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# Study on Pedestrian Rolling Gap Crossing Behavior at Intersection Crosswalks: A Case Study of Gambella Town

**Balam Obang Opiew**

Department of Civil Engineering, Gambella University, Gambella, Ethiopia

**Email address:**

obangbalam@gmail.com

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**Abstract:** Due to rapid urbanization, a rise in vehicle growth, and a lack of adherence to traffic rules and regulations by drivers and pedestrians, traffic accidents involving pedestrians have become a significant safety problem in most developing countries, including Ethiopia. Urban areas account for the majority of pedestrian accidents. Traffic accidents involving pedestrians are more likely to occur when they are crossing the road. The majority of these accidents occur when pedestrians use rolling gap crossing behavior. The main objective of this study is to explore pedestrian rolling gap crossing behavior at intersection crosswalks in Gambella town. Data regarding pedestrian rolling gap crossing, pedestrian, geometric and environmental characteristics were collected through videography survey method, on-site observation, and measurement. An observational checklist was used to conduct on-site observations at each crosswalk at the selected intersection. Road width, lane width, and median width were also measured using meter tape. Using the collected data, a binary logistic regression model was developed. The developed model revealed that three statistically significant factors significantly affected pedestrian rolling gap crossing. These factors included gender, age, and crosswalk condition. Furthermore, secondary sources were reviewed, including ERA manual, AASHTO manual, and Gambella town master plan. The results of on-site observation, measurements, and the review of secondary sources were used to suggest remedial measures at existing intersection crosswalks.

**Keywords:** Pedestrian, Road Crossing Behavior, Rolling Gap Crossing Behavior, Binary Logistic Regression, Intersection Crosswalks, Remedial Measures

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## 1. Introduction

Everyone travels to work, play, or conduct business. All raw materials must be transported from the source to the point of manufacture or use, and all commodities must be transferred from the factory to the market, as well as from the employees to the customers. People employ a variety of modes of transportation to move around, including the road, air, water, and rail. The simplest, most accessible, and closest mode of transportation is the road. As a result, road transportation benefits both governments and individuals by making it easier to move products and people from one location to another [1]. In Africa, over 80% of products and people are transported by road, and in Ethiopia, road transport accounts for over 90% of freight and passenger movements in the country. However, the rapid development of road transportation has led to an increase in road traffic accidents, which have resulted in deaths, injuries, and

property damage [2].

A road traffic accident (RTA) is incident on a public street or road that results in one or more injuries or fatalities and involves at least one moving vehicle. As a result, a road traffic accident (RTA) is defined as a collision involving automobiles, vehicles and pedestrians, vehicles and animals, or vehicles and geographical or architectural objects [3]. According to the 2015 Global Status Report, over 1.2 million people die each year and 50 million are injured due to road traffic accidents. Even though low- and middle-income countries only account for 54% of the world's registered vehicles, more than 90% of road traffic fatalities occur in these countries. Of them, 70 percent of road traffic fatalities involve vulnerable road users such as pedestrians [4].

Traffic accidents involving pedestrians have become a major road safety problem in the entire world, particularly in developing countries, because of high population densities, rapid urbanization, and a lack of adherence to traffic

regulations by both drivers and pedestrians [5]. For instance, in China, 15,123 pedestrians died and 31,683 were injured in traffic accidents in 2015, accounting for 26.07% of traffic fatalities and 15.85% of traffic injuries, respectively [6]. Similarly, a study conducted in Mumbai, found that 57% of road fatalities from 2008 to 2012 were pedestrians [7]. In Africa, the road traffic death rate among pedestrians is relatively higher compared to other developing countries in the world. For instance, pedestrian fatality rates were 65% in Nairobi, Kenya, and 60% among urban regions in Ghana [8].

According to a report from the Federal Police Commission, the number of passengers and pedestrians dying in car accidents is occasionally rising significantly in Ethiopia.

From 2000 to 2009, there were a total of 25,110 accidents in Addis Ababa, with 3415 fatalities. The majority of fatalities were pedestrians (87%), followed by passengers (9%) and drivers (4%) [9]. In addition, a study conducted by Geleta et al. [10] reported that, among those killed in road traffic accidents, 71.3% were pedestrians, 23.1% were passengers, and 5.6% were drivers.

In Gambella town, most of the fatalities and injuries occur among pedestrians. As shown in Table 1, the highest percentage of road traffic accidents in the town involved motor vehicles with pedestrians, followed by motor vehicles with motor vehicles.

