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Pedestrian Gap Acceptance Behavior at Un-Signalized Intersections under Mixed Traffic Conditions- A Case Study at Dukem City, Ethiopia

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ABSTRACT

Transportation System is the most convenient way of making several arrangements for both vehicles and pedestrians to achieve a smooth flow of traffic on the road. The provision of appropriate pedestrian facilities at the desired location as well as increased pedestrian safety while crossing the road are the main goals of the analysis of pedestrians at Un-Signalized crossroads. In Dukem City, one pedestrian follows the other pedestrians at Un-Signalized intersections when crossing the road. The present study is aimed to model and analysis the gap acceptance behavior of pedestrians at Un-Signalized intersections under mixed traffic conditions in Dukem City. Three Un-signalized Intersections namely 'Qera', 'Qayamba', 'Misraq ber' in Dukem city has been selected based on pilot study and pedestrian- traffic data at the study area. Pedestrian Gap acceptance studies are conducted at the selected study locations and the related data such as pedestrian volume, gaps accepted, rejected, their waiting time, age, gender, headway, traffic volume, speed and road geometry at the respective study locations are collected by video graphic method. The total number of 7200 pedestrian gaps are observed cumulatively in all the study locations, for the purpose of analysis and modeling. A Multiple Regression Model is developed from the collected data to analyze the gap acceptance behavior of the pedestrians at un-signalized Intersections at selected study locations in Dukem City. The developed model is validated and found good fitness with R2 value more than 0.9. The results obtained from the model may be useful for predicting pedestrian behavior that will be useful to implement pedestrian safety measures at the selected locations. The maximum and minimum pedestrian waiting times recorded are found to be 59.9 sec, 58.9sec and 58.9 sec. and 16.9 sec, 16.8sec and 16.8sec respectively.

1. Introduction

Traffic accidents involving pedestrians have become a significant safety issue around the world, particularly in developing nations like Ethiopia. This is due to the result of high population density, rapid urbanization, and lack of attention to traffic regulations by both drivers and pedestrians. When vehicular drivers disrespect the pedestrian rules at crossings, the situation becomes tense for the pedestrians and will lead to increase their crossing speed that may attract an accident. On the other hand, busy pedestrian crossings could result in unacceptably long delays for moving vehicles (Islam et al., 2020).

One of the most crucial aspects of microscopic traffic characteristics is gap acceptance, which is essential in determining the capacity and delay of each moment at uncontrolled intersections. Ethiopian cities have grown quickly, and its urban roads are extremely congested. Ethiopian transportation is distinguished by diverse traffic patterns and with median lane enforcement. Gap acceptance behavior is one of the fundamental basis for the pedestrians to cross the road safely that enable to calculate the critical gap on the road. The critical gap is defined as the smallest gap that a driver will tolerate when anticipating an uncontrolled encounter with an oncoming stream of traffic. (Kumar and Sasikumar, 2020).

The acceptance of the gap by the pedestrian mainly depends on the arrival rates, pedestrian volume, headways, traffic speed and road geometrics. The above parameters are dynamic in nature and hence need to analyze the problem at micro level. Drivers who intend to make complex maneuvers at pedestrian crossings will create lot of conflicts among the street vehicles that create different values of the time (Dutta and Ahmed, 2017). The present study is to analyze the required gap at Un-Signalized intersections under mixed traffic conditions by using statistical model.

1.1. Statement of the Problem

Ethiopian Pedestrian typically crosses the road at unprotected Un-Signalized intersections due to ease of access or the lack of zebra crossings near their destinations. However, greater pedestrian crashes are explored as a result of pedestrians miss understanding in navigating the traffic system, automobiles fail to stop for pedestrians, and lack of effective pedestrian crossing planning. Individuals' decisions on crossing the road are complicated and are typically based on variables such as comfort, convenience, and simplicity of crossing (Geremew and Mahto, 2019). The research is carried out at three selected Uncontrolled Unsignalized Intersections in Dukem City, where there is a regular improvement in traffic volume.

