Proceedings of 12th IOE Graduate Conference
Peer Reviewed
ISSN: 2350-8914 (Online), 2350-8906 (Print)
Year: 2022 Month: October Volume: 12

An assessment of Pedestrian Compliance on Using Foot Over Bridge: A Case Study of Kathmandu Valley

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Abstract
A Foot Over Bridge (FOB) is a type of grade-separate crossing facility that is constructed above the roadway and has a profound role in the road network. It is one of the safest road crossing facilities that eliminates conflict between pedestrians and vehicles plying on the road while crossing. Yet, the usage rate of FOB seems to be low as most pedestrians try to cross the road through the road itself. This study focused on determining significant factors affecting the use of FOB and perception of pedestrian toward FOB. Eight FOB locations within the Kathmandu valley were chosen as the study area to fulfill the objectives of the study. The detailed data collected from these locations were analyzed and used in developing Multiple Linear Regression (MLR) models through Statistical Package for Social Sciences (SPSS) using a stepwise method, and the best models were predicted. Furthermore, a set of structured questions was prepared and a questionnaire survey was conducted in these locations in order to determine the behavior and attitude of pedestrians toward FOB. Traffic volume, vehicle speed and road width are found to be significant factors affecting the use of FOB. Similarly, the result from questionnaire survey shows that time saving is the prime reason for not using FOB whereas safety is the prime reason for using FOB.

Keywords
Pedestrian, Foot Over Bridge, Pedestrian Compliance, Pedestrian Perception, Multiple Linear Regression, Grade Separated Crossing

1. Introduction

1.1 Background

The term "pedestrian" refers to anybody who walks, sits, or stands in a public space, regardless of any age, gender, physical ability, or reason for travel [1]. Pedestrians are the most vulnerable road users globally. Every year more than 345,000 pedestrians die in road crashes, accounting for 23% of all road fatalities [2]. In contrast to other countries, the trend of road traffic crashes in Nepal is particularly terrible, as the number of fatalities is sporadically rising. Of total road traffic crashes in Nepal, half of the crashes take place in the Kathmandu valley (Kathmandu, Bhaktapur & Lalitpur) alone. Every year in the valley, there are more than 5500 crashes, which result in more than 180 fatalities [3]. According to Metropolitan Traffic Police Office records, there were 560 pedestrian fatalities from fiscal year 2069/70 to fiscal year 2077/78, and 162 crashes occurred due to pedestrian carelessness over the same time period in the Kathmandu valley.

When a vehicle collides with a pedestrian, the pedestrian may suffer catastrophic consequences, even if the vehicle is moving slowly. Because of which, grade separated crossing facilities like Foot Over Bridge (FOB)s are constructed to provide safe crossing and also to enhance road traffic flow. Several FOBs have been constructed at major area of the Kathmandu valley. These FOBs are provided to reduce vehicle-pedestrian crashes and delays for vehicles. However, it is evident that many pedestrians do not use these bridges and instead cross the road at street level. Every group of pedestrians whether they are males or females, children, adults or elderly people, is seen jaywalking under the FOB. Thus, it appears to be vital to understand the variables affecting the use of FOB, and the guiding principles behind their implementation so that vehicle-pedestrian

crashes around FOB locations can be reduced.

1.2 Research Objectives

The main objective of this research is to assess pedestrian compliance on using foot over bridges in the Kathmandu valley. The specific objectives of the study are as follows;

- To determine the factors affecting the use of FOB and hence to identify the variables that significantly affect the use of FOB using a Linear Regression Model.
- To determine the perception of pedestrians toward FOB.

2. Literature Review

Using or not using a FOB is a habit, not an accidental occurrence [4]. If the travel time required to cross the road using the FOB is 1.5 times or more than the travel time required to cross the road using the road itself, no pedestrian would use the FOB [5]. Inappropriate location of FOB also discourage pedestrians in using FOB [6]. FOB is an expensive pedestrian facility as compared to other at grade crossing facilities and without adequate planning, its utilization cannot be maximized [7]. Thus, before planning and designing FOBs, their advantages over at grade crossing facilities should be examined, and shall only be designed if they can provide high benefit over at grade pedestrian facilities [8].

