STUDY OF DRIVER YIELD BEHAVIOUR AT UNSIGNALIZED PEDESTRIAN CROSSWALKS IN KOCHI CITY

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ABSTRACT

The basic mode of transportation from one place to other is to walk, and we humans with all the modern means of transportation cannot do away with this at any point in our day to day life. In the present scenario where the focus is high on sustainability, walkability & multi-modal transportation in urban and suburban infrastructure; it is time to understand how well these will merge with the existing culture of the road users; both pedestrians as well as drivers.

The aim is to understand the pedestrian-vehicle interaction at unsignalized mid-block pedestrian crosswalks and study the yield behaviour of drivers to a pedestrian waiting to cross. The study is conducted in the undivided two lane city roads of Kochi. Four locations viz., three crosswalks at Park Avenue Road and one at NH 85 are chosen as part of the study. Video survey, radar gun and manual methods were used for data collection. The analysis includes non-parametric tests, viz., the Mann-Whitney U Test, the Chi-Square Test of Independence and the Kruskal-Wallis H Test; as well as development of binary logit model to predict the diver yield, using SPSS from the various variables which were coded and extracted from the collected data. The study also comprises of a questionnaire survey to give an insight towards the behaviour of drivers and their awareness of traffic rules.

Specific outcomes of this study includes (a) analysis of the driver and pedestrian behaviour, (b) report of the questionnaire survey and (c) development of the binary logit model to predict driver yield. The study shows that the voluntary yield of drivers to allow pedestrians to cross is low and over all soft yields of 28.71% is observed in this study. From the binary logit yield model developed, the yield characteristics are found to be dependent on the speed of the vehicle, platoon formation of vehicles, assertiveness and hand actions shown b the pedestrian.

KEYWORDS: Unsignalized mid-block crosswalks, Driver Yielding Behaviour, Pedestrians, Binary Logit Model, Questionnaire survey.

1 INTRODUCTION

Walking is inevitable as far as humans are concerned and when it comes to pedestrians at some point or the other during the journey; they need to cross the streets to reach the destination. The urban India is in a phase where tremendous makeover is underway in terms of sustainability and pedestrian friendly and safe environment. How safe is the urban and suburban settings of India for the pedestrians with its overflowing chaotic mix of heterogeneous traffic and its current integration with the modern means of transportation viz., Metros and BRTS? With the ever increasing traffic and transportation needs, even the suburbs are focusing on more efficient and sustainable transportation infrastructure. This study aims to make a structured examination of the existing culture of the Indian road users, basically the driver's yield behaviour towards the pedestrians at unsignalized midblock crosswalks. The study is restricted to urban environment where the population of pedestrians and vehicle is high on the roads. The interaction between the pedestrians

and drivers is a key area to be researched upon as it provides insight on the attitude of the drivers towards the pedestrians and their co-existence.

The study on the driver yield behaviour at uncontrolled two-lane mid-block crosswalks is carried out in the city of Kochi, Kerala.

The objectives of the study are: (1) Study the driver yield behaviour and identify the yielding characteristics of drivers at midblock unsignalized crosswalks, (2) Classify the yield behaviour of different type of vehicles, and (3) Model the yield of drivers and arrive at the factors which influence the yield. The study confines to two lane undivided roads as a starter, further the analysis can be extended to four lanes and divided highways.

2 LITERATURE REVIEW

The study on driver behaviour dates back to 1998 by Varhelyi in cities of Sweden, which concluded that the willingness to give way to pedestrians at the zebra crossing is low. The frequency of giving way is only 5% of all situations with pedestrian presence. It also points out that if a pedestrian wants to get priority on the zebra crossing he has to be 'bold' and 'force' the approaching cars to brake. Yielding has been empirically linked to pedestrian assertiveness and the presence of multiple pedestrians (Sun *et al.*, 2002) at the crossing. The study was conducted in a typical two-way two-lane uncontrolled cross walk in the University of Illinois at Urbana-Champaign. Schroeder and Rouphail (2011), in a study conducted at two unsignalized mid-block crosswalks in North Carolina, found that drivers were more likely to yield to assertive pedestrians who walk briskly in their approach to the crosswalk. The yield probability was reduced with higher speeds, deceleration rates and if vehicles were travelling in platoons. Kourtellis *et al.,* (2012), conducted opinion surveys and observational surveys to establish the difference between what people know to be the law or the correct behaviour, and what is their actual behaviour, and it was found that the variations are significant. Studies conducted by Foster *et al*.,(2014) in two enhanced midblock pedestrian crossings in Portland, Oregon; tested the effectiveness of the Rectangular Rapid Flash Beacon (RRFB) to make the driver yield. It was found that average driver yield rates were over 90% when RRFB activated during the crossing.

A before-and-after field study conducted at Texas in locations with and without RRFB and pedestrian hybrid beacon (PHB) installed to identify the changes in driver yielding (Fitzpatrick *et al.,* 2014). Also the pedestrian behaviours resulting from installing these treatments at previously untreated crosswalks were studied. The installations resulted in noticeable improvement in the number of yielding vehicles.