1.2. General Objective

To develop a pedestrian behavior model and analyze the Gap acceptance of Pedestrians at selected Un-Signalized Intersections in Dukem City.

1.3. Specific Objectives

- To observe and understand the Pedestrian crossing behavior at the point of Unsignalized Intersection
- To evaluate the effect of pedestrian waiting time and pedestrian gap acceptance on the movement of the vehicles
- To determine the critical Gap for pedestrians at Un-Signalized intersections.
- To analyze the pedestrian behavior from the model developed and to recommend possible guidelines for the safe crossing of pedestrians.

2. Literature Review

As a substantial share of road users, pedestrians are a crucial component of urban landscapes. They interact with other forms of mobility, such as cars, bicycles, and public transportation. Construction of sidewalks, crosswalks, pedestrian signals, and the implementation of traffic laws and regulations that prioritize pedestrian rights and safety are all steps done to ensure pedestrian safety (Antic et al., 2016).

Paul and Rajbonshi, 2014 expressed that Gaps and the site features depend on the conditions that exist when a pedestrian tries to cross. The available space is the one that is accessible for easy crossing of the pedestrians. The gap accepted or rejected depends upon the availability of gap size on the road.

In some studies, researchers used cameras to capture pedestrian movements and conducted surveys to acquire data on pedestrian impressions of the crossing environment. Muley et. al (2017) shows that over 60% of Pedestrians passed toward the intersection (upstream) to reach the retail center's facilities, according to the direction of pedestrian crossing at the marked crosswalk. As shown in this paper, roughly 60% of Pedestrians observed walked at the designated crosswalk, with the rest Pedestrian crossing close or distant from the crosswalk. As a result, Pedestrians lose the motivation to cross at designated crossing points, forcing them to cross at areas, increasing their risk of injury.

3. 3. Material and Methodology

3.1. Study Area

Dukem City is located 37 kilometers southeast of Addis Ababa City along the main road to Adama. Geographically, the research area spans to 35.96 km2 and is situated between latitudes 8045'25''N and 8050'30''N and longitudes 38051'55''E and 38056'5''E. It is situated at 2100 meters above mean sea level on average.

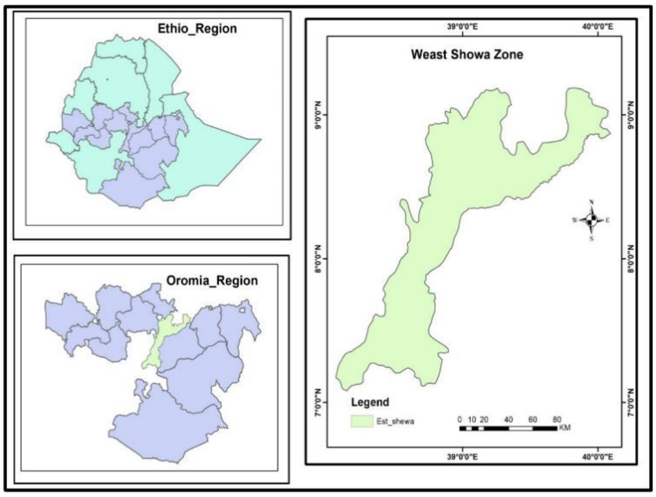

Figure 1. Topography of the Study Area

Three Uncontrolled Unsignalized intersections in Dukem City namely Qera, Qayamba and Misraq were selected for the study. The roads connecting these Intersections are significant in nature and are directly connected to the other routes. The road width of each leg of the Intersection varies between 10 meters to 13 meter with major and minor approaches as shown in the Table 1. The traffic is heavy in all directions with low traffic speeds at the range of 29 to 57 Km/hr.

