedestrians. As far as possible, crosswalks should be placed along major pedestrian crossing paths to increase CCB. Pedestrians should be made aware of the consequences of distracted walking. Since education is associated with an increased level of CCB, road safety education at various levels and awareness campaigns should be conducted. As there exists a gap between reality and perception, a questionnaire based study should be used in conjunction with an observational study for decision making. The outcomes of this research would help policy makers and other stake holders in better understanding of pedestrian crosswalk utilization behaviour. Further it would guide them to take intervention measures to reduce violations and increase safety at signalized intersections.

The present study considered only the effect of pedestrian level factors to assess crosswalk compliance behavior. Various other external factors such as traffic characteristics, built environment and intersection geometry might also affect CCB. Data was collected from two intersections with a limited sample size. In the future more intersections may be included and analysis may be performed considering the effects of other factors as well.

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Persian Abstract

چکیده

ایمنی عابران پیاده در تقاطع های علامت دار یکی از دلایل اصلی نگرانی در سراسر جهان است. خط عابر پیاده با علامت گذاری مناسب ایمنی عابران پیاده را افزایش می دهد زیرا این محل عبور و مرور توسط رانندگان به خوبی شناخته شده است. با این حال تعداد زیادی از تصادفات در تقاطع ها عمدتاً به دلیل رفتار تخلف عابران پیاده گزارش می شود. این مطالعه با هدف درک رفتار استفاده از عابر پیاده در تقاطع‌های علامت‌دار شهری انجام شده است. داده ها از طریق فیلمبرداری و پرسشنامه جمع آوری شد. متغیرهای مهم با استفاده از رگرسیون لجستیک دو جمله ای شناسایی و مدل سازی شدند. فاکتورهای سطح شخصی عابر پیاده به طور قابل توجهی بر رعایت عابر پیاده تأثیر می گذارد. تفاوت‌هایی بین ادراک و واقعیت شناسایی شد، که نشان می‌دهد بین آنچه مردم می‌گویند و آنچه در واقعیت عمل می‌کنند تفاوت وجود دارد. یافته های این مطالعه نشان می دهد که یک مطالعه مبتنی بر ادراک ممکن است به اندازه یک مطالعه مشاهده ای قابل اعتماد نباشد. یافته‌ها هم مفاهیم نظری و هم کاربردی دارند و مطمئناً به سیاست‌گذاران و طراحان در درک بهتر رفتار عابر پیاده در تقاطع‌های علامت‌دار شهری کمک می‌کنند.