Eight locations in Boston and one in Brookline, Massachusetts, studied the effect of vehicle speeds on yielding to pedestrians (Bertulis *et al.*, 2014). It cemented the fact that pedestrian yielding will decrease as driver speed increases. It is notable that the study was conduction based on the 85^{th} percentile speed at the sites and staged crossings were resorted to, so that for each driver the variation in pedestrian characteristics could be nullified. The data show that increasing speeds are inversely correlated with decreasing yield rates – as driver speed increases, the yielding rate decreases.

As per the Central Motor Vehicles Rule, Rules of the Road Regulations 1989; the following describe the rules concerning pedestrian the right of way, in India:-

1. Rule 8: Caution at road junction
2. Rule 11: Right of way
3. Rule 15: Parking of the vehicle
4. Rule 19: Stop sign on road surface

3 METHODOLOGY

The methodology adopted in the study is stated below with the help of a flowchart. The major steps involved are: (1) choosing the study background and identifying the objectives (2) conducting literature review, (2) formulating a framework to achieve the objectives based on the findings of the literature, (3) selection of suitable site for field survey (4) collecting field data (5) extracting and coding the data (6) analysis of driver and pedestrian behaviour (7) model development and conclusion.

3.1 Site Selection

Two lane undivided roads with midblock were chosen for the study purpose. Two road stretches *viz.*, Park Avenue Road (sub arterial road) and NH 85, within the city limits were selected for the study. The locations were chosen such that the Kochi Metro work zones were avoided, to nullify temporary external influences to speed of the vehicles on the road, as well as to include all type of land use in the study. The NH 85 section has comparatively less pedestrian activity. Three pedestrian crossings in Park Avenue Road *viz.*, at Cochin Municipal Corporation Office, in front of Maharaja's College, in and front of District & Sessions Court, Kochi was chosen. One location at NH 85 was chosen, i.e. in front of Nucleus Mall.

The first three sites have mainly two types of land use, recreational and public or semi public government offices, with the exception that SITE 2 has an educational institution. The speed limit in the Park Avenue Road is 30 km/hr. Illegal parking is observed on either side of the road stretch and street vendors consume a considerable amount of the footpath on either side. The case is more severe near the SITE 1 in front of Cochin Municipal Corporation Office.

The fourth site (on NH85) in partly residential and partly commercial thus has mixed land use. The area has schools nearby and hence the speed is restricted to 30 km/hr.

3.2 Data Collection

The field data collection, from the selected sites was conducted with the assistance of videographic survey, radar gun and manual observations. Road Inventory Survey, Pedestrian Crosswalk Inventory Survey, Classified Traffic Volume Count, Classified Traffic Volume Count of Yielding v/s Non Yielding Vehicles, Spot Speed Survey, Pedestrian Volume Survey and Pedestrian Waiting/ Crossing Time Survey were conducted.

Schroeder *et al.*, (2011) defined "pedestrian-driver interaction event" as follows:- "a pedestrian arriving in the crosswalk influence area (CIA) while a driver is on the approach of the crosswalk". Crosswalk Influence Area (CIA) is defined as the area in the proximity of the crosswalk that is within line. A driver's decision to yield can also be broken down into a binary choice of yield or no yield for a pedestrian, also the type of yield can be classified as a complete stop (called hard yield) and a rolling stop or slowing down (called soft yield). The type of yield can also be forced or voluntary. There are three potential outcomes to the interaction that occurs between a pedestrian and a vehicle:

1. Pedestrian Gap Crossing – The pedestrian decides that there is sufficient time for a safe crossing and steps into the crosswalk.

2. Driver Non-Yield Decision [NY] – The pedestrian decides that the time until the expected vehicle arrival time to the crossing point is too short to safely cross the facility, i.e. he/she rejects the lag or gap. At the same time, the driver decides that it is either physically impossible to yield to the pedestrian, or he/she is unwilling to yield.

3. Driver Yield Decision [Y] – The approaching driver decelerates and creates a crossing opportunity for the pedestrian, which may occur with or without coming to a complete stop.

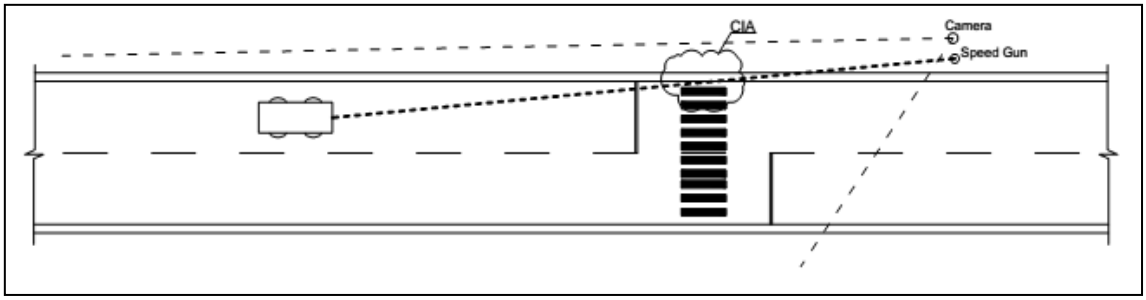

FIGURE 1 Data Collection Set Up

The pedestrian crossings chosen were mid block crossings, without any external sources to control the behaviour of the traffic. Contrary to this SITE 1 has police personnel deployed at times when the traffic flow is high and congestion occurs during peak hours. Care was taken as to not conduct the data collection at this time of the day.