*Table 1. Types of collision in Gambella town (Source: Compiled by Researcher from the survey (2019 G. C)).*

Types of collision highly prevailing in the town	Frequency	Percentage (%)
Motor vehicle with motor vehicle	7	27
Motor vehicle with pedestrian	19	73
Motor vehicle with animal	0	0
Motor vehicle with static object	0	0
Total	26	100

The majority of accidents involving pedestrians are more likely to occur on urban roads. Of the 5588 pedestrian accidents that occurred in 2016, 84% of them took place on urban roads. This is due to higher population densities in urban areas, as well as more pedestrians crossing busier roads, resulting in a higher number of vehicle-pedestrian interactions [11].

A study conducted by Wang et al. [12], showed that the majority of pedestrian accidents occur when pedestrians are crossing the road at an intersection or midblock rather than walking or standing along the roadside. For instance, a study in Ghana found that 68% of pedestrian deaths occurred when pedestrians were attempting to cross the road [8]. In addition, a study conducted on traffic accidents among children in Addis Ababa, Ethiopia, revealed that, regarding the movement of the children during the accidents, 64.4% of the accidents occurred while the children were crossing the road [13].

In many urban centers across the world, collisions between motor vehicles and pedestrians have gotten worse over time. These collisions occur when pedestrians cross the road section, sometimes in a straight line, diagonally, or zigzag (rolling gap) and in both directions, at officially designated locations (controlled or uncontrolled crosswalks), or at any location convenient to the pedestrian. The ability of pedestrians to properly evaluate the situation of traffic flow and accept adequate gaps is a significant factor in determining their safety [14]. The term "rolling gap crossing" refers to pedestrians crossing the roadway discontinuously because a vehicle or vehicles are traveling on the same side as the pedestrians. As a result, they might stop or adjust their speed to avoid collisions with vehicles. Pedestrians who use the rolling gap crossing strategy may experience the highest risk of collisions with moving vehicles as compared to those who use the other two crossing strategies [15]. According to

the Ethiopian Federal Police Commission report, 19 pedestrian accidents occurred in Gambella Town. Of them, 12 were caused by illegal pedestrian crossing behavior [16].

Previous studies have examined pedestrian rolling gap crossings in terms of both pedestrian and environmental characteristics. Regarding pedestrian characteristics, Zhang et al. [17] developed three ordered probit (OP) models to examine the relationship between pedestrian crossing strategies and factors, including gender, age, waiting time, and traffic volume at an uncontrolled multi-lane mid-block crosswalk. They found that male pedestrians showed fewer rolling gap crossing than female pedestrians. Furthermore, Zafri et al. [18] investigated the factors that influenced pedestrians' decisions to cross the road at intersections by rolling gap crossing and discovered that young pedestrians showed more evidence of rolling gap crossing than older pedestrians. In the case of environmental characteristics, driver and pedestrian behavior as well as their understanding of the right-of-way laws for marked and unmarked crosswalks were examined by Mitman et al. [19]. They discovered that pedestrian behavior improves in well-marked crosswalks when compared to unmarked crosswalks.

According to the literature, several studies have been done to investigate the influence of pedestrian characteristics on pedestrian rolling gap crossing behavior. However, few have attempted to explore the effect of both pedestrian and environmental characteristics on pedestrian rolling gap crossing behavior (in particular, gender, age, and crosswalk condition). Furthermore, no study has addressed these factors in the context of a developing country's city like Ethiopia. Therefore, the purpose of this study is to explore pedestrian rolling gap crossing behavior at intersection crosswalks by considering the effects of both pedestrian and environmental characteristics.

## 2. Research Methodology

### 2.1. Study Area

The study was conducted in Gambella town, Gambella People's National Regional State. The region is located in the southwest of Ethiopia and is bordered to the east and north by the Oromia region, to the south by the Southern Nations, Nationalities, and People's Regional State, and to the west by South Sudan. The term Gambella refers to both the region and the city, which is located 526 meters above sea level and about 753 kilometers west of Addis Ababa. The town is found on the bank of the Baro River, Ethiopia's widest and the only navigable river. The town covers a total area of 15.5757 km<sup>2</sup>, and its geographical location is 8°15'N latitude, 34°35'E longitude with an estimated population of 66,100.

### 2.2. Description of the Selected Intersections

In Gambella town, there are 9 intersections. Roundabouts, T-intersections, and four-legged intersections are the most common in the town. Out of 9 intersections, 6 intersections were selected based on pedestrian crossing volume and vehicle volume. The selected intersections varied in terms of traffic characteristics and geometric characteristics. The crosswalks were either located on four-lane divided or two-lane undivided roads.