The effectiveness of FOB depends upon the use and non-use of FOB by pedestrians. The effectiveness of utilization of FOB can be determined by calculating the percentage of pedestrians using the bridge [9]. The percentage of pedestrian using the FOB is calculated based on the number of pedestrian crossing the road and number of pedestrian using FOB [9].

Regression models such as Multiple Linear Regression (MLR) and Binary Logistic (BL) model are widely used in determining the significant variables affecting the use of FOB [4, 8, 10, 11, 12]. While using MLR model, utility rate of FOB is taken as dependent variable and other possible factors affecting the use of FOB are taken as independent variables [8, 10, 11]. On the other hand, while using BL model, the selection of FOB (use or not use) is taken as dependent variable and other possible factors affecting the use of FOB are taken as independent variables [4, 12]. Pearson correlation matrix is widely use to determine multicollinearity among independent variables.

Traffic volume was cited in several studies as a major factor influencing the use of FOB [7, 8, 10]. One study, however, did not find traffic volume to be a significant influence [13]. This may be due to large traffic platoon and sufficient time gap that is enough to allow pedestrians to cross the road.

Similarly, other major factors influencing the use of FOB are posted speed limit [10, 11],width of road [11], existence of median barrier [8, 11], speed of vehicle [7], existence of road side fences [7, 8], crossing time through road [7], directional flow of vehicle [8], traffic light distance [8], number of lanes [10] and soon. The usage rate is higher in wet weather and at broader FOBs than at taller FOBs [14].

Many studies have indicated that pedestrian demographic features like as age and gender are also important factors determining the usage of FOB [12, 15]. However, one study found that age is inversely proportional to FOB use [16]. Similarly, one study found that the usage or non-use of a FOB is determined by pedestrian attitudes and behavior patterns [17].

The primary reason for pedestrians not utilizing FOB while crossing the road is to save time [4, 8, 10]. On the other hand, safety is primary reason for pedestrians that motivate to use FOB [4].

The utilization of FOBs can be maximized if they are constructed by fulfilling the parameters such as safety, comfort and convenience [9, 18]. Including an escalator in FOBs can also encourage pedestrians to use them [4, 6, 10, 15]. Similarly, installation of fences on road side can also actuate pedestrians to use FOBs. However, self enforcement, awareness programs and strict rules & regulations also play vital role in increasing the use of FOBs.

3. Methodology

3.1 Study Area

Kathmandu Valley is Nepal's political and cultural center, consisting of three districts: Kathmandu, Bhaktapur, and Lalitpur, encompassing an area of 570 km². It is Nepal's most developed and inhabited region, with a population of 3,059,466 people living in 683,954 houses [19]. The FOB located at Thimi

chowk, Koteshwor chowk, Ekantakuna chowk, Pulchowk (Near Labim Mall), Baneshwor Chowk (way to thapagaun), Chabahil chowk, Newroad gate and Ratnapark (Near NEA building) are taken as study area for this study.

3.2 Sample Size

Cochran's formula (developed by William G Cochran in 1977) has been used to calculate an ideal sample size. The Cochran's formula is given by:

$$n = \frac{Z^2.p.q}{e^2} = 384.16 \approx 385 \quad (1)$$

(for 5% margin of error and 95% level of confidence)
Here,
n = Sample Size = 385
Z = Standard error associated with the chosen level of confidence = 1.95 for 95% level of confidence obtained from normal table
p = Estimated proportion of an attribute that is presented in the population = 0.5, which give maximum variability
q = 1-p = 0.5
e = Acceptable sample error, 0.05 for % marginal error

From Cochran's formula the overall sample was found to be 385. The sample size is used to determine parameters such as: pedestrian volume, pedestrian road crossing time, pedestrian perception and speed of vehicle. Since, eight FOB locations were chosen as the study area. So, for each location the sample size can be taken as $48.125 \approx 50$ ($n = 385/8 = 48.125 \approx 50$ for each FOB location).