The next step was to choose an appropriate time to record the video for analysis. The pedestrian crossing on the lane near to the video camera setup was only taken for analysis. The data was collected effectively for a period of one hour each, on week days; avoiding the peak hours. The time chosen was between 11:00 am to 2:00 pm. To reduce the complexity of study; the effect due to time of the day variations, peak hour traffic issues which results in anxious behaviour of the driver and pedestrian due to urgency to reach the office in the morning or in the evening were avoided. This might introduce more intensive analysis of the situation and much larger data set, which is outside the scope of the study due to the limited time frame.

The count of the pedestrians for which the yield or no yield event was account for is summarized in Table I. The remaining had to be discarded owing to gap crossings, where the presence of vehicle was not there and those which added to the behaviour that could not be coded into the selected variables.

TABLE 1 Composition of Road Users accounted for the study

	SITE 1	**SITE 2**	**SITE 3**	**SITE 4**
Vehicle Count (in PCU/hr)	3831	2754	3039	1984
Pedestrian Count (Actual)	334	192	221	120
Pedestrian Count (Analyzed)	273	127	108	115
Number of Events (Yield/ No Yield/ Gap)	208	203	201	203

The yield characteristics by two wheelers were coded separately into two *viz.*, soft yield and *pass by*. Soft yield is the condition, when the driver reduces the speed, allows the pedestrian to cross and then passes across the crosswalk. *Pass by* is the condition, when the driver reduces the speed and instead of allowing the pedestrian to cross and then proceed, the pedestrian and driver is found to be in close interaction with each other on the crosswalk. In the *pass by* condition the pedestrian and the driver are found to co-exist on the crosswalk. This in the case of two wheelers may seem a natural practice in Indian conditions, but chances of accidents are high in such situations, and should not be encouraged.

In general, the following site observations were made in all the sites. It was observed that parking of vehicles is a common in no parking zones. It is a common sight on the pedestrian crossings along the Park Avenue road for the private buses, auto rickshaws and private vehicles to illegally stop on the zebra cross to embark and disembark passengers. As per the CMV Rules, 1989 it is against the

rules to stop any vehicle on the pedestrian crossing. Basically there is no regard to the presence of crosswalk. Spontaneous pedestrian crossings are observed at locations where crosswalk is not provided. Considerable number of pedestrians' does not have any regard for the crosswalk and don't use it.

The spot speed studies of the vehicles were carried out in conjunction with the video survey as explained before. This was tabulated into MS Excel sheet. Along with these the classified count of yielding and non yielding vehicles according to the vehicle type viz., two wheelers, three wheelers, cars and heavy vehicles were taken, and pedestrian characteristics were noted

3.3 Data Extraction

The data from the video survey were extracted under three categories *viz.*, first vehicle characteristics, pedestrian characteristics and site characteristics and the same were coded. At each of the four sites a minimum of 200 yield or no yield events were recorded for the following variables:-

First Vehicle Characteristics:- Yield, Speed, Type of Yield, Opposite Lane Yield , Platoon Movement, Low Speed Platoon, First Vehicle Type - Two wheeler, Yield of Bike First Vehicle Type - Car, Three wheelers, Heavy Vehicle, Vehicle Type – Hired/ Non Hired, Private/Public Transport. Pedestrian Characteristics:- Gender, Age, Multiple Pedestrians, Staged/Random Pedestrian, Walk Time, Walk Speed, Initial Waiting Time, Yield/Gap, Crossing Behaviour, Crossing Direction, Pedestrian Group Size, Hand actions by Pedestrian. Site characteristics:- Land use, Presence of parking, Presence of School, Bus Stops, Width of crossing, Length of crossing, Type of marking, Crosswalk distance from nearby Intersection, Presence of Sign board, Studs, Double/Single Stop Line.

4 ANALYSIS

The collected and reduced data needs to be analyzed to get quantitative and qualitative inferences. This can be done by two methods; descriptive statistics as well as inferential statistics.

4.1 Descriptive Statistics – Driver and Pedestrian Characteristics

The first observation is that the phenomenon of hard yield (HY) was not observed in the recorded data. From the data collected 815 events of yield and no yield were extracted from the four sites. A total of 234 yield events, 487 no yield events and 94 gap crossings were recorded. It implies that the 234 yield events are soft yield (SY) or speed reductions, providing an overall yield percentage of 28.71%. The percent of yield that happened before or on the stop line is 32.91% i.e., 77 out of 234 soft yield cases, this shows low compliance to traffic rules. The percentage composition of pedestrians compared to the total traffic volume is given in **Error! Reference source not found.**.

