Modeling Pedestrian Behavior in Transportation Engineering

Anjum Mirza[a], Late. P J Gundaliya[b]

[a] Assistant Professor, L.D Engineering College, Ahmedabad, Gujarat, India

[b]Professor, L.D Engineering College, Ahmedabad, Gujarat, India

***Abstract*— In the realm of transportation research, numerous methodologies have been employed to enhance safety. Among these, the investigation of pedestrian behavior stands out as particularly intricate. The actions of pedestrians, especially the myriad factors influencing their decision-making processes, have sparked considerable scientific interest across various perspectives. This paper aims to delve into the diverse range of behavioral modeling approaches within the transportation sector, with a specific focus on pedestrians. It will elucidate the intricacies of pedestrian behavior, particularly during intersection crossings, and explore the multitude of influential factors shaping their choices. Through the identification of these factors, the paper will delve into pedestrian behavioral modeling, primarily through the discussion of two key models: the Binary Logistic Model and the Multinomial Logistic Model.**

***Keywords*—Pedestrian Crossing behavior, Binary Logistic Model, Multinomial Logistic Model**

I. INTRODUCTION

Walking serves as a primary mode of transportation for a significant portion of the population in numerous cities, particularly among low-income individuals who may lack alternative means of mobility. Additionally, it plays a crucial role in facilitating access to public transport services, enhancing the overall quality of urban life, ensuring accessibility within built-up areas, and offering a viable alternative to private vehicle usage for short-distance journeys. Short trips are prevalent in Indian urban centers, which are distinguished by their exceedingly high population densities and diverse land-use patterns.

Hence, pedestrians form an integral component of the transportation system. However, analyzing and simulating pedestrian behavior presents a complex challenge compared to vehicular movement. Given the significance of walking as the most sustainable mode of travel, this study aims to comprehensively understand pedestrian behavior and model their actions across various locations within Ahmedabad City. Ahmedabad, being one of India's congested urban centers, suffers from inadequate infrastructure for pedestrians, cyclists, and other slow-moving traffic. This deficiency often results in unsafe conditions for pedestrians and slow-moving vehicles, while exacerbating congestion for motorized traffic. Notably, in Ahmedabad, pedestrians, cyclists, and motorized two-wheelers (MTWs) collectively account for 65% of total fatalities in road traffic accidents.

As infrastructure catering specifically to non-motorized vehicles (NMVs) remains lacking, bicyclists and pedestrians persist in sharing road space, thereby facing elevated risks of involvement in road traffic accidents alongside high-speed vehicles. Among all road users, pedestrians constitute the highest proportion of fatalities. Particularly concerning is the upward trajectory of this share over the years compared to other demographic groups involved in accidents.

Consequently, forecasting the movement patterns of individuals through urban spaces is increasingly becoming a focal objective for urban and transportation planners who seek to craft efficient and pedestrian-friendly urban environments.

Numerous studies have scrutinized pedestrian crossing behavior, analyzing a multitude of factors. The aim of this review is to provide a comprehensive overview of the diverse array of factors that influence pedestrian behavior, ultimately impacting the pedestrian's Level of Service (LOS).

II. LITERATURE REVIEW

Jensen Soren Underlien et al., (2007) developed pedestrian satisfaction model using cumulative logit regression of ratings given by pedestrians and variables which relate to the satisfaction ratings. Roadway segments were rated on a six point scale i.e. very dissatisfied, moderately dissatisfied, a little dissatisfied, a little satisfied, moderately satisfied and very satisfied. The model includes type of walking area (asphalt, concrete, bicycle track, paved shoulder, driving lane), type of roadside development or landscape (residential, shopping, mixed, rural fields, rural forest), average motor vehicle speed, motor vehicle volume, pedestrian volume, bicycle and mopeds, buffer area, parked motor vehicles, presence of median, width of walking area, number of driving lanes and presence of trees. The model developed by him is in the form of utility function based on all these variables. The model provides traffic planners and others the capability to rate roadways with respect to pedestrians satisfaction and may be useful in the process of evaluating existing roads, designing new roads or redesigning existing roads. However the model is very exhaustive i.e. it includes almost every element present in the walkway segments. Furthermore incorporating all these factors and evaluating them is tedious job. Biasness of pedestrian's perception towards satisfaction of particular facility or elements cannot be denied.

