Study on Driver Yielding to Pedestrians at Unsignalized Crosswalks

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Abstract— The basic mode of transportation from one place to other is to walk. In the present scenario where the focus is high on sustainability, walkability and multi-modal transportation in urban 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. With this work the aim is to understand one aspect, the pedestrian-vehicle interaction at unsignalized mid-block pedestrian crosswalks. An attempt to study the yielding behaviour of drivers to a pedestrian waiting to cross is made. 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 is using non-parametric tests for the various variables which were coded and extracted from the collected data. Specific outcome of this study include analysis of the driver and pedestrian behaviour and the characteristics that contribute to yielding of drivers. The observations showed 28.71% soft or rolling yield and that yield of the driver depended on speed of the vehicle, and assertiveness of the pedestrian.

Index Terms— Driver Yielding Behaviour, Pedestrian Behaviour, Pedestrian Vehicle Interaction, Hard or Soft Yield, Two Lane Undivided Roads, Unsignalized mid-block crosswalks, Video Survey.

1 Introduction

ANY travel starts and ends with a walk, which might or might not require the pedestrian to cross the streets many a times to reach his or her destination. In the urban and suburban settings of India which is getting jam packed with traffic and all the modern means of transportation, to execute this basic and reliable method is quite a risk. With the ever increasing traffic and transportation needs, even the suburbs are focusing on more efficient and sustainable transportation infrastructure. Through this study, the aim is to understand one aspect of the existing culture of road users in India i.e., the driver yielding behaviour towards the pedestrians at unsignalized midblock crosswalks. The study is confined to urban environment where the population of pedestrians and vehicle is high on most of the roads, with various types of land uses coexisting *viz.*, commercial, educational, institutional, recreational etc. to name few. The interaction between the pedestrians and drivers is thus a key area to be studied. This would give insight into what is the attitude of the drivers towards the pedestrians and how do they co-exist.

The study on the driver yielding behaviour at uncontrolled two-lane mid-block crosswalks is carried out in the city of Kochi, Kerala. The site is chosen because; the city is on the verge to witness a tremendous technological leap in the arena of transportation infrastructure, with the Kochi Metro on its way to fulfillment. Kochi Metro is expected to bring a major modal shift in the transportation sector and it is anticipated that the pedestrian population will also increase considerably across the city.

The objectives of the study are:

(1) Study the driver and the pedestrian behaviour at unsignalized midblock crosswalks,

(2) Identify the factors which influence the yield behaviour of drivers at midblock unsignalized crosswalks,

(3) Study the yield behaviour among the various class of vehicles and the attitude of pedestrians towards different class of vehicles.

The scope of the study is limited to select two lane undivided roads in Kochi city.

2 Literature Review

Some of the early works on driver behaviour by Varhelyi [1] in cities of Sweden, state 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 at crossings in a study by Sun, Ukkusuri, Benekohal, and Waller [2]. 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 [4], 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, Lin, and Gawade,[7] conducted opinion surveys and observational surveys to establish the difference between what people know to be the law or the correct behaviour, and

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what is their actual behaviour, and it was found that the variations are significant. Studies conducted by Foster, Monsere, and Carlos,[6] 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 were conducted at Texas in locations with and without RRFB and pedestrian hybrid beacon (PHB) installed, to identify the changes in driver yielding by Fitzpatrick, Brewer, and Avelar,[8]. 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, were studied by Bertulis and Dulaski,[9] to understand the effect of vehicle speeds on yield. It cemented the fact that pedestrian yielding will decrease as driver speed increases. It is notable that the study was conduction based on the 85th 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[13]; the following describe the rules concerning pedestrian the right of way, in India:-

1. Rule 8: Caution at road junction –

The driver of a motor vehicle shall slow down when approaching at a road intersection, a road junction, pedestrian crossing or a road corner, and shall not enter any such intersection, junction or crossing until he has become aware that he may do so without endangering the safety of persons thereon.

2. Rule 11: Right of way –

The pedestrians have the right of way at uncontrolled pedestrian crossings. When any road is provided with footpath or cycle track, especially for other traffic; except with permission of a police officer in uniform, a driver shall not drive on such footpath or track.

3. Rule 15: Parking of the vehicle –

Every driver of a motor vehicle parking on any road shall park in such a way that it does not cause or is not likely to cause danger, obstruction or undue inconvenience to other road users and the manner of parking is indicated by any signboard or marking on the road side, he shall park his vehicle in such manner.