TABLE I: Percentage Composition of Pedestrians versus Traffic Volume and 85th Percentile Speed

Legend	Vehicle Count (PCU/hr)	85th Percentile Speed (km/hr)	Pedestrian Count (Actual)	Pedestrian Percent Composition
SITE 1	3831	22	334	8.02
SITE 2	2754	32	192	6.52
SITE 3	3039	30	221	6.78
SITE 4	1984	42	120	5.70

Individually for each site the percentage of yields versus no yields are described in the TABLE II. At each site at the least 200 events were analyzed as part of the study.

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It was observed that considerable percentage of pedestrians had to cross in the safe gaps that were found rather than getting a proper vehicle yield for them to cross safely. This again points to the mindset of the drivers wherein they do not comply with the yield behaviour. Considerable people waited and did not get a yield from the drivers and found a suitable gap themselves after waiting to cross over. This can be viewed from two aspects either the pedestrian is not willing or fears to cross until a suitable gap is available to cross, or even with his or her presence on the zebra the drivers did not yield. From the observations, it was found that pedestrians willing to cross, indicating their presence on the zebra line but the lack of yield lead to their wait. Also those who crossed without wait time either risked their crossing by choosing small gaps or got enough large gaps to cross safely. Statistics are shown in Fig. II.

TABLE II: Composition of Events

Events	**TOTAL**	**SITE 1**	**SITE 2**	**SITE 3**	**SITE 4**
	815	**208**	**203**	**201**	**203**
Yield Events	**234**	**50**	**50**	**57**	**77**
	(28.71%)	(24.03%)	(24.63%)	(28.35%)	(37.93%)
No Yield Events	**487**	**131**	**123**	**123**	**110**
	(59.76%)	(65.87%)	(60.59%)	(61.20%)	(54.19%)
Gap Crossings	**94**	**27**	**30**	**21**	**16**
	(11.53%)	(10.10%)	(14.78%)	(10.45%)	(7.88%)

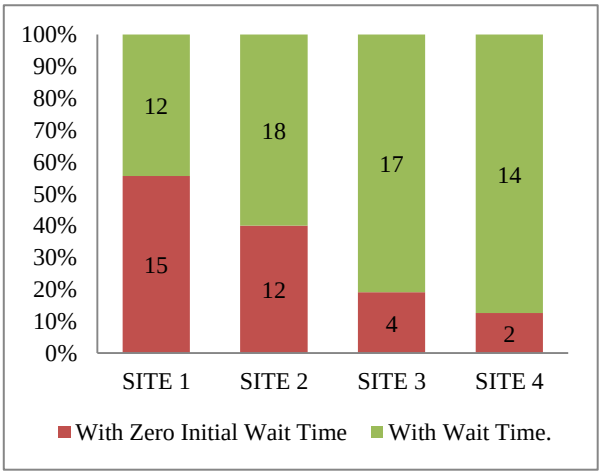

FIGURE II Gap Crossings With and Without Waiting Time

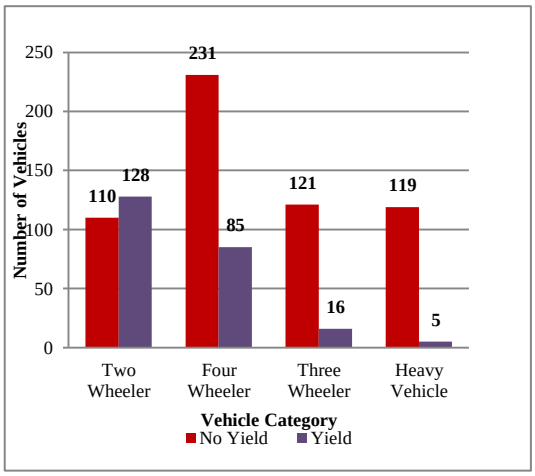

FIGURE II Category of Vehicles Yielding

If one specifically analyses the category of vehicles *viz.*, two wheelers, three wheelers, four wheelers and heavy vehicles, highest yield is shown by two wheelers (53.78%), followed by four wheelers (26.89%) and only 11.68% of the three wheelers yielded to the pedestrians. Considering the heavy vehicles only 4% yielded. One thing to be remembered in all these conditions is that all yields were just reduction in speeds.

The yield by two wheelers was grouped under two categories soft yield or *pass by*. This shows that in majority of the cases the two wheelers just pass by (82.73%) and thus a case of not even soft yield. The total number of two wheelers is 238, of which 128 yielded (18 soft yields, 118 pass by).

If one analyses the yield in term of hired versus non hired vehicles, and private versus public transport, trends show that yield is higher with private (33.81%) and non-hired (41.4%) vehicles. Gap crossings trends also show the acceptance in favoured towards private and non hired vehicles.