#### 2.2.1. Gilo Intersection

Gilo intersection is a three-legged roundabout located at the town's entrance. The area is surrounded by shops, hotels, offices, bars, and other public facilities. It has three approaches: GRRRA, Gogbajomi, and Matohaya. All three approaches are two-lane (one lane in each direction) two-way roads.

#### 2.2.2. Owalinga Intersection

Owalinga intersection is a four-legged intersection which is located around the office of Ethiopian Airlines. The area is surrounded by shops, churches, banks, hotels, and other public facilities. It has four approaches: Ajwomara, Omininga, Tierkidi, and Baro Akobo. All four approaches are two-lane (one in each direction) two-way roads.

#### 2.2.3. Gogbajomi Intersection

Gogbajomi intersection is a T-intersection near matohaya intersection. This is the town's third busiest intersection which is surrounded by shops, banks, hotels, bars, pharmacies, schools, churches, vendors, and other public facilities. It has three approaches: Comboni, Matohaya, and Gilo. Both Comboni approach and Matohaya approach are major roads with four lanes (two lanes in each direction) while Gilo approach is a minor road with one lane in each direction.

#### 2.2.4. Matohaya Intersection

Matohaya intersection is a four-legged intersection located near Gambella Stadium. This is the town's second busiest intersection. It is a traffic signal-controlled intersection but it was controlled by a traffic police officer due to the signals not working during the early visit of the researcher to the site. The

area is surrounded by shops, offices, bars, vendors, pharmacies, schools, and other public facilities. It has four approaches: Gogbajomi, Baro Bridge, Gambella Hospital, and Gilo. Both Gogbajomi and Baro Bridge approaches have four lanes (two in each direction), whereas Gambella Hospital and Gilo approaches have one lane in each direction.

#### 2.2.5. Ajwomara Intersection

Ajwomara intersection is a four-legged roundabout in the town's center. This is the town's busiest intersection among all the other types of intersections in the town. It is a traffic police-controlled intersection. The area is surrounded by shops, banks, offices, hotels, bars, and other public facilities. It has four approaches: Baro Bridge, Jabjabe Bridge, Wibur P/School, and Abattoir. Baro Bridge approach, Wibur P/School, and Abattoir approach are four lanes-divided two-way roads while Jabjabe Bridge approach is a four lanes-undivided two-way road.

#### 2.2.6. Baro Akobo Intersection

Baro Akobo intersection is a T-intersection near the regional state administrative office. It is a traffic signal-controlled intersection but the signals were not working during the early stage of the site visit. A lot of public offices, schools, hotels, and other public facilities are found in this area. It has three approaches: Wibur P/School, Owalinga, and Donbosco. Both Wibur P/School approach and Donbosco approach are major roads with four lanes (two lanes in each direction) while Owalinga approach is a minor road with one lane in each direction.

### 2.3. Research Design

For this study, both quantitative and qualitative research designs were used. According to Gasu [20], combining the two research approaches yields better explanations because information missed by one may be captured by the other, resulting in an enhanced and integrated result from the analysis. Closed-ended questions were used to collect quantitative data while on-site observation, measurements, and review of secondary sources were used to collect qualitative data.

### 2.4. Population of the Study

The target populations of this study were all pedestrians in Gambella town. In this study pedestrians who crossed the road at a crosswalk or near a crosswalk were considered as samples.

### 2.5. Sampling Technique & Sample Size

#### 2.5.1. Sampling Technique

A convenience sampling technique was employed to conduct this study. Convenience sampling is a sort of non-probability sampling in which people from the target population who meet particular criteria, such as easy accessibility, geographical proximity, availability at a specific time, or willingness to participate, are included in the study [21]. The convenience sampling technique can be

applied to both quantitative and qualitative research, however, it is most commonly used in quantitative research.

**2.5.2. Sample Size**

The sample size was calculated by using a single proportion formula considering the following assumptions:

- A 95% confidence interval
- 50% population's proportion
- 5% marginal error

$$n = \frac{Z^2 \times P \times (1-P)}{d^2} \tag{1}$$

Where

n= Required sample size for the study

z= Critical value in which 1.96 is selected based on a 95% confidence interval

p= The proportion of people the researcher is expected to have the basic knowledge about the problem (pedestrian rolling gap crossing, 50% in this case).

d= Margin of error (sometimes called confidence interval) is the range in which the true value of the population is estimated to be.

$$n = \frac{Z^2 \times P \times (1-P)}{d^2} \tag{2}$$

$$n = \frac{1.96^2 \times (0.5) \times (1-0.5)}{0.05^2} \tag{3}$$

n= 384.16

The total sample size became 385.