Table 1. Selected Study Intersections

Intersection Name	Major Approach	Minor Approach	Major Road width (m)	Minor Road Width(m)
Qera	Post office-Church	Mosque-Commercial center	12.5	11
Qayamba	Inat Bank-Hibret Bank	Dashen bank-Cooperative Bank	11.5	10
Misraq Ber	Abyssinia Bank-Commercial Bank	Manicuplity-wegagan Bank	13	11.5

3.2. Data Collection and Study Variables

Keeping the concept of general and specific objectives, traffic data that includes traffic volume with composition and speed were collected at all the three study locations. Similarly, the pedestrian data that includes pedestrian crossing volume, age, gender, waiting time were also collected. Time headway at all the study locations was collected to understand the behavioral nature of the pedestrians for different headways during crossing time. The entire data was collected at all the study locations for a period of 12 hours in a day and for every 15 minutes consecutive intervals.

3.3. Materials and Tools Used

A digital camera, stopwatch, mobile phone, paint, chalk, and a data record sheet were some of the equipment and software used to complete this study. Digital cameras were employed in the primary data collection to record video graphics, which includes gathering information about the headway, volume, and speed of the cars as well as the acceptable and rejected gaps and the number of pedestrians. To draw reference lines for data collection, paint, and chalk were utilized. Measurement of the reference line, the length of the road, and the width of the road are all measured with tape. AutoCAD 2007 was used to sketch the intersection's geometry underneath the study area. ARC GIS was used to develop the map of the study area for digitizing the road link network study area boundary. Microsoft Excel was used for organizing, filtering, and visualizing data.

Table 2. Pedestrian and traffic data for Un-signalized Intersections

Time	Age	Gender	Waiting time (sec)	Gap accept.(sec)	Pedestrian volume	Ped. Crossing speed (m/s)	Total volume	Avg.Speed(Km/h)	Avg.time headway (sec)
8:00-8:15	35	1	45.6	20.7	150	2.109	191.85	57.6	5.43
8:15-8:30	25	0	45.5	15.8	110	2.076	181.55	53.664	3.522
8:30-8:45	27	1	55.1	13.5	88	2.142	168.9	38.744	3.389
8:45-9:00	33	1	45.8	15.7	65	1.901	166.45	35.555	4.4
9:00-9:15	18	0	44.7	14.6	49	2.076	154.6	37.402	2.677
9:15-9:30	35	0	48.9	14.5	45	2.25	134.55	37.894	3.773
9:30-9:45	63	1	55.7	12.5	38	2.327	164.9	40.563	3.268
9:45-10:00	25	0	33.6	14.6	50	2.25	130.75	41.941	2.894
10:00-10:15	33	1	45.8	15.8	45	2.142	139.1	39.272	3.086
10:15-10:30	35	0	33.7	18.9	42	1.985	114.55	32.603	3.597
10:30-10:45	43	1	28.9	11.5	52	1.985	142.8	40.563	4.134
10:45-11:00	32	0	20.9	11.5	33	2.647	141.45	48.268	4.16
11:00-11:15	30	1	16.9	12.5	46	2.812	142.75	36.923	4.438
11:15-11:30	32	0	45.8	15.8	32	2.177	162.8	41.73	4.009
11:30-11:45	52	1	56.9	16.8	35	2.454	133.75	41.142	3.158
11:45-12:00	35	0	55.7	19.9	50	2.410	127.95	35.555	4.274
12:00-12:15	28	1	43.8	18.8	88	2.076	120.3	43.417	4.694
12:15-12:30	20	0	54.8	22.8	90	2.045	115.45	35.850	4.158
12:30-12:45	26	1	23.8	17.9	95	1.985	146.65	30.857	4.689
12:45-1:00	33	1	32.8	17.8	48	2.014	144.45	40.947	3.234
1:00-1:15	41	1	28.9	13.5	40	2.327	130.4	45.473	3.326
1:15-1:30	35	0	54.8	13.7	98	2.368	125.05	38.230	3.532
1:30-1:45	37	0	44.8	11.5	95	2.177	126	33.882	3.773
1:45:2:00	40	1	32.8	10.5	38	2.014	127.35	34.285	3.438
2:00-2:15	62	1	54.8	11.5	46	2.5	128.1	46.451	3.2
2:15-2:30	33	0	45.8	10.8	49	2.647	167.25	47.472	2.075
2:30-2:45	36	1	44.8	15.9	45	2.076	153.4	52.048	2.486
2:45-3:00	30	0	55.9	19.9	52	2.213	141.55	48.268	2.986
3:00-3:15	28	1	58.9	18.8	58	2.109	136.3	39.815	2.576
3:15-3:30	55	0	59.8	17.8	52	2.076	135.6	38.230	3.284
3:30-3:45	28	1	57.9	16.8	46	2.327	135.95	42.772	3.225
3:45-4:00	28	0	55.8	20.9	50	2.410	157.65	34.015	2.952
4:00-4:15	56	1	59.9	17.9	56	1.985	147.9	36.302	5.261
4:15-4:30	30	0	55.8	18.8	57	2.812	172.7	35.409	3.245
4:30-4:45	30	1	57.8	17.9	53	2.327	171.15	29.488	4.577
4:45-5:00	14	0	58.9	15.8	54	2.177	146.05	29.589	3.618
5:00-5:15	15	1	55.7	16.8	60	2.076	137.85	30.747	3.279
5:15-5:30	18	0	55.8	19.8	80	2.454	137	32.977	4.202
5:30-5:45	34	1	45.8	17.8	100	2.177	159.55	36	3.461
5:45-6:00	61	0	56.8	20.1	120	2.014	186.35	52.363	3.829