3.3 Data Collection and Extraction

All the data were collected during weekdays in normal weather condition. The data were collected through following surveys:

3.3.1 Pedestrian Survey

It consists of:

1. Determining the pedestrian volume:
   Pedestrians crossing the road using the FOB and using the road below the FOB (within the vicinity of 50m from the bridge edge in both directions as shown in Figure 1) were counted manually for a one-hour period at each FOB location. The survey was conducted during the peak hour, i.e., from 9:30am to 10:30am. The data collected were extracted using the Excel program.

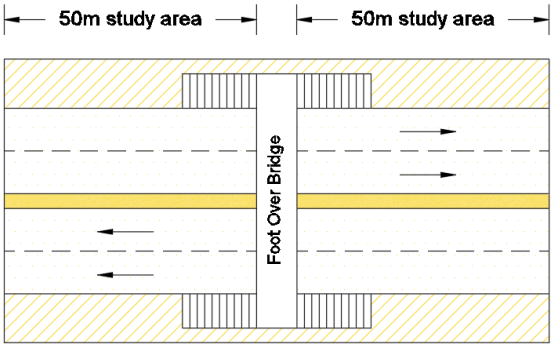

Figure 1: Scheme of Observation Area

2. Determining the crossing time of pedestrians:
   The crossing time of pedestrians crossing the road through FOB and the street below FOB (within the vicinity of 50m from the bridge edge) was determined using the stopwatch. This survey was also carried out during peak hours, i.e., from 9:30 am to 10:30 am. However, the survey time was extended until the sample size was met. At each FOB location, the crossing time of at least 50 pedestrians was noted. Of the total samples collected at each FOB location, half of them were pedestrians crossing the road using FOB and the other half were pedestrians crossing the road through the street below FOB. While in the FOB locations where pedestrians crossing the road using the street below the FOB were fewer, the majority of the samples were collected include pedestrians crossing the road using FOBs. The crossing time of pedestrians crossing the road at street level was determined by measuring the time each pedestrian spent crossing the road. The stopwatch was started as soon as the pedestrian stepped into the road and stopped as soon as the pedestrian reaches the sidewalk on the other side of the road. Similarly, the crossing time of pedestrians, crossing the road using FOB was computed by measuring the time each pedestrian spent on FOB to cross the road. Stopwatch was started as soon as the pedestrian stepped into the step of FOB and stopped as soon as pedestrian stepped out from the FOB (from opposite side). For the

pedestrians moving in the platoon, the crossing time of leading pedestrian was considered. Data were extracted using pivot table in MS-Excel.

3. Determining the pedestrian's perception toward FOB:
   A pedestrian perception survey was carried out by distributing a set of structured questions to the pedestrians crossing the road through FOB and the street below FOB (within the vicinity of 50m from the edge of FOB). At least 50 pedestrians were interviewed at each location. Of the total interviewees, half of them were pedestrians crossing the road using FOB, and the other half were pedestrians crossing the road through the street below FOB. While in the FOB locations where pedestrians crossing the road using the street below the FOB were fewer, the majority of the interviews were conducted with pedestrians crossing the road using FOBs. However, in both the scenarios, a minimum of 50 pedestrians were surveyed. The collected data were extracted using a pivot table in MS-Excel.

3.3.2 Traffic Survey

It consists of:

1. Determining the traffic volume:
   A traffic volume survey was also carried out in the eight FOB locations mentioned above. The survey was carried out through a video recording technique. One-hour video was recorded through a video camera at each FOB location from 9:30am to 10:30am. Data were extracted by playing the video repeatedly at a lower speed and manually counting the vehicles category-wise.

2. Determining the vehicle speed:
   Same as Traffic volume survey this survey was also carried out through one-hour video recording technique. The speed of vehicles was determined by specially located poles with 50m gap. First the camera was fixed at the top of the FOB at proper angle and the recording was started. Then two surveyors stand with pole at the edge of road at a distance of 25m from edge of bridge for 15 seconds and then moved to another 50m distance (i.e., 75m from bridge edge) and again stand still for 15 seconds. The recorded video was played on VLC media player adding time extension for viewing the video in millisecond. While examining the recorded video two lines were drawn on the screen indicating 50m distance. The first line was drawn at 75m distance from bridge edge and second line was drawn at 25m distance from edge of the bridge. As the front bumper of vehicle passed the line drawn on screen at 75m distance, the time in millisecond displayed on screen was noted as initial time then another time in millisecond was noted as the vehicle's front bumper passed the line drawn on screen at distance 25m from bridge edge as final time. The distance is constant i.e., 50m and the time the vehicle spent to cover this distance was measured by subtracting final time from initial time. Hence, the speed of vehicle was determined by distance travel by time.