**2.6. Data Collection Method**

**2.6.1. Primary Data**

Primary data were collected through videography survey method, on-site observation, and measurement under fair weather conditions. To capture the busy roadway condition, a normal workday was selected for the survey. The survey was conducted between peak hours in the morning (from 8:00 a.m. to 10:00 a.m.) and the evening (from 4:00 p.m. to 6:00 p.m.). Videography survey method was done through a Lenovo tablet, which was placed at an appropriate elevation where the focused leg of the intersection was well-covered and the pedestrians were visible. Details about the collected data are shown in Table 2.

*Table 2. Details about the collected data.*

Variable	Type of variable	Definition and Label
Rolling gap crossing	Categorical	Rolling gap: Pedestrians discontinuously crossed the road by searching gaps between the continuous flow of vehicles by adjusting their speed and direction of movement, and consequently they rolled over the small vehicular gaps to cross the road. Other: Pedestrian who did not cross by rolling gap crossing.
Gender	Categorical	Gender of pedestrian: Male and Female
Age	Categorical	Estimated age of pedestrian from visual appearance: Child: 0–15, Young: 15–35, Adult: 35–60, and Old: above 60 years
Crosswalk condition	Categorical	Highly visible: Crosswalk was present in the focused leg and crosswalk marking was not fully or partially eroded.
		Poorly visible: Crosswalk was present in the focused leg and crosswalk marking was partially eroded.
		Not available: Crosswalk was not present in the focused leg or crosswalk marking was fully eroded.

On-site observation and measurement were also used to collect data on intersection geometric characteristics. An observational checklist was used to conduct on-site observations at each of the six intersection crosswalks. Based on a literature review and field conditions, the observational checklist was prepared according to selected variables (i.e., crosswalk marking visibility, curbside parking, curb ramps, curb cuts, zebra crossings, raised medians, and waiting (holding) areas). Details of the observational checklist are presented in Table 3.

*Table 3. Details about the observational checklist.*

Existing Intersection Crosswalks Condition		
Yes	No	
<input type="checkbox"/>	<input type="checkbox"/>	Is zebra crossings marking visible enough to be seen by both driver and pedestrian?
<input type="checkbox"/>	<input type="checkbox"/>	Is there a curb cut at each crosswalk location?
<input type="checkbox"/>	<input type="checkbox"/>	Is there a curb ramp at each crosswalk location?
<input type="checkbox"/>	<input type="checkbox"/>	Are there any parked vehicles that restrict sight distance at the intersection?
<input type="checkbox"/>	<input type="checkbox"/>	Is sufficient holding area provided at each crosswalk location?
<input type="checkbox"/>	<input type="checkbox"/>	Is raised median of enough width provided at each approach of intersection?
<input type="checkbox"/>	<input type="checkbox"/>	Is zebra crossings provided at crosswalk location?

Furthermore, road width, lane width, and median width

were measured on each approach at the selected intersection using meter tape. As on-site observation and measurement could not be done due to excessive traffic flow, data related to intersection geometric characteristics were collected early in the morning (6:00 a.m. to 7:00 a.m.) to avoid the busy roadway condition.

**2.6.2. Secondary Data**

Secondary data were collected from secondary sources such as design manual and master plan. Secondary sources used included ERA (Ethiopian Road Authority), AASHTO (American Association of State Highway and Transportation Officials), and Gambella Town Master Plan.

**2.7. Data Extraction**

When conducting a videography survey, data on crosswalk conditions were collected through on-site observation. The principal investigator manually extracted the rest of the necessary data from the video recording. Although the pedestrian's gender was easily extracted from the video recording, it was more challenging to extract the pedestrian's age. The pedestrians' approximate ages were estimated based on their visual and physical appearance and extracted from the video recording. Pedestrian rolling gap crossing related data were also extracted from the video recording. If multiple

pedestrians were crossing at once, only the first one arriving at the roadway was selected because groups of pedestrians can exhibit different behavioral patterns.

**2.8. Study Variables**

**2.8.1. Dependent Variable**

Pedestrian rolling gap crossing

**2.8.2. Independent Variables**

- 1) Gender
- 2) Age
- 3) Crosswalk condition

**2.9. Data Processing and Data Analysis**

The data were checked for completeness and accuracy after data collection; then, it was cleaned, coded, and entered into the computer for further analysis.