Hubbard et al., (2009) presented a statistical analysis using a binary logit model that provides new insight into the factors that affect the likelihood that a pedestrian is compromised (delayed, altered their travel path, or altered their travel speed) in response to traffic turning right (on green) during concurrent vehicle/pedestrian direction of travel, right- turn traffic volume, number of pedestrian crossing, whether the pedestrian arrived late and began crossing after the end of the walk interval, and the crosswalk characteristics including location (downtown versus suburban) and one way - / two – way street.

Hoogendoorn et. al., (2004) proposes a theory and a model to describe pedestrian walking behaviour. He reviews some literature concerning pedestrian behaviour and the factors that influence it. According to his theory, pedestrians are driven by cost minimization.

Raghuram et al., (2013) investigate the pedestrian road crossing behaviour at the uncontrolled midblock location in India under mixed traffic condition. They modelled the size of vehicular gaps accepted by pedestrian using Multiple Linear Regression (MLR) technique. Also choice model was developed to capture the decision making process of pedestrian i.e., accepted or rejected vehicular gaps based on the discrete choice theory.

Akash Jain et al., (2014) worked on pedestrian behaviour at intersection. It presents the analysis of pedestrian crossing behaviour from a study conducted at Roorkee city (Uttarakhand, India). The effect of pedestrian characteristics like age, gender and that of carrying baggage and luggage as well as their crossing patterns were examined on pedestrian flow characteristics like crossing speed and waiting time. Pedestrian safety was also analysed with respect to safety margins and gaps accepted by pedestrian in traffic stream. Crossing patterns were observed for different age group and gender.

III. BEHAVIOURAL MODEL OF PEDESTRIAN’S

Through literature survey and site observations, the factors affecting the crossing behaviour of pedestrians at intersection which in turn will affect level of service of pedestrians incorporated in studies are as follow:

A. *Conflict with motorized and non-motorized vehicles*
B. *Initial Waiting time, Median Wait time and total crossing time of each pedestrian’s*
C. *Crossing behaviour of individual and in group of various size*
D. *Pedestrian Walking speed*
E. *Behavioural change if they handle baggage*
F. *Crossing Pattern of pedestrian’s*
G. *Signal Condition while crossing etc.*

The pedestrian crossing behaviour is influenced by factors discussed above. Pedestrians’ moving in groups’ show different characteristics when compared to those who move as individuals. If we compare male and female pedestrian, they also shows differences in their road crossing behaviour. In this study binary logistic regression and multinominal logistic is used to model the behaviour of pedestrians under different conditions.

IV. LOGISTIC MODEL

Logistic regression is portion of a category of statistical models called generalized linear models. This comprehensive class of models includes ordinary regression and ANOVA, as well as multivariate statistics such as ANCOVA and log linear regression. An excellent treatment of generalized linear models is presented in Agresti (1996). Logistic regression is used to predict a categorical (usually dichotomous) variable from a set of predictor variables. With a categorical dependent variable, discriminant function analysis is usually employed if all of the predictors are continuous and nicely distributed; logit analysis is usually employed if all of the predictors are categorical; and logistic regression is often chosen if the predictor variables are a mix of continuous and categorical variables and/or if they are not nicely distributed (logistic regression makes no assumptions about the distributions of the predictor variables)

The dependent variable in logistic regression is usually dichotomous, that is, the dependent variable can take the value 1 with a probability of success Θ, or the value 0 with probability of failure 1-Θ. This type of variable is called a Bernoulli (or binary) variable.

$$\theta = \frac{e^{(\alpha+\beta_1 x_1+\beta_2 x_2+...+\beta_i x_i)}}{1+e^{(\alpha+\beta_1 x_1+\beta_2 x_2+...+\beta_i x_i)}}$$

Where Θ = the constant of the equation and,
Θ = the coefficient of the predictor variables.