3.3.3 Observation and Measurement of FOB and street below FOB

It consist of determining the physical characteristics of FOB such as number of stairways, length of bridge & height of bridge and physical characteristics of road below FOB such as width of road, number of lane, directional flow of vehicle, existence of median barrier & fence installation.

3.4 Variable Selection

The variables selected for this study are based on a literature review. The selection of variables to determine significant factors affecting the usage rate of FOB depends upon various factors such as: traffic condition, pedestrian behavior, physical characteristics of road and FOB. The usage rate is defined as the percentage of pedestrians who use the FOB while crossing the street. The variables considered in this study are described below in Table 1. These variables are used to form regression models.

Here, variables Y, X_1, X_2, X_3, X_9, X_{10}, X_{11}, X_{12}, and X_{13} are continuous variables. Likewise, X_4, X_5, X_6, X_7, and X_8 are categorical variables. Categorical variables were re-coded before entering into the regression model. Here, variable X_4 was re-coded as 0,1,2,3 and 4 for 2,4,5,6 and 8 lanes respectively. For one-way and two-way traffic flow, respectively, X_5 was re-coded as 0 and 1.Similar to variable X_6, it was re-coded as 0, 1, and 2 for fully, somewhat, and not at all facilitated with median barrier. Likewise, X_7 was re-coded as 0,1 and 2 for fully, partially and not at all

facilitated with road side fence. Finally, X_8 was re-coded as 0 for 2 legs FOB and 1 for 4 legs FOB.

Table 1: Description of Variables

SN	Variable	Description
1	Usage rate (Y)	Usage rate of FOB in percentage (%)
2	Traffic volume X_1)	Number of vehicles plying on the road for an hour (Veh/hr)
3	Vehicle speed X_2)	85th percentile speed of vehicles (Km/hr)
4	Road width X_3)	Total width of road including median
5	Number of lanes X_4)	Whether the road below the FOB is facilitated with 2,4,5,6 or 8 lanes
6	Directional flow of vehicle X_5)	Whether the road is facilitated with one way or two-way traffic flow
7	Existence of median barrier X_6)	Whether the road is facilitated with median barrier or not
8	Fence installation X_7)	Whether the fences are installed on road sides or not
9	Number of stairways X_8)	Whether the FOB is facilitated with 2 legs or 4 legs
10	Bridge height X_9)	Total height of bridge from road level (m)
11	Length of bridge X_{10})	Total length of bridge excluding length of stairways (m)
12	Crossing distance through FOB X_{11})	Total distance to walk through FOB in order to cross the road (m)
13	Average crossing time through road X_{12})	Average time required by pedestrians to cross the road through street below FOB (sec)
14	Average crossing time through FOB X_{13})	Average time required by pedestrians to cross the road through FOB (sec)

3.5 Multiple Linear Regression Model

Multiple Linear Regression (MLR) is a statistical technique which is used to predict the outcome of a dependent variable by using several independent variables. It helps to establish a linear relationship between dependent and independent variables. A relationship between dependent and independent variables usually takes the following form:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \ldots + \beta_n X_n$$

Where,
Y = Dependent variable,
β_0 = Intercept
$\beta_1, \beta_2, \ldots, \beta_n$ = Variable coefficients,
$X_1, X_2, X_3, \ldots, X_n$ = Independent variables.

In this study, SPSS software was used to establish regression models. The usage rate of FOB is taken as a dependent variable (Y) and possible factors affecting the use of FOB are taken as independent variables (X_i). The variables considered in the study are described in Table 1. The best regression models were predicted using a stepwise method, and the models were ranked based on the adjusted R^2 value and F test value obtained in the models.

4. Data Analysis and Results

4.1 Factor Affecting the Use of FOB

Data collected from the eight FOB locations as mentioned above were used to perform MLR analysis to determine the factors affecting the use of FOB. The data collected from these locations and also the data entered in SPSS are tabulated in Table 2.