**2.9.1. Pearson’s Chi-square Test**

For categorical factors, Pearson’s chi-square test was conducted to check the statistical significance between the categorical factors and pedestrian rolling gap crossing. For the binary logistic regression model, factors having a p-value of less than 0.05 (p<0.05) were included in the model.

**2.9.2. Model Formulation**

Binary logistics regression was used to evaluate the effect of pedestrian and environmental characteristics on pedestrian

rolling gap crossing. According to the pedestrian rolling gap crossing, there were only two possible outcomes: using a rolling gap or not using a rolling gap while crossing the crosswalk. This rolling gap crossing was modeled using a binary logistic model (an individual choice model which has two alternative outputs for choice). The probability of choosing an alternative is based on a linear combination function (utility function), which is expressed as:

$$U_i = \alpha + \beta_1 X_1 + \beta_2 X_2 + \dots + \beta_n X_n \tag{4}$$

Where  $U_i$  = the utility of choosing the alternative  $i$   
 $i$  = the number of alternatives (two in the case of binary logistic regression model)

$n$  = the number of independent variables

$\alpha$  = constant

$\beta_1 \dots \beta_n$  = coefficients

To predict whether a particular alternative will be chosen or not, the utility of alternative  $i$  has to be transformed into a probability. The probability of choosing alternative  $i$  versus any other alternative is calculated by using the following function:

$$P(i = 1) = \frac{1}{1 + e^{-U_i}} \tag{5}$$

Binary logistics regression model assumptions: before running a binary logistics regression model, the data must be checked if it meets the required assumptions.

*Table 4. Binary logistic regression model assumptions.*

Assumptions	Description
Categorical dependent variable	The dependent variable must be a categorical variable measured on a dichotomous scale
Linear relationship	There should be a linear relationship between any continuous independent variable and the logit transformation of the dependent variable
Multicollinearity	The independent variables should not be highly correlated with each other
Outliers/influential cases	There should be no significant outliers

**2.9.3. Existing Intersection Crosswalks Problems and Remedial Measures**

For existing intersection crosswalks problems, on-site observation was conducted based on an observational checklist on each crosswalk of the existing intersection, and appropriate remedial measures were suggested. Furthermore, road width, lane width, number of lanes, and median width were measured on each approach of the selected intersection using meter tape and compared with ERA (Ethiopian Road Authority), AASHTO (American Association of State Highway and Transportation Officials), and Gambella Town Master Plan.

**2.10. Data Quality Assurance**

Data collectors and supervisors were trained for two days on data collection procedures and proper handling. The overall fieldwork was supervised by an expert having a first degree in civil engineering. At the end of each day, recorded data were checked for incompleteness and inconsistency of the data, and then corrective measures were immediately

taken in the field.

**3. Results and Discussion**

**3.1. Identification of Major Factors Affecting Pedestrian Rolling Gap Crossing Behavior**

Based on the outcome of an intensive review of related literature and onsite observations, several possible factors affecting pedestrian rolling gap crossing behavior were identified. The selected factors are listed in Table 5 below.

*Table 5. Selected variables and descriptions.*

Variable	Measure	Description
Gender	Categorical	0 Male
		1 Female
		0 Child
Age	Categorical	1 Young
		2 Adult
		3 Old
Crosswalk Condition	Categorical	0 Not Available
		1 Poorly Visible
		2 Highly Visible

Pearson’s chi-square test was performed to examine the significant association of categorical factors with pedestrian rolling gap crossing. A 95% confidence level was selected with a corresponding p-value of 0.05. Table 6 below shows that gender, age, and crosswalk condition were found to be statistically significant factors with a p-value less than 0.05 ( $p < 0.05$ ).

**Table 6.** Association of factors with pedestrian rolling gap crossing.

Categorical Predictors	Rolling Gap Crossing		Total	X <sup>2</sup> (df)	P Value
	Yes	No			
Male	78.0	22.0	63.6	142.7 (1)	0.000*
Female	15.0	85.0	36.4		
Child	45.1	54.9	18.4	19.8 (2)	0.000*
Young	46.7	53.3	43.4		
Adult	69.4	30.6	38.2	28.9 (2)	0.000*
Not Available	56.7	43.3	40.8		
Poorly Visible	73.5	26.5	26.5		
Highly Visible	38.1	61.9	32.7		

**3.2. Effect of Pedestrian and Environmental Characteristics on Pedestrian Rolling Gap Crossing**

To evaluate the effect of pedestrian and environmental characteristics on pedestrian rolling gap crossing, a binary logistics regression model was developed. For developing the model, major factors that were significant from the result of