3.4. Traffic Volume, Speed and Headway

The traffic volume, speed and headway on the road decides the probability of gap acceptance by the pedestrian. Higher traffic volume, speed and lower headways results for less probability of acceptance and vice versa. For a given road geometrics, these three variables are interrelated to each other. The Intersections in Dukem City are found to be narrow with heavy traffic volume, as in the Figure 2.

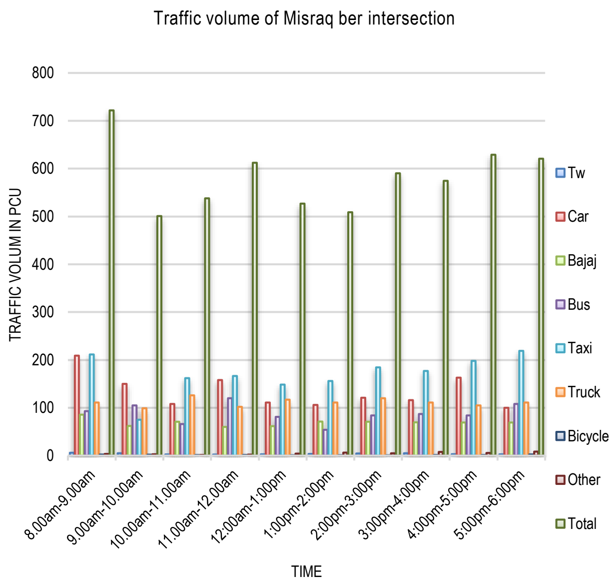

Figure 2. Total traffic volume in the Qera intersection

Figure 3 indicates the relationship between speed and cumulative percentage of vehicles at the study locations. From the graph, It is observed that 98th percentile speed is at the range of 40 to 50 km/hr. whereas 85 th percentile speed in at the range of 50 to 60 km/hr and 50th percentile speed is in between 30-40 km/hr. This clearly indicates that the vehicles are moving at a slower rate at the study locations that brings the pedestrians to take more crossing time. Also, at higher traffic flow rates, vehicles with small headways are observed. The highest and lowest headways are recorded and are found to be 5.43 sec, 5.58sec, 5.41 sec and 2.07 sec, 2.15 sec, 2.27 sec at Misraq ber, Qayamba and Qera Intersections respectively.