$$\mathbf{logit}[\theta(\mathbf{x})] = \mathbf{log}\left[\frac{\theta(x)}{1-\theta(x)}\right] = \alpha + \beta_1 x_1 + \beta_2 x_2 + ... + \beta_i x_i$$

The main aim of logistic regression is to suitably predict the categorical outcome for discrete cases using the best parsimonious model. To achieve this, a model is created that includes all prognosticator variables that are useful in forecasting the response variable. Several different options are available during model creation. Variables can be entered into the model in the order specified by the researcher or logistic regression can test the fit of the model after each coefficient is added or deleted, called stepwise regression. There are two main uses of logistic regression. The first is the forecast of relationship. Since logistic regression calculates the probability of success over the probability of failure, the results of the analysis are in the form of an odds ratio.

V. SIGNIFICANCE TEST FOR LOGISTIC MODEL

1. WALD TEST

The Wald test is a parametric statistical test named after the Hungarian statistician Abraham Wald. Whenever a relationship within or between data items can be conveyed as a statistical model with parameters to be estimated from a sample, the Wald test can be used to test the true value of the parameter based on the sample estimate.

$$z = \frac{\hat{\mathrm{B}}}{SE}$$

This z value is then squared, yielding a Wald statistic with a chi-square distribution.

2. LIKELIHOOD-RATIO TEST

The likelihood-ratio test uses the ratio of the maximized value of the likelihood function for the full model (L1) over the maximized value of the likelihood function for the simpler model (L0). The likelihood-ratio test statistic equals:

$$-2\log\left(\frac{L_0}{L_1}\right) = -2[\log(L_0) - \log(L_1)] = -2(L_0 - L_1)$$

This log transformation of the likelihood functions yields a chi-squared statistic. This is the recommended test statistic to use when building a model through backward stepwise elimination.

3. HOSMER-LEMESHOW TEST

The Hosmer–Lemeshow test is a statisticaltest for goodness of fit for logistic regression models. It is used frequently in risk prediction models. The test assesses whether or not the observed event rates match expected event rates in subgroups of the model population. The Hosmer–Lemeshow test specifically identifies subgroups as the deciles of fitted risk values. Models for which expected and observed event rates in subgroups are similar are called well calibrated.

VI. MODEL DEVELOPMENT

The model is developed in SPSS 20 (Statistical Software of Social Science) it is a statistical software that can perform various statistical analysis as well as many models can be easily calibrated in it.

Since the work focuses on behavioral analysis of crossing of pedestrian different logistic models can be created by considering various factors. For example model showing behavioral analysis while crossing based on gender, based on preference to crossing in group or individual. Even multinomial logistic model showing how speed is affected based on gender and handling baggage can be created.

General Steps to create model:

1. Entering data and defining each variable for model.
2. Coding the variable into discrete variable.
3. If there are continuous variables they are recoded by giving specific range
4. Click Analyze >> Regression >> Binary Logistic.