4. Rule 19: Stop sign on road surface-

When any line painted on or inlaid into the surface of any road at the approach to the road junction or to a pedestrian crossing or otherwise, no driver shall drive a motor vehicle so that any part thereof projects beyond that line at any time when a signal to stop is being given by a police officer or by means of a traffic control light or by the display of any traffic sign.

A driver of a motor vehicle shall not park his vehicle; at or near a road crossing; near a traffic light or pedestrian crossing; on a foot-path.

Based on the findings from the literature review; the factors that lead to the decision taken by a driver to yield or not is expected to be a dependent on vehicular characteristics, and pedestrian as well as driver behaviour. Yield characteristics in heterogeneous traffic without lane disciple were not found in the studies. An attempt is made to conduct a study in heterogeneous traffic conditions, with the earlier works forming a foundation for the study.

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 behavioural aspects (7) arriving at results and concluding the same.

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[12], 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[11]. 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. [11]

3.2 Data Collection and Extraction

The field data collection, were conducted with the assistance of videographic survey, radar gun and manual observations.

Schroeder and Rouphail[4] 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. A driver's decision to yield can 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.[4] 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.[4]

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.[4]

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.[4]

The data collection set up is shown in Error! Reference source not found..

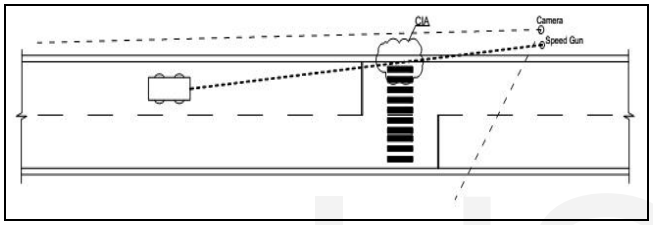

Fig. 1. Data Collection Set Up

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 accounted for is summarized in TABLE . 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.

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.

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 analysis consists of 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 TABLE .

TABLE 2
PERCENT COMPOSITION OF PEDESTRIANS VERSUS TRAFFIC VOLUME AND 85TH PERCENTILE SPEED

Site No.	Vehicle Count (PCU/hr)	85th Percentile Speed (km/hr)	Pedestrian Count	Pedestrian 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 . At each site at the least 200 events were analyzed as part of the study.

TABLE 3
COMPOSITION OF EVENTS

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

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. Error! Reference source not found. shows the details. If one specifically analyses the category of vehicles *viz.*, two wheelers, three wheelers, four wheelers and heavy vehicles,

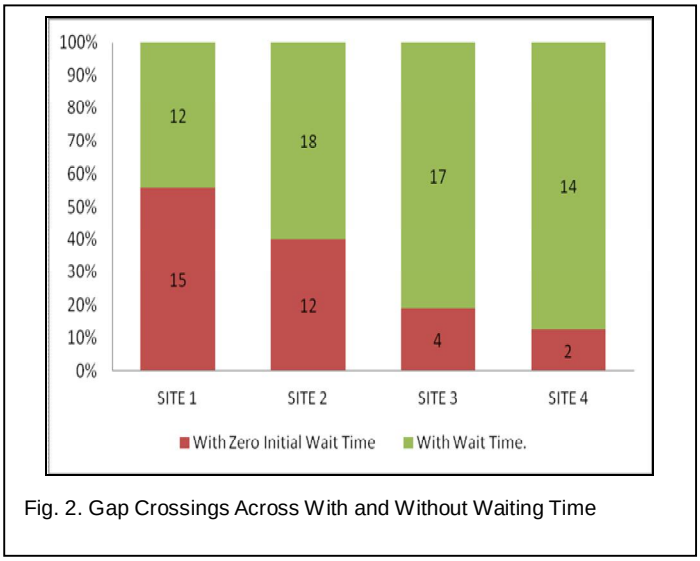

Fig. 2. Gap Crossings Across With and Without Waiting Time

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. The statistics are shown in Error! Reference source not found.. 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.

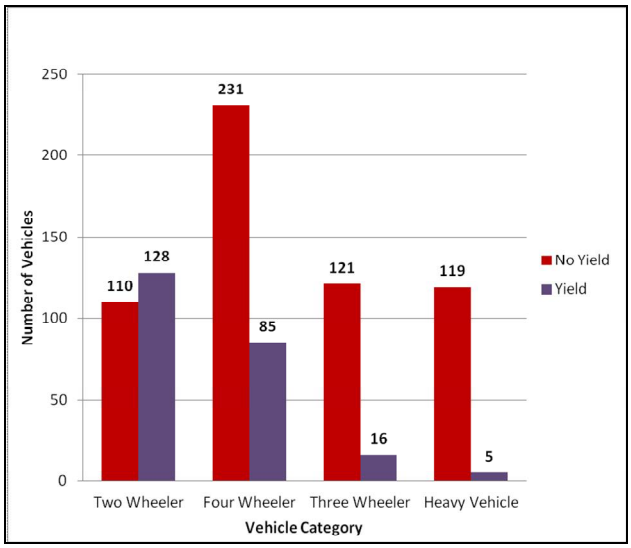

Fig. 3. Percentage of Different Category of Vehicles Yielding

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*).