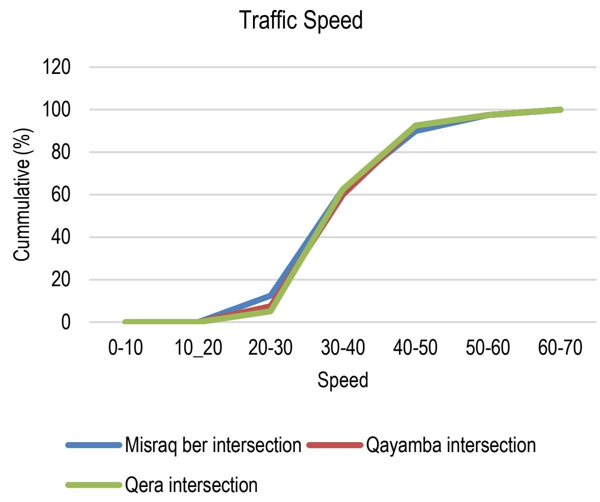

Figure 3. Cumulative Speed distribution curve

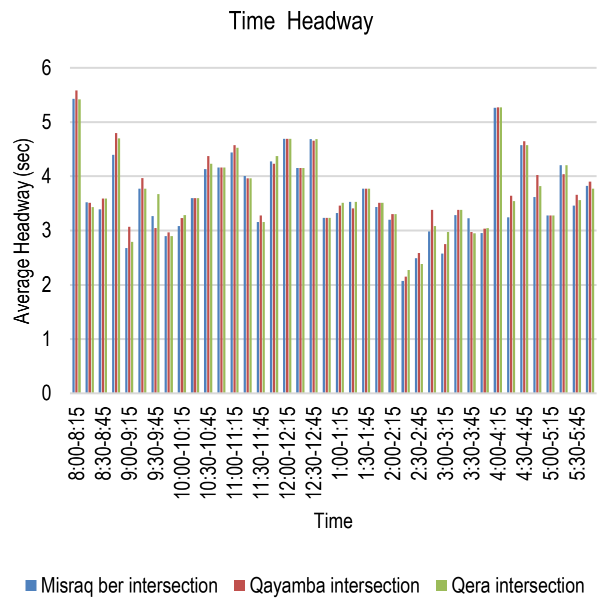

Figure 4. Time Headway at Qera Intersection

3.5. Pedestrian age and waiting time

The crossing behavior of the pedestrian depends on their age and waiting time. Obviously, aged people need more time to cross the road and moreover, they will wait for longer time to cross the road. The young and middle-aged group people will take less time to cross the road and moreover, they do not take more waiting time.

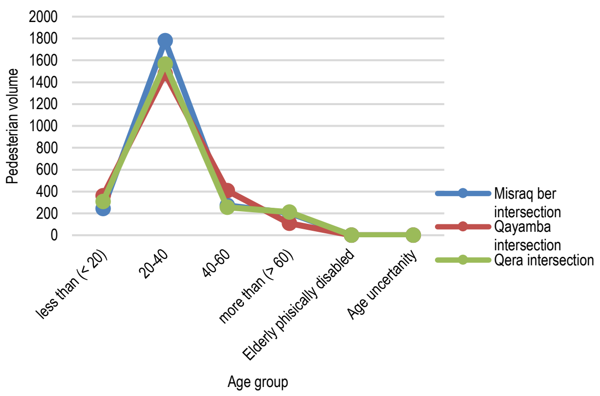

Figure 5. Volume vs pedestrian age group

The waiting time of the pedestrian also depends on the traffic flow and road geometrics at a particular section. The study locations are Unsignalized Intersections with continuous traffic movements and due to this factor, the crossing behavior of the pedestrian slightly changes and subjected to little tense in crossing the road. The same thing is reflected in the present study. Figure 5 shows the variation of pedestrian volume at different study locations with larger pedestrian volume at Misraq ber Intersection. Figure 6 indicates the variation of waiting time at different study locations with highest waiting time during morning and evening peak hours.

