# An Observational Study to Identify the Naturalistic Crossing Behavior of Pedestrians


## ABSTRACT

This study presents a framework to identify crossing behavior among pedestrians while crossing a road. The data is collected from Board bazar bus stand crossing in Gazipur city of Bangladesh. The recorded data is observed to identify distinct crossing behaviors among pedestrians. A logistic regression model is employed to estimate the influence of factors such as gap size and waiting time on pedestrians' gap acceptance behavior for each crossing behavior. A total of four different crossing behaviors are identified among the pedestrians: aggressive, cautious, group and hesitant. Also, Young, and middle-aged pedestrians tend to be more aggressive in nature and they wait less and are willing to accept as little gap as possible while crossing the road. However, the opposite behavior is observed for cautious nature where pedestrians are willing to wait longer for a safer or larger gap before crossing the group. In group crossing behavior an individual tends to act like a leader and others follow while crossing the road and the collective behavior of the group seems to be influenced by the leader. Pedestrians face a dilemma of whether or not to move forward due to an approaching vehicle in hesitant crossing behavior and they are seen to be acting more cautiously because of this. In terms of the gap acceptance behavior model, pedestrians tend select larger gap but with the increasing in waiting time their likelihood of accepting a larger gap decreases in aggressive crossing nature whereas in cautious crossing nature the likelihood is likely to increase with increasing waiting time. The findings from this study could be useful to come up with policy recommendations for improving the crossing safety of pedestrians.


## INTRODUCTION

Pedestrians are the most vulnerable road users and in crashes they are likely to be exposed to more fatal injuries. The conflicts between pedestrians and motor vehicle traffic are constantly increasing as they share the roadway and some of them results in fatality (Hatfield et al., 2007, Shaon et al., 2018). According to the World Health Organization (WHO), 1.3 million people die every year because of road accidents and around 20 to 50 million people suffer from injuries. Also, around 230,000 pedestrians die every year as a result of road crashes. In 2021, around 8984 pedestrians died in traffic and non-traffic accident in the US (National Center for Health Statistics). The latest data from National Highway Traffic Safety Administration (NHTSA) shows that 7388 pedestrians died in traffic crashes occurred in public roads. In addition, 84% of the pedestrian's death occurred in urban areas, while 77% occurred in open road and 23% occurred in intersection in 2021 (NHTSA). Pedestrians from low- and middle-income countries face more fatality compared to developed European countries (WHO, 2018). In these countries traffic collisions are one of the major concerns as the risk for fatality is three times higher in compared to high income countries (WHO, 2018). The main reason behind this is the lack of investment in pedestrians walking in safety infrastructure such as crosswalks, signalized intersection (Hoque et al., 2013). It is evident that fatalities related to pedestrians in road accidents are a major concern in developed and developing countries. Also, road injuries were ranked ninth as the leading cause of death in 2011 and projected to be the seventh in 2030 (WHO, 2018). To address this issue there have been a lot of studies on pedestrian crossing

behavior and safety improvement focusing on traffic related factors, physical space, interaction between vehicle and pedestrian, and the behavior and psychological state of drivers and pedestrians (Yannis & Golias, 2009, Das et al., 2011, Tezcan et al., 2019). However, understanding how people actually behave while crossing a road still remains a challenge and these behaviors vary from country to country. The crossing behavior of pedestrians in developing countries is difficult to predict as most of them lack the basic traffic rules knowledge (Jiangang et al., 2007). As a result, they cross the road wherever they find convenient in order to minimize delay (Das et al., 2014).

## RESEARCH OBJECTIVE

This study focused on identifying naturalistic crossing behavior of pedestrians in an unsignalized and uncontrolled crosswalk in Gazipur city of Bangladesh. The main objective is to identify distinct crossing behavior of pedestrians without any controlled or experimental traffic settings and the gap acceptance behavior of pedestrians related to this crossing behavior considering factors such as gap size and waiting time.

## LITERATURE REVIEW

Over the years there have been several studies on pedestrian crossing behavior focused on location aspect (i.e., pedestrian crossing at intersections and mid-block crossings), and factors such as age, gender, pedestrian crossing speed, intended waiting time, pedestrian characteristics, traffic signals, and many more influencing the crossing behavior (Li, 2013, Fricker et al., 2020, Hamedi et al., 2022, Zafri, 2023, Anik et al., 2021, Raoniar et al., 2022).