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Thus, we can see that heavy vehicle drivers and hired vehicles are more tending towards non yielding behaviour.

From the study it is observed that pedestrian's behaviour is cumbersome. The pedestrians do not cross at their intended safe cross zones and are impulsive. The observations made in this study are restricted to pedestrian crossings on the crosswalk with a buffer length of 3m on either side of the crosswalk. Thus in total the effective width of the crossing observed is 9m i.e., the space between the two stop lines. Also a classification was made, whether the pedestrian is strictly on the crosswalk or in the buffer zone. The buffer zone was kept within 9m for the ease to make observations and to account for the angle of the video, as beyond this many of the observations could not be captured. From preliminary observations it was also observed that considerable pedestrians jaywalked disregarding the oncoming traffic. It was found that 70.67% of the pedestrians were completely on the zebra, while the remaining pedestrians were in the buffer zone. Of the percentage which crossed 50% were passive pedestrians, indicating they are bound to have longer wait time.

One important point to be noted is that apart from the crossings on the pedestrian crosswalk, a considerable number of pedestrians crossed on other locations and most of these were impulsive. It was observed that more impulsive crossings took place at such crossings. This made the motorists to yield involuntarily as well. This shows that there is no regard for the traffic rules as far as the pedestrians are concerned. The unruly crossing behaviour of the pedestrians can also be a reason for the motorists to not yield to a pedestrian waiting to cross.

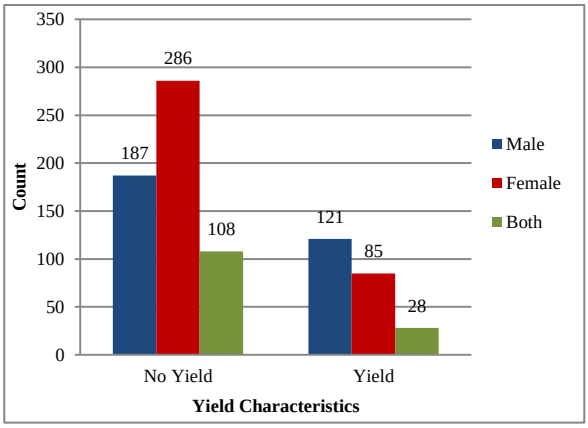

FIGURE IV Yield Variation with Gender

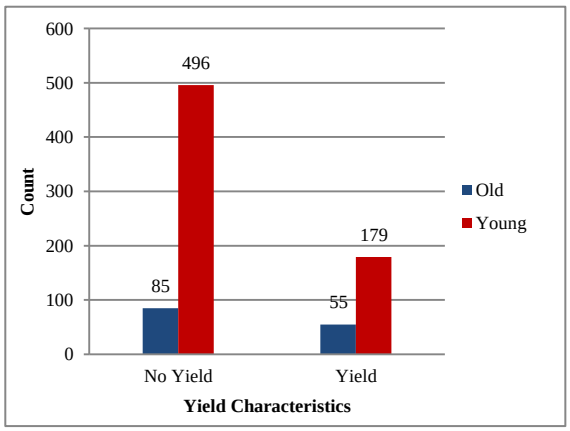

FIGURE V Yield Variation with Age

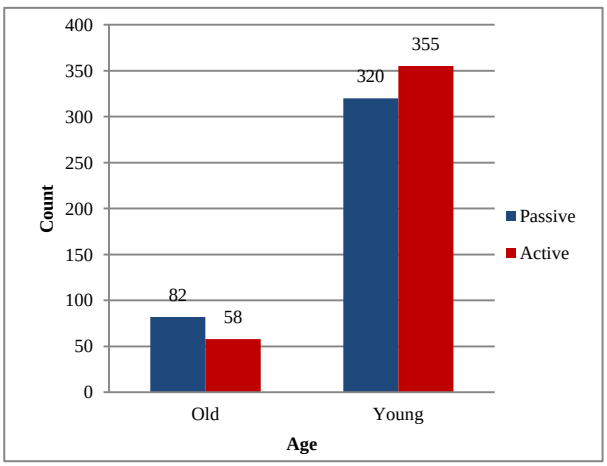

FIGURE VI Assertiveness versus Age

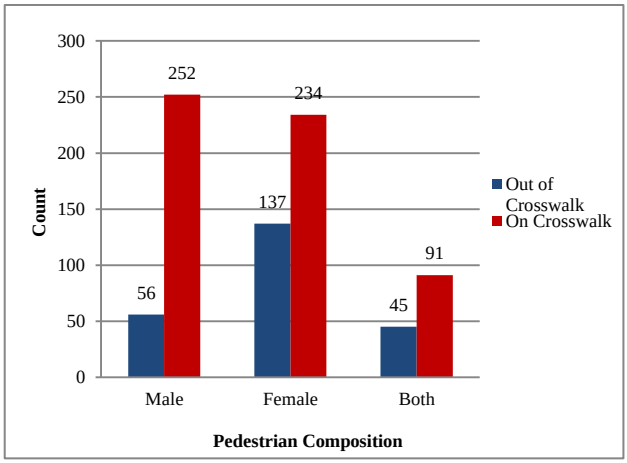

FIGURE VII Use of Crosswalk versus Gender

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The effect of yielding behaviour towards males, females and when both they are present in group was also analyzed. The age of the pedestrians were grouped into young and old (or disabled). The old and disabled were grouped into the same category as they both might take longer time to cross. Comparing the yield trends with the gender and cases of multiple pedestrians there are no specific trends in preliminary observations, except that the non yielding percentage is high in all the cases. The presence of female pedestrians also does not make the drivers to yield. The trends are shown in the Figure IV.