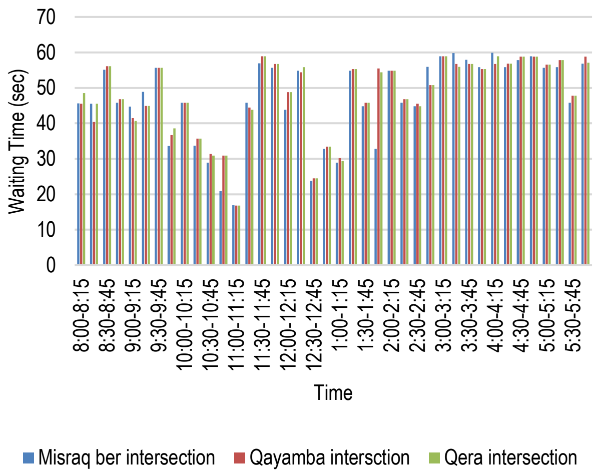

Figure 6. Pedestrian waiting at study locations

3.6. Pedestrian Gap acceptance

The available gap for the pedestrian to cross the road depends on various factors such as traffic composition, headway, Intersection size, pedestrian age, volume, etc. When the headway is more, the probability of gap acceptance is more by the pedestrian. Hence, it is desired to curtail the traffic flow at certain locations, where the pedestrian crossing volume is more. The present study is conducted to verify this situation.

The probability of getting gap acceptance increases as more pedestrians are waiting and are unable to find a chance to cross the road. The maximum acceptable gaps found at Misraq ber, Qayamba and Qera Intersections are 22.8 sec, 21.5 sec and 22.1 sec respectively followed by minimum acceptable gaps of 10.5 sec, 10.5 sec and 11.5 sec.

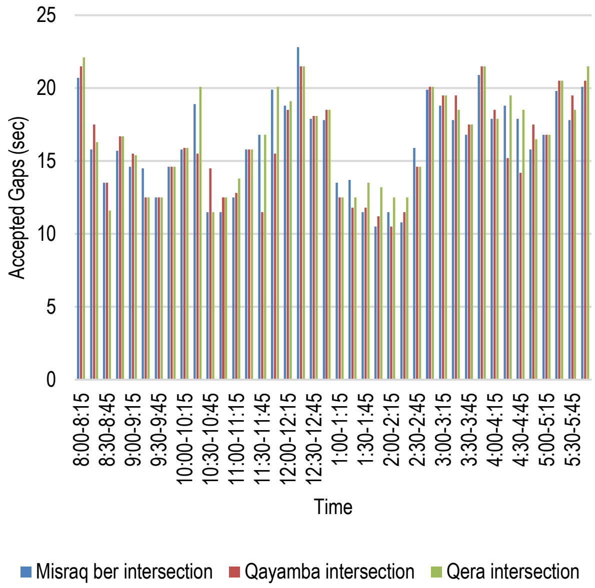

Figure 7. Gap Acceptance variation

Table 3. Gap Acceptance behavior at study locations

Parameters	Average values of Misraq ber	Average values of Qayamba	Average values of Qera
Waiting Time	38.4	37.85	38.35
Headway	3.7525	3.866	3.7105
Pedestrian volume	91	85	83
Pedestrian crossing speed	2.351	69.71	2.17
Traffic volume	43.54	99.55	129.2
Traffic speed	7.1	43.1035	42.05
Road geometry	16.65	6.15	6.75
Gap acceptance	16.65	16	16.8
Age	38.5	38.5	39.5

3. Analysis and Discussion

The majority of statistical data analysis is carried out by using SPSS tools. To determine the variables that influence the speed of pedestrian crossings, parametric procedures like t-tests and ANOVA tables are prepared.

4.1. Model development

The process of creating a model is iterative, before a model that confirms the requirements is created. Several models are developed and tested, and the best one is selected. In the context of this study, all pedestrian crossings have been modeled using the method of multiple linear regression analysis. The model was developed using SPSS tools. To calculate the pedestrian crossing speed (Walking) mathematical formulas are used.

$$Pcs = \frac{Distance\ (m)}{Avage\ time(Sec)}$$

where

$$Avage\ time = \frac{Time\ (\sec)}{N}$$

and

Pcs = Pedestrian crossing speed, N = Number of samples and Distance (m) is the width of the road at the point of crossing the respective intersection.

4.2. Multiple Regression Model

Multiple Regression models were developed from the collected data by considering dependent and independent variables. Two models were developed by considering Pedestrian crossing speed and Pedestrian Gap acceptance as dependent variables and traffic volume with composition, pedestrian volume, headway, existing road width at the point of crossing the intersection as independent variables.