In a recent study in Dhaka, Bangladesh Zafri, (2023) aimed to identify the factors that influence pedestrian decision regarding their crossing patterns whether they will walk or run. It was found that intersection characteristics, age, gap acceptance between pedestrian and vehicle, and controlled or uncontrolled intersection have significant influence on whether an individual will walk or run while crossing the road. Walking pattern was mostly found in controlled intersection with larger gap acceptance and among female and older pedestrians whereas running pattern was mostly found in uncontrolled section with lower gap acceptance among male pedestrians. Shiwakoti et al., (2021) employed linear mixed models and generalized linear mixed models to analyze the impact of gender, age, usage of device while crossing and carrying items on pedestrian crossing behavior for signalized and unsignalized crosswalks in Tehran. They considered avoiding collision, awareness, experience of conflict, and crossing speed as the measure for pedestrians crossing behavior and found that males tend to start their crossing at ‘don’t walk’ signal and cross the road quickly. Also, pedestrians show more careful crossing behavior in signalized crosswalk than unsignalized crosswalk.

Poó et al., (2018) did an observational study in Ushuaia, a city in Argentina to understand the risky crossing behaviors of pedestrians in traffic intersections. They found that pedestrians waiting on the street rather than on the sidewalk, distracted while crossing the road and crossing outside the crosswalk presented a higher risky behavior while crossing the road. Traffic signal violations and dangerous crossing behavior are quite common in pedestrians where factors such as waiting time or red-phase time (Saunier et al., 2013), arrival time, type of median and time of

the day are very crucial (Hashemi et al., 2022). Pedestrians' cautious behavior is influenced by the distance from the curb, checking for the traffic (Harrell 1991), road surface, pedestrian volume and not distracted by device usage or eating (Henry et al., 2005).

Marisamynathan & Perumal (2014) analyzed pedestrian crossing behavior at signalized intersection and found the crossing speed for old pedestrian is 0.95 m/s and 1.12 m/s for adults which varies significantly than the standard assumed values. They found that crossing type, utilization of crosswalk, compliance with the signal phase have a significant impact on pedestrians crossing speed. In a similar type of study in Dhaka, Bangladesh it was found that the design crossing speed for pedestrian was 1.15 m/s. Also, pedestrians were likely to wait around 20-30 s before crossing the road and the waiting time varies based on the control type of intersection, age, flow of vehicles, and location where pedestrians are waiting (Zafri et al., 2019). Moreover, pedestrians are likely to change their speed in accordance with red-phase signal, and length of the crosswalk (Alhajyaseen & Iryo-Asano, 2017). These prior studies on pedestrian crossing behavior mostly focused on the factors influencing the crossing behavior at intersections and mid-block crosswalk. There is not enough study that focused on the naturalistic crossing behavior of pedestrians i.e., how an individual actually behaves while crossing the road. This study focuses on bridging this gap and identifying distinct naturalistic crossing behavior of pedestrians at an unsignalized and uncontrolled roadway.

## DATA AND METHODOLOGY

### Study Area

In this study "Board bazar bus stand crossing" is selected aiming to identify the distinct naturalistic crossing behavior of pedestrians. It is worth mentioning that the selected location does not have any traffic lights for either vehicles or pedestrians' movement. However, traffic police are assigned to control the movement of vehicles. The selected location has a lot of vehicular and pedestrian movements as it is surrounded by a university area, shopping complex (bazar), restaurants and bus stop. Figure 1 shows a snapshot of the focused area.


**Figure 1:** Board bazar bus stand crossing

## Data Collection

A high-definition camera was used to video record the movement of pedestrians. The data was collected for about 35 minutes. The camera was set up from a height of approximately 20 ft, so the movement of pedestrians and vehicles are clearly visible and easy to understand. Figure 2 shows a snapshot of recoded video of pedestrian movements.

The video recorded data was visually observed to identify the distinct crossing behavior of pedestrians. To calculate the gap acceptance model for each crossing behavior following **Equation 1** is used (Valent et al., 2002, Zhao et al., 2019). The outcome variable is binary, if an individual accepts the available gap (1) or rejects the available gap (0), and the expected value is the probability of accepting a gap.

$$Y = logit\ (P) = \ln\left[\frac{P}{(1-P)}\right] = \beta_o + \beta X_1 + \beta X_2 \quad (1)$$

Here,

$\beta = Coefficient\ or\ Parameter\ associated\ with\ independent\ variables$

$X = Independent\ Variable$

After extracting and organizing the data in excel, MATLAB is used to do the logit model.