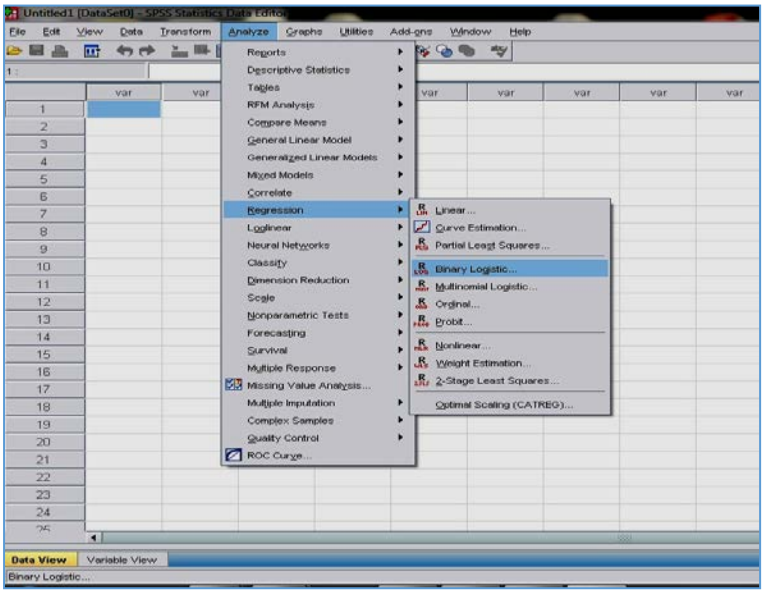

Figure 1 Screen shot of Binary logistic stating window

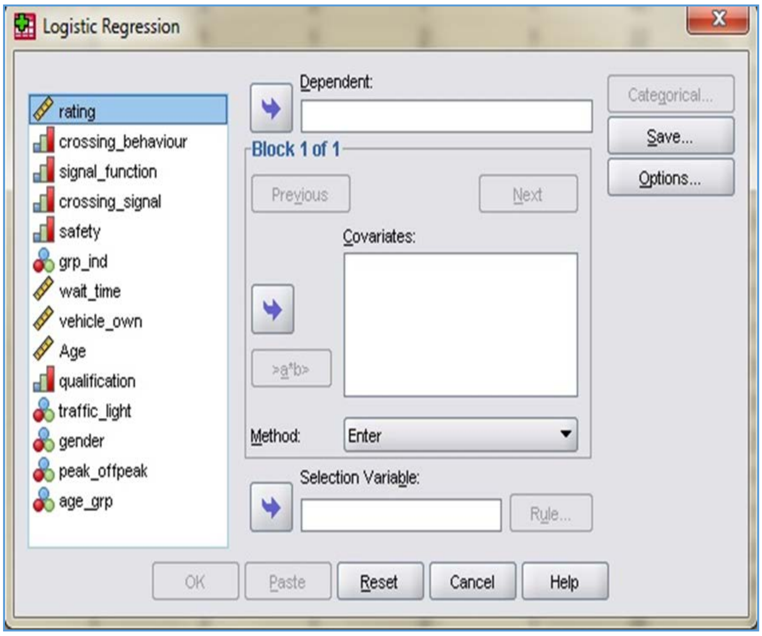

Figure 2 Screen shots of Logistic regression

The pedestrian behavioral model used in transportation engineering has been discussed. Various researchers have developed behavioral model for pedestrians by considering various factors such as type of walking area, average motor vehicle speed, motor vehicle volume, pedestrian volume, age, gender etc. that have prominent effect on their behavior.

The logistic model is explained and how this model can help to develop relation between various factors such as crossing time, gender, and age, and speed, conflict with motorized and non-motorized vehicle etc. The detail model development procedure is highlighted with the use of which various behavioral model for crossing of pedestrians can be developed. The result of this model provide insight how each factor influence the behavior of pedestrian while crossing.

Thus pedestrian crossing behavior analysis is the important factor for deciding the assurance of pedestrian safety on roads and various factors considered in this study can be used to decide the need of pedestrian facility in the area.

VIII. References

[1] Soren Jensen, “Pedestrian and Bicyclist Level of Service on Roadway Segments”. *Journal of Transportation Research Board,* **2007**, 43-51.

[2] Hubbard “Right Turns on Green and Pedestrian Level of Service: Statistical Assessment”. *Journal of Transportation Engineering*, 135, Issue 4, **2009** 153-154.

[3] Daamen, W, & Hoogendoorn, SP “Experimental research on pedestrian walking behavior”. *Transportation Research Board Annual meeting 2003 Washington DC National Academy Press*, **2003**, 1-16.

[4] B Raghuram Kadali , P Vedagiri Modelling ,“Pedestrian road crossing behaviour under mixed traffic condition”. *European Transport Journal Issue* 55, **2013**, 1825-3997.

[5] Akash Jain; Ankit Gupta; Rajat Rastogi, “Pedestrian Crossing Behaviour Analysis at Intersections” *International Journal for Traffic and Transport Engineering*, **2014**, 103 – 116.

[6] Nisha G, Thesis “Pedestrians’ Road Crossing Behavioural Analysis At An Intersection of Delhi” National Institute Of Technology Karnataka, Surathkal **2012.**

[7] *www.google.com*

[8] *www.wikipedia.org*