Similar trends are show for age as well; comparatively, yielding is comparatively high in case of old aged pedestrians (39.28%) against youngsters (26.5%). Younger people are found to be more assertive than older in their crossing behaviour, but the difference is small. Under the study area considered considerable number of crossings are found on the crosswalk as shown in Figure VII. The waiting time was found to be high at SITE1, SITE2 and SITE3 with the value of 61s, 55s, and 52s respectively. The maximum wait time in SITE4 was 27s.

The average wait time of pedestrians in the SITE1, SITE2, SITE3 and SITE4 are 9s, 7s, 9s, and 4.6s respectively. The average crossing time in all the sites is 7s. There are visible differences in the assertiveness or usage of crosswalk across the males or females or when they are in a group. Comparatively, we may say that females are more passive, which might be one of the reasons as to why the driver yield towards the pedestrians is low compared to males. Also, majority of them favour using the crosswalk than otherwise. But these trends may be attributes of the small sample size as well.

4.2 Inferential Statistics

Non parametric tests were used for testing the values extracted from the video survey to get a clearer picture of the yield behaviour of drivers and pedestrian crossing trends. Two tests the Chi-square test of independence and the Mann-Whitney U Test were used for the purpose. The coded data was input into SPSS for conducting these tests.

The Chi-square test of independence, also known as the Chi-square test; was adopted to test the variables with data that were coded nominally. The independency was tested for yield and gap acceptance, two each pertaining to the vehicle and the pedestrian.

The dependency of the yield of a vehicle was tested against the following vehicular characteristics *viz.*, opposite lane yield, platoon movement, low speed platoon, type of vehicle i.e. public or private transport, and hired or non-hired vehicle; against following pedestrian characteristics *viz.*, gender, age, multiple pedestrians, staged or random crossing, crossing behaviour (passive or assertive), crossing pattern (out or on the crosswalk), hand actions shown by pedestrian, accepted or rejected gap; against the various land use categories, presence of parking, school, bus stops, presence of studs, and stop line.

The Chi-square test is conducted under the following hypothesis:

Null hypothesis- H_0: A and B are independent of each other
Alternate hypothesis- H_1: A and B are dependent

The test is conducted at level of significance 0.05. In the test the values having a "*p*-value" greater than 0.05 are considered to have no significant relationship between the two variables; or in other words are independent of each other.

From the Chi square test results; it can be observed that land use, presence of stop line, multiple pedestrians do not have significant dependence on the yield event. This shows that the yield

behaviour of the drivers is not voluntary and only assertive pedestrians have chance to cross the road. Also, the test was done for the categorized vehicle type versus yield and chi-square value of 141.255 was obtained with *p*-value as 0; showing high dependence between the two variables. While as a specific case four wheelers and yield were found to be independent of each other, at 0.05 level of significance, with a *p*-value of 0.576.

The Mann-Whitney U test is adopted to test the variables with data that were coded as continuous variables against those which are coded into binary groups. This is used to test the speed of the vehicle against the following variable vehicular characteristics which were nominally coded *viz.*, yield, type of vehicle (hired versus non-hired; private versus public). It is also used to test the speed against the following site characteristics *viz.*, land use categories, presence of parking, school, and stop line.

It is concluded from the Mann Whitney U test that speed variations are not affected by the presence of stop line; and that there is no considerable variation in speed among the different types of vehicle. Also, there is speed variation with yield or no yield condition, presence of parking and school as well as land use characteristics.

5 MODEL DEVELOPMENT

A Binary Logit (BL) model is used to predict a binary response based on one or more predictor variables. For the present study it is the driver's yield or non-yield characteristics to the waiting or on coming pedestrian. The yielding of a vehicle is taken as dependent variable for binary logistic regression technique. In BL model, the probabilities of selecting an alternative (accept/reject) is based on a linear combination function (utility function) expressed as:

$$U_i = \alpha_i + \beta_{i1} X_1 + + \beta_{i2} X_2 + \beta_{i3} X_3 + \beta_{i4} X_4 + \ldots\ldots\ldots\ldots\ldots + \beta_{in} X_n \quad (5.1)$$

where;

U_i=the utility of choosing alternative i; i=the alternative (yield/ no yield);
n= number of independent variables;
X_1= independent variables in the equation
α= constant; β = coefficients;

These estimates explain the relationship between the independent variables and the dependent variable, where the dependent variable is on the logit scale. The utility of alternative *i* has to be transformed into a probability in order to predict whether a particular alternative will be chosen or not.

$$U = \log\left(\frac{p}{1-p}\right) \quad (5.2)$$

So, the probability that a pedestrian crosses the street is:

$$P = \frac{e^U}{(e^{U+1})} \quad (5.3)$$

Binary logistic regressions helps estimate the probability of "yield" given the values of explanatory variables, in this case a single categorical variable. Based on the utility equation obtained the effect of the variables on the yield can be interpreted.