Model 1:
Pedestrian crossing Speed =3.396+0.002TV-0.263PV+0.027HW+0.074RW
Where: TV = Traffic volume, PV = Pedestrian volume, HW = Headway, and RW = Road width.

As displayed in Table 3 the first two explanatory variables' P values for the constant estimator are less than the level of significance. With R2 adjusted = 0.953, all predictor factors strongly predicted the pedestrian crossing speed. This can be translated to mean that traffic volume, pedestrian volume, headway, and road width are accountable for around 95.3% of the variation in pedestrian crossing speed. The R2 value for the MLR model's fitness using the training data set is 0.958, while the adjusted R2 value of 0.953. Therefore, the values of correlated are strong relationships.

Model 2:
Pedestrian Gap acceptance = 6.5 - 0.014 TV + 6.71 HW + 3.28 Rw

Table 4. Anova Table for Pedestrian Crossing Speed

Coefficients[a]							
Parameters		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	3.396	.375		9.064	.000
	Traffic Volume	.002	.002	.035	.966	.341
	Pedestrian volume	-.263	.012	-.807	-21.576	.000
	Headway	.027	.055	.017	.482	.633
	Road width	.074	.003	.772	21.227	.000
	R^2	0.958				
	Adjusted R^2	0.953				
a. Dependent Variable: Pedestrian Crossing speed						

Table 5. Anova Table for Pedestrian Gap Acceptance

Coefficients[a]					
Parameters	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	0.650	2.045		.318	.752
Traffic Volume	.027	.012	.124	2.301	.027
Headway	-.371	.324	-.064	-1.145	.260
Road width	-.030	.220	-.026	-.137	.892
R^2	0.896				
Adjusted R^2	0.888				

As displayed in Table 5. The first two explanatory variables' P values for the constant estimator are greater than the level of significance. With R2 adjusted = 0.888, all predictor variables strongly predicted pedestrian gap acceptance. This shows that the Traffic volume, headway, and road width explain about 88.8% of the variation in pedestrian gap acceptance. The R2 value and Adjusted R2 values for the MLR model's fitness with the training data set are found as 0.888 and 0.896, respectively. Therefore, the independent variables are strongly correlated with dependent variables.

4.3. Model Validation

Model validation is a step that comes after model training and involves comparing the trained model with a test set of data. The two models developed are validated in the present study by plotting and comparing the predicted and observed values as indicated in the figure.