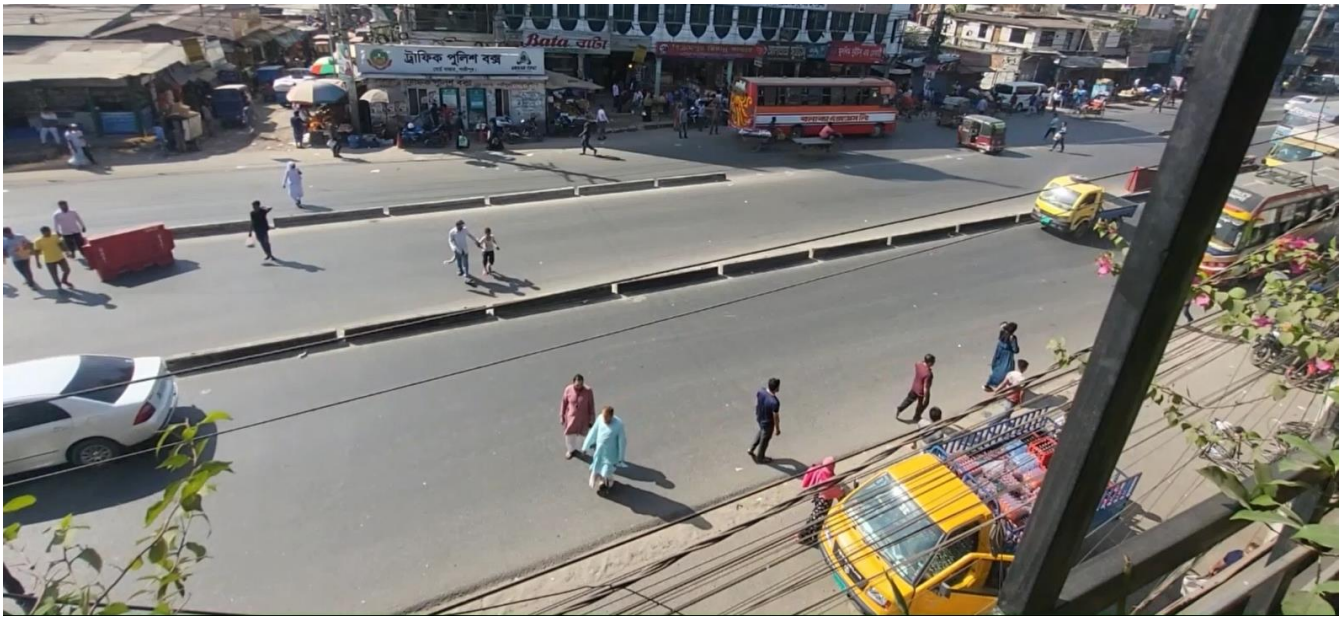


**Figure 2:** Snapshot of pedestrian movements

## ANALYSIS AND RESULT

The collected data was observed carefully, and different crossing behavior was identified. Some parameters were considered while identifying the distinct crossing behavior.

- **Consideration of vehicle type** - whether pedestrians are taking into consideration the type of vehicle approaching towards them while crossing the road (i.e., bus, truck, car, rickshaw, motorcycle etc.)
- **Consideration of vehicle speed** - whether pedestrians are concerned about the speed of the approaching vehicle.
- **Waiting time** - how much pedestrians are willing to wait before crossing the road.
- **Gap acceptance** - how much gap size they are willing to accept while crossing the road.
- **Presence of children** - if pedestrians have any children with them or not.

Based on these considerations the crossing behavior of pedestrians was divided into four distinct categories:

**Aggressive crossing behavior** – in this behavior pedestrians seem to not care about the approaching vehicle type or speed. They just want to cross the road. They are willing to accept as little gap as possible to cross the road. In some cases pedestrians use hand gestures towards the approaching vehicle asking them to slow down or even stop so that they can cross the road. From the observation it was found that young or middle-aged pedestrians are likely to be aggressive in nature while crossing the road irrespective of their gender.

**Cautious crossing behavior** – pedestrians tend to wait for a longer time to have a safe margin between them and the approaching vehicle before crossing the road. One key thing is noticed in this behavior is that older pedestrians and pedestrians with children tend to be more cautious while crossing the road.