On examining the 85th percentile speed, the city road – the Park Avenue Road had a speed of 30km//hr, where as that on NH 85 had a speed of 42km/hr. Therefore two separate models were developed for the two classes of road, one for the Park Avenue Road and another for NH 85.

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5.1 The Park Avenue Road Sites – City Road Model

Numerous trials were conducted with the coded variables to develop a binary logistic regression to estimate the decision of the driver to yield or not to yield to the oncoming pedestrian trying to cross the street. Initially all the variables found to have dependence on the yield behaviour as obtained from the non parametric tests were selected for the model. The first vehicle variables included are speed, platoon, speed of the platoon, type of vehicle, and whether the vehicle was private or public transit, and hired or no hired; the pedestrian variables *viz.*, gender, age, staged or random crossing, crossing behaviour – on or off the crosswalk and passive or assertive crossing, and on hand actions shown; and the site variables *viz.*, presence of parking, school and bus stops. The coefficients having *p*-values less than alpha (0.05) are statistically significant. Based on this parameter the variables were eliminated to arrive at the model. The variables included in the model are Speed, Platoon, Vehicle Type- Private or Public(VT_1), Age, Crossing Behaviour- Assertive/ Passive (CB_Pa_As), Hand Action and a Constant. Except for speed all the variables are binary coded. The descriptive of the developed model is given in Table IV.

Table IV: Estimated Coefficients – City Road Model

Parameter	Coefficient β	Standard Error	p-Value
Speed	-0.039	0.021	0.050
Platoon	-0.905	0.315	0.004
VT_1	2.320	0.523	0.000
Age	-1.004	0.303	0.001
CB_Pa_As	1.546	0.303	0.000
Hand Action	3.300	0.359	0.000
Constant	-2.831	0.756	0.000

U_1 = (-2.8.31) - 0.039*Speed - 0.905*Platoon + 2.320*VT_1 - 1.004*Age + 1.546*CB_As_Ps + 3.3*HandAction (5.4)

The utility equation shown above gives the probability of yield, i.e., U_1 (i=1 for yield). The equation is interpreted as follows, the probability of yield is increased by 2.320 times if the vehicle type is of private transit, and by 1.546 times if the crossing behaviour is assertive as well as 3.3 times if hand actions are shown by the pedestrian. Speed and platoon are found to reduce the yield probability by 0.039 times and 0.905 times respectively.

The validation of the present model is carried out with success and prediction table. The overall prediction accuracy was found as 87.6%. The Receiver Operating Characteristics (ROC) curve was used to check the prediction accuracy of the model. The area under the ROC curve was found to be 0.917. Hence, the proposed model is strong enough to predict probability of a driver to yield towards an oncoming pedestrian at uncontrolled midblock crosswalks in city roads.

5.2 The NH 85 Site – NH Model

Numerous trials were conducted with the coded variables to develop a binary logistic regression to estimate the decision of the driver to yield or not to yield to the oncoming pedestrian trying to cross the street. Initially all the variables found to have dependence on the yield behaviour as obtained from the non parametric tests were selected for the model. The first vehicle variables included are speed, platoon, speed of the platoon, type of vehicle, and whether the vehicle was private or public transit, and hired or no hired; the pedestrian variables *viz.*, gender, age, staged or random crossing, crossing behaviour – on or off the crosswalk and passive or assertive crossing, and on hand actions shown; and the site variables *viz.*, presence of parking, school and bus stops. The coefficients having *p*-values less than alpha (0.05) are statistically significant. Based on this parameter the

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variables were eliminated to arrive at the model. The variables included in the model are Speed, Platoon, Crossing Behaviour- Assertive/ Passive (CB_Pa_As), Hand Action and a Constant. Except for speed all the variables are binary coded. The descriptive of the developed model is given in Table VI.

Table VI: Estimated Coefficients - NH Model

Parameter	Coefficient β	Standard Error	p-Value
Speed	-0.558	0.107	0.000
Platoon	-2.368	0.882	0.007
CB_Pa_As	3.280	0.786	0.000
Hand Action	4.941	1.474	0.001
Constant	15.770	3.391	0.000

$$U_1 = 15.770 - 0.558*Speed – 2.368*Platoon + 3.280*CB\_As\_Ps + 4.941*HandAction \quad (5.5)$$

The utility equation shown above gives the probability of yield, i.e., U1 (i=1 for yield). The equation is interpreted as follows, the probability of yield is increased by 3.280 times if the crossing behaviour is assertive as well as 4.941 times if hand actions are shown by the pedestrian. Speed and platoon are found to reduce the yield probability by 0.558 times and 2.368 times respectively.