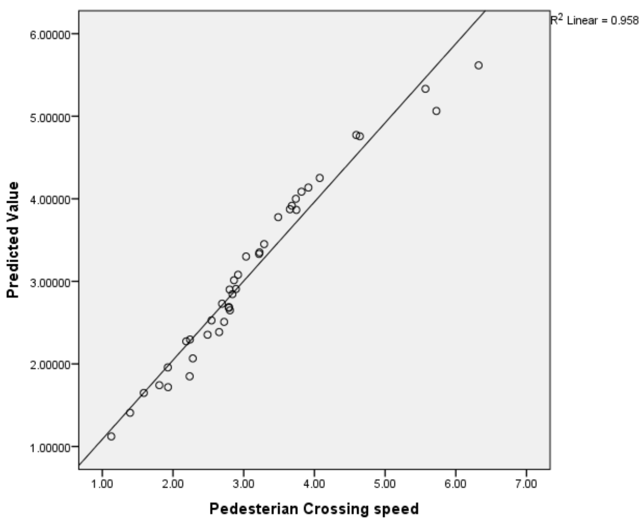

Figure 8. Observed vs predicted values of speed

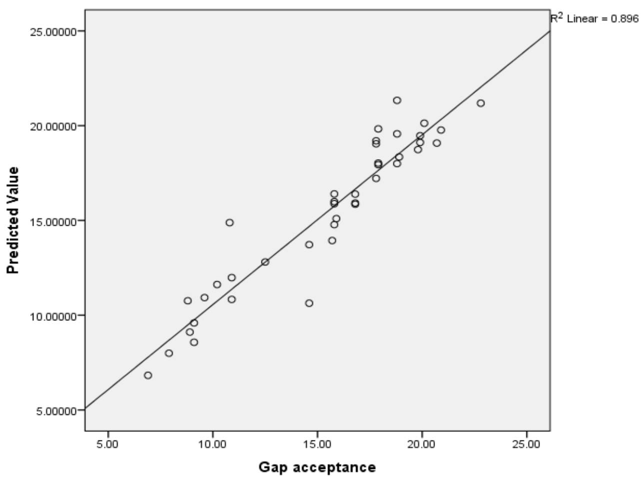

Figure 9. Observed and predicted gap values

The above figure 8 indicates that the observed and predicted values of the Speed are identical, which indicates that the above model 1 is validated. From the above figure of model validation as suggested by the Multiple Linear regression model, independent variables include Traffic speed, waiting time, Pedestrian gender, Headway, and Road width. The MLR which only takes factor variables with significant R-Squared values, was found to be 89.6%.

4.4. Gap Acceptance and Headway

In order to understand the relationship between the headway and gap acceptance, analysis is carried out using Pedestrian Gap Acceptance model. Figure 9 indicates the variation of Gap acceptance for different headways and for a given road width. The traffic volume is considered between 500 to 4000 pcu/hr, the headways are considered from 2 to 10 m, for a constant road width of 12m.

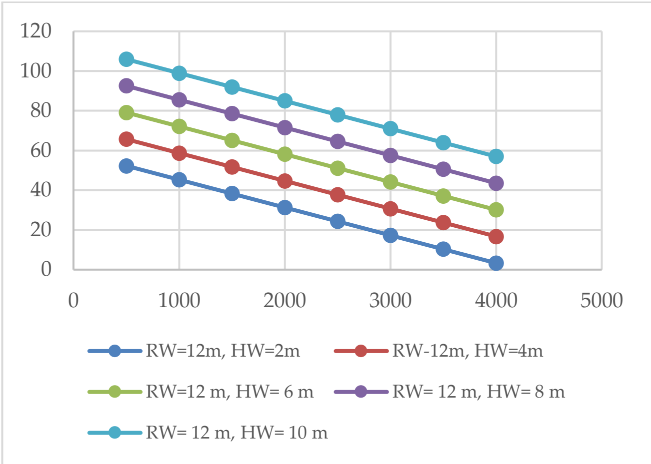

Figure 10. Traffic Volume vs Gap Acceptance

Figure 10 clearly shows that for a given road width and given headway, as the traffic volume is increasing, the gap acceptance decreases. Similarly, for a given road width and traffic volume, as the advances are increasing, the gap acceptance increases. This is because of that higher volumes on the road create less headway and hence that situation is subjected to more rejections. Similarly, lower traffic volumes create larger headways and hence that situation is more favor for accepting the gaps.

5. Conclusion

The most Vulnerable component of the transportation system is the pedestrian. Hence, Special consideration should be given to understand their unique requirements behavior. The study is to understand and analyze the behavior of the pedestrians while they are crossing the road at Unsignalized Intersections. The behavioral aspects pertaining to the pedestrian age, waiting time, volume are correlated with traffic movements and headway at the Intersection point. Multiple linear regression models are developed by considering the factors responsible for the occurrence of gaps to cross the road. The results indicated that the gap acceptance and Rejectance mainly depend upon the behavioral aspects of the pedestrians, their age, waiting limits and also depends upon the available headway and traffic composition on the road at the point of intersection.

It is concluded that higher the age of the pedestrian needs more gaps to cross the road. But in certain cases, even though the age is more, but the pedestrian takes less time to cross the road. This is due to the behavioral concepts of the pedestrians and their reaction time. Similarly, higher the headway on the road requires less gaps to cross the road. The crossing behavior of the pedestrians at the intersection is observed to be slightly different and delicate compared to the crossing phenomena at the mid-block. The minimum and maximum gap acceptance values range from 10 to 22 seconds in all the intersections, which indicates that the traffic volume at the selected road intersections are to be managed such that at least 10 seconds headway should occur at those locations for safe crossing of the pedestrians.

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