The yield in term of hired versus non hired vehicles, and private versus public transport trends are as shown in TABLE . 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. Thus, heavy vehicle drivers and hired vehicles are more tending towards non yielding behaviour.

TABLE 4
YIELD COMPARED AGAINST VEHICLE TYPE

	Vehicle Type I Classification		Vehicle Type II Classification	
	Private	Public	Hired	Non Hired
Yield	211	23	27	207
No Yield	332	155	267	220
Gap	81	13	21	73

As, per the traffic rules the yield for safe crossing should be before the stop line. From the recorded data, the yield were found to be either just ahead of the crosswalk or on it in 67.09% of the cases.

The pedestrian crossings were observed to be impulsive and it was observed that they do not cross at their intended safe cross zones. 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. From the captured video, it was found that 70.67% of the pedestrians were completely on the crosswalk, while the remaining pedestrians were in the vicinity of the crosswalk. The percentage which crossed, 50% of them was passive pedestrians, indicating that these pedestrians are bound to have longer wait time. Comparatively, yielding is high in case of old aged pedestrians (39.28%) against youngsters (26.5%).

Younger people were found to be more assertive than older in their crossing behaviour. But on comparing the use of crosswalk, among the young and old, both groups have similar trends.

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. Three tests (1) the Chi-square test of independence; (2) the Mann-Whitney U Test and (3) the Kruskal-Wallis Test were used for the purpose.

The Chi-square test of independence, also known as the Pearson 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 dependence of the acceptance or rejection of gap was tested against the following vehicular characteristics *viz.*, type of vehicle i.e. public or private transport, hired or non-hired vehicle, the categorized vehicle type; and against following pedestrian characteristics *viz.*, gender, age, crossing behaviour (passive or assertive), crossing pattern (out or on the crosswalk), and multiple pedestrians.

The results show that multiple pedestrians and acceptance of gap are fairly independent and rest of the values show high dependence with the gap acceptance. Also age is found to have a border value slightly close to 0.05 *p*-value, indicating less dependence. Chi square test cannot be done for continuous variable. Thus to get further inferences on the characteristics the following tests are done.

The Mann-Whitney U test was adopted to test the variables with data that were coded as continuous variables against those which are coded into binary groups. This was 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 was also used to test the speed against the following site characteristics *viz.*, land use categories, presence of parking, school, and stop line.

It was 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.

The Kruskal-Wallis test was adopted to test the variables

with data that were coded as continuous versus variables which are coded into more than two groups. This was used to test the continuous dependent variable speed of the vehicle against the classified category of vehicles.

At 0.05 level of significance the null hypothesis was rejected with *p*-value 0.047, implying there is a variation in distribution of speed across different categories of vehicle.

5 Conclusion

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* (82.73%). This has been observed under very low operating speeds of two wheelers.

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.

The inferences from the non parametric test results show that that the yield characteristics of the driver depends 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.

The yield was found to depend on speed from the Mann Whitney U test conducted. 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. This shows that the yield behaviour of the drivers is not voluntary and only assertiveness can get a pedestrian across the road safely.

6 Limitations and Future Scope

The limitations of the study are as follows:-

- The crossings from one side were only taken into account, as the speed gun and camera could not be employed in both the lanes simultaneously.
- The study was not conducted to account peak hour effects, the presence of enforcement measures (presence of police personnel) and the evening or night time pedestrian crossings.

Pedestrian's behaviour changes with the time of the day and so does the driver behaviour. This shall be studied by including a more comprehensive and extensive data set. The effectiveness of the signboards, speed limits and studs installed is another crucial area that needs to be studied. The effectiveness of sign boards (passive signs) against Rectangular Rapid Flash Beacon, Pedestrian Hybrid Beacon, Traffic Calming measures can be installed at specific sites and studied. An insight into the behaviour of male and female drivers also needs to assessed.

The study can be extended to four lane roads and other sites to study the behaviour. Also the effect of road geometry, weather conditions, land use patterns are to be studied in detail.

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