The validation of the present model is carried out with success and prediction table. The overall prediction accuracy was found as 93.6%. The Receiver Operating Characteristics (ROC) curve was used to check the prediction accuracy of the model. The area under the ROC curve was found to be 0.981. Hence, the proposed model is strong enough to predict probability of a driver to yield towards an oncoming pedestrian at uncontrolled midblock crosswalks in NH roads.

6 CONCLUSIONS

The studies indicate that in general the there is no proper yield behaviour observed among the various class of drivers. The obtained yield percentages are case of soft or rolling yield (28.71%) wherein the drivers just slow down enough to let the pedestrian cross over. Two wheelers were found to soft yield by slowing down and pass by; a special case observed. The studies in the literature review and the present study could be related and it confirmed that the yield behaviour is dependent on the speed of the vehicle and the assertiveness of the pedestrian.

Descriptive statistics show that yield is higher with private (33.81%) and non-hired (41.4%) vehicles and that pedestrian gap crossing trends show the acceptance is favoured towards private and non hired vehicles. In general, passive pedestrians were found to have longer wait time, and pedestrian gap acceptance depended on the gender and age of pedestrians.

From the non parametric tests, it can be stated that the yield characteristics of the driver were found to depend on the following vehicle characteristics viz., speed, platoon, speed of the platoon, type of vehicle, and whether the vehicle was private or public transit, and hired or no hired. It was found to be dependent on the following pedestrian characteristics viz., gender, age, staged or random crossing, crossing behaviour – on or off the crosswalk and passive or assertive crossing, and on hand actions shown. The site characteristics that influenced the yield were presence of parking, school and bus stops.

It was observed that if yield and opposite lane yield are dependent, i.e., if yield happened in the adjacent lane, the chances of yield on opposite lane are high. With the knowledge from non parametric tests, an attempt is made to develop a logit model. Chi square test of independence confirmed at 5% level of significance that land use, presence of stop line, multiple pedestrians did not have significant dependence on the yield event.

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Analysis of the speeds greater than 20km/hr and the yield percentages, showed inverse linear trends. But when all the speeds were considered, it was observed that at very low speeds and very high speeds yield behaviour was low. Thus, a vehicle approaching at speed less than 35km/hr can yield to an oncoming pedestrian, provided the driver of the vehicle intends to yield. It was observed that maximum yield percentage observed was close to 60% corresponding to speed of 20 km/hr. Thus, the willingness of the drivers, which is a major factor contributing to yield behaviour.

The binary logit model developed for the two road conditions viz., city roads and NHs show that the driver yield behaviour is more dependent of the pedestrian behaviour and driver attitude rather than the speed or other vehicular characteristics. An assertive and bold pedestrian has higher chance to get a yield than a passive pedestrian, especially in the second model i.e., the NH model, where the speed of the vehicles is higher.

6.1 Suggestions

Specifically, the following basic remedial measures have to be done immediately to ensure the safety of the pedestrians at each of these sites.

At the first three sites *viz.*, Cochin Municipal Corporation Office Crosswalk; Maharaja's College Crosswalk; and District Court Crosswalk:-

- On either side of the pedestrian crossings, upto the SSD, parking of vehicles should not be allowed, to ensure visibility of the pedestrians on the crosswalk
- The encroachments by street vendors on the footpaths shall be shifted to locations such that the pedestrian movement on foot path are not hindered.
- On the either side of footpath guard rails should be installed to ensure confinement of pedestrians within the footpath, this would to some extent prevent crossings off the crosswalk.
- Proper maintenance of pedestrian crossing signs, street lights, and studs shall be installed to ensure the visibility of pedestrians in the early night hours.

The fourth site; crosswalk in front of Nucleus Mall, though a part of NH 85, the basic installation of road signs are not ensured. The speed limit sign board and pedestrian crossing signs are to be put up at these sites. The shoulders on either side are not paved and dedicated separate path of safe movement of pedestrians is not present even though the land use pattern is considerably residential. The following measures can be adopted to ensure yield of the drivers to the pedestrians:-

- The following engineering measures can be tested for effectiveness - traffic calming measures and advance yield bars at the crosswalks.
- Enforcement measures can be more strictly enacted by installing cameras and monitoring the yield behaviour.
- Measures to ensure that no vehicles stop on crosswalks. Many a times it is observed that bus drivers, auto rickshaws and private vehicles stop their vehicle on the crosswalk or park vehicles on and in the vicinity of the crosswalk, thus making improper use of the facility for the pedestrians.
- Enforcement measures should be extended to pedestrians as well so that unwanted illegal crossings can be avoided.
- Pedestrian signals, for example; Rectangular Rapid Flash Beacon and Pedestrian Hybrid Beacon can be installed and tested for effectiveness.

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