Pearson correlation matrix was developed for all the variables as listed in Table 1 to test multicollinearity among independent variables. It was found that seven independent variables, X_3, X_4, X_9, X_{10}, X_{11}, X_{12}, and X_{13}, were highly correlated with one another. Hence, out of these seven independent variables, only one independent variable that highly correlate with the dependent variable i.e., X_3 was taken into account for developing a new correlation matrix and for establishing the MLR models.

Table 3 shows the best predicted regression models with the coefficient of determination R^2, adjusted R^2 and F test value derived from SPSS using stepwise method. Model 4 is the first best regression model with highest value of adjusted R^2 and F test followed by Model 2, Model 1 and Model 3 respectively.

Table 2: Collected Data for Dependent and Independent Variables

FOB Location	Y	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}	X_{13}
Thimi Chowk	96.93	5956	53	23.00	3	1	0	1	1	5.65	29.50	56.60	28.11	78.29
Koteshwor Chowk	85.01	6130	53	29.50	4	1	2	0	0	7.70	40.00	112.89	52.43	126.76
Ekantakuna Chowk	79.57	4352	58	29.50	4	1	2	2	1	7.00	34.40	66.89	41.98	89.04
Pulchowk (Labim Mall)	78.05	6410	40	19.20	1	1	1	2	1	5.90	20.00	57.12	22.30	68.9
Baneshwor (Way to Thapa Gaun)	7.85	2975	33	6.30	0	1	2	2	0	5.60	18.90	43.91	10.05	60.18
Chabahil Chowk	94.48	8201	50	16.80	1	1	2	1	0	6.20	28.90	53.24	23.49	71.17
Newroad Gate	97.95	8613	56	12.60	1	0	2	1	1	5.10	13.56	39.72	24.45	56.51
Ratnapark (NEA)	98.56	7338	53	15.00	2	0	2	1	0	5.70	21.20	48.94	23.80	67.00

Table 3: Best Predicted Regression Models

	Regression Model	R^2	Adjusted R^2	F Test
1	$Y = -61.863 + 2.862X_2$	0.658	0.601	11.547
2	$Y = -69.968 + 1.941X_2 + 0.009X_1$	0.879	0.831	18.172
3	$Y = -0.587 + 0.013X_1$	0.648	0.589	11.038
4	$Y = -38.669 + 0.013X_1 + 1.896X_3$	0.905	0.867	23.807

The first-best model, Model 4, shows that traffic volume and road width have a significant impact on the usage rate of FOB. The second-best model, Model 2, indicates that usage rate of FOB depends up on vehicle speed and Traffic volume. Similarly, the third best model, Model 1, indicates that usage rate of FOB is affected by Vehicle speed only. And the fourth best model, Model 3, depicts that usage rate of FOB is affected by Traffic volume only.

4.2 Perception of Pedestrian toward FOB

4.2.1 FOB Use and Non-use

The use and non-use of FOB for each group of respondents are categorized according to age, gender and FOB use & not use. The total number of respondents were 409 among which 56.72% were male and 43.28% were female. Likewise, the respondents were further categorized into three age group (<20, 20-50 and >50), among which 28.85% of respondents fall under age group of <20 years, 63.81% of respondents fall under age group of 20-50 years and remaining 7.33% of respondents fall under age group of >50 years. These respondents were further divided into two sub group (i.e., Pedestrian crossing using FOB and Pedestrian crossing using street below FOB), among which 65.04% were respondents crossing using FOB and 34.96% were respondents crossing using street below FOB.

4.2.2 Frequency of FOB Use

Participants were asked about their frequency of FOB use, and 44.99% stated that they sometimes use FOB, 43.52% stated that they frequently use FOB, 10.27% stated that they always use FOB and remaining 1.22% stated that they never use FOB. Of this percentage, 65.04% were FOB users and 34.96% were non users.