**Table 7.** Multicollinearity statistics of the predictors.

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
	B	S. E	Beta			Tolerance	VIF
Constant	0.849	0.054		15.848	0.000		
Gender	-0.627	0.044	-0.606	-14.265	0.000	0.895	1.118
Age	-0.006	0.029	-0.008	-0.191	0.849	0.884	1.131
Crosswalk Condition (CC)	-0.070	0.024	-0.119	-2.953	0.003	0.986	1.014

*Assumption #3:* There should be no significant outliers in the data

Significant outliers can affect the regression equation that is used to predict the value of the dependent variable based on the independent variables. It can change the output that SPSS produces and reduce the predictive accuracy of the results as well as the statistical significance. When running binary logistic regression on SPSS, significant outliers can be checked using Cook’s Distance. A predictor variable with Cook’s Distance value greater than 1 is a significant outlier and can cause serious problems in statistical analyses. In this study, significant outliers were checked using Cook’s Distance and all the values of Cook’s Distance for all the predictor variables were less than 1. Therefore, significant

Pearson’s chi-square were considered for the model.

**3.2.1. Testing of Binary Logistic Regression Assumptions**

Before conducting the binary logistics regression, the four major assumptions were checked for validation. To get an appropriate result these assumptions have to be met.

*Assumption#1:* The response variable is binary

The dependent variable should be measured on a dichotomous or binary scale. The dependent variable is pedestrian rolling gap crossing which was coded as yes (1) and no (0).

*Assumption#2:* There is no multicollinearity among independent variables

When two or more predictor variables are highly correlated with each other, they do not provide unique or independent information in the regression model. One way to detect multicollinearity is by using tolerance and its reciprocal, called variance inflation factor (VIF). If VIF is less than ( $< 1$ ) or greater than ( $> 10$ ) and tolerance is less than ( $< 0.1$ ) then multicollinearity is likely to occur. From Table 7 below, the variance inflation factor (VIF) for all the independent variables is between 1-10, while tolerance for all the independent variables is greater than ( $> 0.1$ ), this implies that there is no multicollinearity.

outliers did not exist in the data.

*Assumption#4:* Linear relationship

There should be a linear relationship between the continuous independent variable and the logit transformation of the dependent variable. This assumption was not tested because there was no continuous independent variable in this study.

**3.2.2. Cox & Snell R Square and Nagelkerke R Square**

The percentage of the total variation of the dependent variable that is explained by the model is measured by the Cox & Snell R Square and the Nagelkerke R Square. Table 8 below shows that the explained variation in the dependent variable by the model ranges from 38.2% to 51.1% and correctly classified 75% of cases.

**Table 8.** Cox & snell r square and nagelkerke r square.

	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	344.473*	0.382	0.511

**3.2.3. Hosmer and Lemeshow Test**

The Hosmer and Lemeshow test is a statistical test for goodness of fit for the binary logistic regression model. It indicates a good fit if the significance value is greater than 0.05 ( $P > 0.05$ ). From Table 9 below, the Hosmer and Lemeshow test was not found to be significant ( $P > 0.05$ ), indicating that the developed model fitted the data well.

Table 9. Hosmer and lemeshow test.

Step	Chi-square	df	P value
1	11.564	8	0.172

### 3.2.4. Omnibus Test

The omnibus test examines whether the overall model is statistically significant. Table 10 shows that the overall model is statistically significant,  $X^2(5) = 262.046$ ,  $p < 0.05$ .

Table 10. Omnibus test.

	Chi-square	df	P value
Step	185.292	5	0.000*
Block	185.292	5	0.000*
Model	185.292	5	0.000*

### 3.2.5. Binary Logistic Regression Model Estimation

Table 11. Binary logistic regression model results.

	B	S. E	Wald	df	Sig.	Exp (B)
Constant	0.665	0.479	1.926	1	0.165	1.945
Gender (Ref: Male)						
Female (1)	-3.924	0.453	75.167	1	0.000*	0.020
Age (Ref: Child)						
Young (1)	1.483	0.584	6.446	1	0.011	4.407
Adult (2)	0.061	0.406	0.022	1	0.881	1.063
Crosswalk Condition (Ref: Not Available)						
Poorly Visible (1)	1.160	0.368	9.917	1	0.002	3.190
Highly Visible (2)	-0.174	0.394	0.194	1	0.660	0.841