**Group crossing behavior** – pedestrians form a cluster and cross the road as a group. Two or more pedestrians in a cluster is considered to define a group. One interesting thing that is noticed in this crossing behavior is that one individual from the group tends to take the role of a leader and others follow that individual while crossing the road. In group crossing behavior, both crossing dynamic (aggressive and cautious behavior) is available mostly depending on the leader.

**Hesitant crossing behavior** – in this behavior at the beginning or in the middle of their crossing pedestrians tend to hesitate for a moment whether or not to move forward because of the approaching vehicle. As a result of this incident, pedestrians are seen acting more cautiously while crossing the road.

Table 1 shows the result for the gap acceptance model for aggressive crossing behavior. Several iterations have been executed to reach the results.

**Table 1:** Model result for aggressive crossing behavior

| Crossing Behavior | Variables | β | P Value | Odds Ratio |
|---|---|---|---|---|
| **Aggressive** | Constant | -2.79 | 0.07 | 0.061 |
| | Gap Size (s) | 1.33 | 0.01 | 3.764 |
| | Waiting Time (s) | -0.23 | 0.31 | 0.798 |
| | No. of Observation | | 30 | |
| | Log Likelihood | | -13.29 | |
| | Pseudo R-square | | 0.36 | |

In this study, it can be said that the odds of a pedestrian accepting a gap are 3.764 times higher with each increase in available gap size and 0.798 lower with each unit increase in waiting time. In aggressive crossing behavior the likelihood of gap acceptance is likely to increase with larger gap size but with the increase in waiting time the likelihood of accepting larger gaps is likely to decrease. It makes sense as it is seen that pedestrians are willing to wait less and accept smaller gaps while crossing the road in aggressive crossing behavior.

Based on the result shown above, the probability of pedestrians accepting the available gaps can be expressed using Equation 2 and Equation 3.

$$Y = -2.79 + (1.33 * GS) + (-0.23 * WT) \quad (2)$$

$$P = \frac{1}{1+e^{-Y}} \quad (3)$$

A similar approach is taken to model the gap acceptance behavior for the remaining crossing behaviors. However, as the number of observations is very small the results are not significant. The result for the remaining crossing behaviors is shown in Table 2. Even though the results are not significant from the table we can have an idea how the likelihood of gap acceptance and the factors influencing it can vary in different crossing behavior.

**Table 2:** Model result for cautious, group and hesitant crossing behavior

| Crossing behavior | Variable | β | P Value |
|---|---|---|---|
| Cautious | Constant | -223.84 | 1 |
| | Gap Size (s) | 43.95 | 1 |
| | Waiting Time (s) | 2.81 | 1 |
| Group | Constant | -229.46 | 1 |
| | Gap Size (s) | 95.94 | 0.99 |
| | Waiting Time (s) | -71.53 | 0.99 |
| Hesitant | Constant | -78.43 | 1 |
| | Gap Size (s) | 78.45 | 0.99 |
| | Waiting Time (s) | -102.34 | 1 |

Even though the results are insignificant because of the small observation number, we can have an idea how gap acceptance varies in different crossing behavior from the above table. For example, in cautious crossing behavior pedestrians are willing to accept larger gaps while crossing the road and with the increase in waiting time their likelihood of accepting larger gaps increases.

## CONCLUSION AND FUTURE WORK

The main objective of this study is to identify distinct crossing behavior of pedestrians. The data for this study is collected from board bazar bus stand crossing in Bangladesh. The recorded data is observed and analyzed thoroughly to identify distinct crossing behavior and a gap acceptance model is estimated associated with each crossing behavior.

A total of four different crossing behaviors are observed among the pedestrians: aggressive, cautious, group, and hesitant. Young and middle-aged pedestrians are likely to be aggressive in nature whereas older and pedestrians with children are likely to be more cautious in nature while crossing the road. A leader and follower behavior are observed when pedestrians are crossing in a group. Findings from the estimate model show that pedestrians tend accept larger gaps, but the likelihood decreases with the increased waiting time in aggressive crossing nature.

One immediate extension of this work would be to estimate the influence of several factors on pedestrians' gap acceptance behavior for each crossing nature. The next step would be to link these distinct crossing behaviors with pedestrians' activity type. A travel diary for pedestrians can be kept having information about their origin, destination and the type of activity and a relationship can be formed between different crossing behaviors and activity type.

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