4.2.3 Reason for Using and Not-using FOB

Participants using the FOB were asked about the reason for using FOB and participants not using FOB for crossing were asked about the reason for not using FOB. There were 266 respondents using the FOB. Out of 266 respondents 65.04% of respondents answered that Safety is their primary concern for using FOB in order to cross the road, while 23.68% of respondents answered that heavy traffic is their reason for using FOB. Similarly, remaining 7.52% have other reasons and 3.76% of respondents replied to Forced due to barrier. The other reasons included availability of enough time, just to enjoy view from bridge,

waiting their friends and so on.

Similarly, out of total respondents there were 143 respondents not using FOB. Out of total non-user respondents 69.23% of respondents replied that Time saving is their priority concern for choosing street over FOB. While, 18.18% have other reasons, 8.39% replied to difficulty in climbing and remaining 4.20% said that road is safer to cross as shown in Figure 4-25. Here, as per respondents the other reasons include inconvenient environment, low vehicle speed, bridge is too long and so on.

4.2.4 Considerable Walking Distance to FOB

The respondents were asked about their willingness to walk in order to reach FOB before crossing the road. It was observed that 52.08% of respondents will to walk less than 50m to reach FOB before crossing the road, while 32.52% of respondents will to walk up to 100m, 10.51% will to walk up to 150m and remaining 4.89% will to walk more than 150m to reach FOB before crossing.

4.2.5 Treatment that Influence FOB Use

Respondents were asked about the treatment that may influence the pedestrians to use FOB. The respondents were suggested four choices and the majority of respondents (35.45%) voted for strategic location followed by awareness programs (29.10%), enforcement/fined (28.12%) and fence installation (7.33%) respectively.

4.2.6 Favorable Type of Crossing Facility

Another question was asked to respondents about their favorable type of crossing facility. Four choices were provided to the respondents including Underpass, FOB, Signalized crossing and Zebra crossing. Majority of respondents (65.53%) voted for zebra crossing as their preferable crossing facility while 20.54% of respondents prefer signalized crossing for crossing the road. Remaining 13.69% said FOB and 0.24% said underpass is their favorable crossing facility. The result shows that FOB is not highly preferable by pedestrians.

4.2.7 Compliance Awareness

Final question was designed to investigate whether the pedestrians (respondents) are aware of road safety or not. It was found that 47.19% of respondents are aware of road safety, while 44.25% of respondents are partially aware about road safety and remaining 8.56% of respondents are not aware of road safety.

5. Conclusion and Recommendation

5.1 Conclusion

Based upon the results, following conclusions are extracted from the study:

1. Data from eight FOB locations within the Kathmandu valley were collected and analyzed to develop Multiple Linear Regression Models in SPSS using stepwise method in order to determine significant factors affecting the use of FOB. And the significant factors affecting the use of FOBs were found to be: Traffic Volume, Traffic Speed and Road Width. Four best models were predicted, and based on the adjusted R^2 and F test value Model number 4 was found to be best regression model which indicate that Usage rate of FOB is affected by Traffic volume and Road width.

2. A pedestrian perception survey was also carried out at same eight FOB locations in order to determine perceptions of pedestrians toward FOBs. A structured questions was prepared and distributed to the pedestrians crossing the road using FOB and at street level within the vicinity of 50m from bridge edges. Time saving was found to be the main reason for not using FOB whereas safety was found to be the main reason for using FOB. Similarly, most of the pedestrians think that strategic location of FOBs will increase the use of FOB. Maximum number of pedestrians prefer Zebra crossing as a preferable road crossing facility over FOB. Out of the total participants nearly half of them are aware about road safety while remaining half of them are partially aware and completely unaware about road safety.

5.2 Recommendation

Following recommendations can be generated from the study:

1. Placing of FOB at the locations having high vehicular volume, high traffic speed and wider road can maximize the use of FOBs.

2. With regard to the locality's features, placing FOBs in a strategic place (i.e., less than 50 meters from a high pedestrian traffic area) might improve their utilization.

3. Conducting awareness programs related to road safety can aware and motivate pedestrians to us FOBs.

4. Zebra crossing and signalized crossing are highly preferred by pedestrians over FOB. Thus, appropriate investigation shall be carried out before planning and designing FOB as it requires a significant expenditure to build.

5. Conducting similar studies by considering more FOB locations and variables in regression model can help to identify other significant factors affecting the use of FOBs.

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