Based on the results presented in Table 11, the binary logistic regression model equation can be written as:

$$U_1 = 0.665 - 3.924 \text{ Female} + 1.483 \text{ Young} + 0.061 \text{ Adult} + 1.160 \text{ Poorly visible} - 0.174 \text{ Highly visible} \quad (6)$$

In general, for the categorical independent variable, a positive coefficient (B) value means that maintaining the corresponding particular category increases the likelihood of showing a rolling gap crossing compared to the reference category. Besides, a negative coefficient (B) value means vice versa. The odd ratio (OR) statistic is also used to interpret the regression model easily (OR is the exponentiation of coefficients). If the OR value X for a specific category is greater than one for a categorical variable, it indicates that the likelihood of exhibiting rolling gap crossing is X times higher than the reference category. Besides, If the OR value X for a specific category is less than one for a categorical variable, it indicates that the likelihood of exhibiting rolling gap crossing is X times lower than the reference category.

Results show that the likelihood of showing rolling gap crossing was found to be 0.020 times lower for females compared to males. This factor was found to be significant. This finding is supported by Guo, Gao, Yang, and Jiang [22], who found that male pedestrians are more likely to terminate the waiting times and violate traffic rules than female pedestrians. In addition, according to Nicholas [23], only 39.8% of males and 53.2% of females used available crossing facilities. This demonstrates that women are nearly a third more likely than men to correctly use the infrastructure at crossings. Furthermore, Gen et al. [24] found that male pedestrians tend to violate traffic rules more frequently than

females and are more likely to cross in risky situations.

Results also indicate that the likelihood of showing rolling gap crossing was found to be 4.407 times higher for young pedestrians compared to child pedestrians holding the other predictors constant. This result is consistent with the finding concluded by Marisamynathan and Vedagiri [25] which states that the violation of traffic laws by adult pedestrians is higher than child pedestrians. Similarly, Diaz [26] reported that young pedestrians are more likely to commit violations than other groups of pedestrians.

Crosswalk condition was also found to be a significant factor. The likelihood of showing rolling gap crossing was found to be 3.190 times higher at a crosswalk with poor marking visibility compared to a crosswalk with no marking, holding the other predictors constant. This finding is consistent with the study conducted by Diependaele [27], which states that pedestrians are more likely to commit red light violations when zebra markings are in bad condition (the paint is worn off). In addition, a study by Vijayawargiya [28] showed that well-marked crosswalks attract pedestrians for crossing who otherwise would cross the street at random locations endangering their life.

### 3.3. Remedial Measures for Improving the Existing Conditions of Intersection Crosswalks

On-site observation, measurement, and manual review

were conducted on the crosswalks of the selected intersections. Remedial measures were suggested based on the results of on-site observation, measurements, and manual review. Problems that were found and remedial measures are presented below.

### 3.3.1. Gilo Intersection

Observed problems at Gilo Roundabout

- 1) An accessible curb ramp was not provided on both sides of the road
- 2) Curbside parked vehicles reduced the sight distance
- 3) Zebra crossing markings were not provided at each crossing location

Suggested remedial measures

- 1) Curb ramp should be provided at each crosswalk to assist handicapped, children, and elderly pedestrians to cross the road
- 2) Zebra crossing markings should be provided at each crosswalk point
- 3) Traffic regulations such as prohibiting curb-side parking at intersections and pedestrians crossings should be enforced

### 3.3.2. Owalinga Intersection

Observed problems at Owalinga Intersection

- 1) An accessible curb ramp was not provided on both sides of the road
- 2) No zebra crossing markings

Suggested remedial measures

- 1) Curb ramp should be provided at each crosswalk to assist handicapped, children, and elderly pedestrians to cross the road
- 2) Zebra crossing markings should be provided at each crossing location

### 3.3.3. Gogbajomi Intersection

Observed problems at Gogbajomi Intersection

- 1) Curb cut and curb ramp were not provided in the median and at the edge of the sidewalk at each crosswalk of the intersection
- 2) Most of the vehicles were parked on the curbside which reduced the sight distance
- 3) The insufficient waiting area due to vendors occupying the sidewalk
- 4) Zebra crossing markings were not provided at the crosswalk location

Suggested remedial measures

- 1) Curb cut and curb ramp should be provided in the median and at the edge of the sidewalk at each crosswalk of the intersection
- 2) Traffic regulations such as prohibiting curb-side parking at intersections and pedestrian crossings should be enforced
- 3) Restriction of activities such as vendors occupying space near the crosswalk at each intersection should be enforced
- 4) Zebra crossing markings should be provided at each crosswalk location

### 3.3.4. Matohaya Intersection

Observed problems at Matohaya Intersection

- 1) Invisible zebra crossing markings
- 2) An accessible curb ramp was provided only on one side of the road
- 3) Zebra crossing marking was not provided at Gambella Hospital approach and Gilo approach

Suggested remedial measures

- 1) Accessible curb ramps should be provided on both sides of the road for the safe crossing of pedestrians
- 2) Zebra crossing markings should be improved through routine maintenance and checks
- 3) Zebra crossing markings should be provided at Gambella Hospital approach and Gilo approach

### 3.3.5. Ajwomara Intersection

Observed problems at Ajwomara Roundabout

- 1) An accessible curb ramp was provided only on one side of the road
- 2) Invisible zebra crossing markings
- 3) There was no raised median at Jabjabe Bridge
- 4) The Jabjabe Bridge approach had no zebra crossing markings.

Suggested remedial measures

- 1) Curb ramps should be provided on both sides of the road for the safe crossing of pedestrians
- 2) Zebra crossing markings should be improved through routine maintenance and checks
- 3) The raised median should be provided at Jabjabe Bridge approach
- 4) At the approach to the Jabjabe Bridge, zebra crossing markings should be installed.

### 3.3.6. Baro Akobo Intersection

Observed problems at Baro Akobo Intersection

- 1) An accessible curb ramp was not provided on both sides of the road
- 2) Invisible zebra crossing markings
- 3) Zebra crossing marking was not provided at Owalinga approach

Suggested remedial measures

- 1) Accessible curb ramps should be provided on both sides of the road for the safe crossing of pedestrians
- 2) Zebra crossing markings should be improved through routine maintenance and checks
- 3) Zebra crossing marking should be provided at Owalinga approach

### 3.3.7. Comparison of Existing Intersection Geometric Characteristics with the Standards

Some of the problems of existing intersections observed during on-site observation were the improper designs of the roadway. The existing values of cross-section elements of each intersection were measured and compared with ERA geometric design manual, AASHTO manual, and Gambella town master plan. As shown in Table 12 below the measured road width and lane width at each intersection are too wider compared to the ERA manual, AASHTO manual, and

Gambella town master plan. In addition, the measured median width is less than the ERA manual, AASHTO manual, and Gambella town master plan. Therefore, the road

should be designed and constructed following national and international standards.

**Table 12.** Comparison of existing intersection geometric characteristics with ERA manual, AASHTO, and Gambella town master plan.

No.	Roadway Element	ERA Values 2013	AASHTO Values (2001)	Master Plan Values	Measured Values
1	Road Width	6 m-7.3 m 6.6 m (urban)	6 m-7.3 m 6.6 m (urban)	6 m-8 m	6.34 m-8.34 m
2	Lane Width	3 m-3.65 m 3.3 m (urban)	3 m-3.65 m 3.3 m (urban)	3 m-4 m	3.17 m-4.17 m
3	Median Width	1.5 m-9.2 m 5 m (urban)	1.2 m-24 m 3 m-6.6 m (urban)	3 m	1.70 m-1.78 m

## 4. Conclusion

The main objective of this study is to explore pedestrian rolling gap crossing behavior at intersection crosswalks. To fulfill the aim, three factors related to pedestrian characteristics and environmental characteristics were considered. A binary logistic regression model was developed using these three factors to estimate the likelihood of showing a rolling gap crossing by the pedestrian. All three factors were found to be statistically significant in the developed model: gender, age, and crosswalk condition.

Results of the study showed that the likelihood of showing rolling gap crossing was found to be 0.020 times lower for female pedestrians compared to male pedestrians. The results also indicated that the likelihood of showing rolling gap crossing was found to be 4.407 times higher for young pedestrians compared to child pedestrians holding the other predictors constant. This study also showed that the likelihood of showing rolling gap crossing was found to be 3.190 times higher at a crosswalk with poor marking visibility compared to a crosswalk with no marking, holding the other predictors constant. On-site observations, measurements, and reviews of secondary sources were conducted on each crosswalk of the selected intersection. The study finally suggested some remedial measures for intersection crosswalks based on the results of on-site observation, measurements, and review of secondary sources.

These findings will be helpful in the planning and design of intersection facilities and will improve existing intersection control measures. Several significant factors, including pedestrian education and safety awareness, crosswalk width, and vehicle speed which are related to pedestrian rolling gap crossing behavior were not considered in this study. To provide a greater understanding of pedestrian rolling gap crossing behavior, future studies should consider these factors.

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