MAKERERE UNIVERSITY

INVESTIGATING THE RELATIONSHIP BETWEEN TRAFFIC LOADING ON EDGE BREAK FOR FLEXIBLE ROADS IN KIREKA

BY

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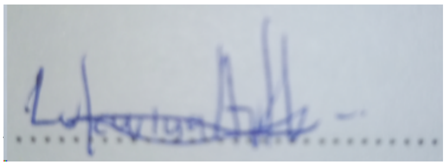
A RESEARCH DISSERTATION SUBMITTED TO THE DIRECTORATE OF RESEARCH AND GRADUATE TRAINING FOR THE FINAL YEAR PROJECT OF MAKERERE UNIVERSITY

JUNE 2023

DECLARATION

I, LUKWIYA ARTHUR, duty declare with affirmative's, this report to have been compiled by me and all the content is first hand.



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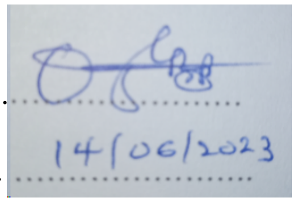

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ACKNOWLEDGEMENT

I would like to express my heartfelt gratitude to several individuals who have played significant roles in the successful completion of my research. First and foremost, I extend my deepest appreciation to my supervisor, Mr. Odongkara Billy Brian, for his invaluable guidance, expertise, and unwavering support throughout this journey. His insightful feedback, constructive criticism, and constant encouragement have been instrumental in shaping the direction and quality of my work. I am immensely grateful to my parents for their unwavering belief in my abilities and their unwavering financial support, which has allowed me to pursue this research endeavor. Their sacrifices and encouragement have been the cornerstone of my academic journey. Lastly, I would like to acknowledge the role of a higher power, God, whose divine guidance and unwavering support have provided me with strength, inspiration, and resilience. His blessings and grace have been the driving force behind my achievements. The combined impact of my supervisor, parents, and God on my research cannot be overstated; their unwavering support, guidance, and belief in me have been truly invaluable and have shaped my research in remarkable ways.

ABSTRACT

This research addresses the problem of road edge break, which poses a significant challenge for road authorities in maintaining the safety and longevity of road infrastructure. The deterioration of pavement edges can result in increased risks to drivers and costly repair work. To tackle this problem, the study focuses on analyzing the vulnerability to edge break on Ndagire road and Kamuli road, with the objective of identifying the key factors contributing to this phenomenon and providing effective recommendations for mitigation. The research adopts a systematic approach, employing data collection and analysis methods to examine the relationship between traffic volume, shoulder to pavement difference, and edge break. The Average Annual Daily Traffic (AADT) represents traffic volume, while the Elevation difference from pavement to shoulder (ESTEP) quantifies the shoulder to pavement difference. Through statistical analyses, including coefficient calculations, the vulnerability of Ndagire road and Kamuli road to edge break is assessed.

Key findings reveal that Ndagire road exhibits higher vulnerability to edge break in terms of the shoulder to pavement difference, as evidenced by a higher coefficient (10.82) compared to Kamuli Road (6.21). Conversely, Kamuli Road is more susceptible to edge break due to increased traffic volume, with a higher coefficient (0.012) compared to Ndagire road (0.009). Furthermore, a significant difference in traffic volume of approximately 10% is observed between the left and right sides of both roads, resulting in more edge break on the left side. Based on these findings, the study provides explicit recommendations for mitigating edge break. For Ndagire road, interventions should focus on addressing the shoulder to pavement difference through regular monitoring, proper shoulder support, erosion control, and effective drainage systems. For Kamuli road, strategies should prioritize traffic management measures, such as traffic calming, infrastructure improvements, and alternative transportation options to alleviate congestion and manage increased traffic volume.

Furthermore, strengthening the pavement and implementing regular maintenance, particularly on the left side, is crucial. Proactive measures, including routine resurfacing, sealants, and protective coatings, are also recommended to minimize the impact of time and enhance the durability of pavement edges. By implementing these recommendations, road authorities can effectively mitigate edge break, ensuring the long-term safety and sustainability of the road infrastructure.

TABLE CONTENTS

1. INTRODUCTION

1.1 BACKGROUND

At the global level, sustainable and resilient infrastructure development is a key focus, as emphasized in the Sustainable Development Goals (United Nations, 2015). In the context of the Works and Transport Sector, sector indicators were adopted in 2011 (Works and Transport Sector, 2011). One of these indicators, known as golden indicator 5, measures the expenditure on national road maintenance relative to the overall budget. This indicator offers insights into the current state of the National Road Network. Specifically, for the Financial Year (FY) 2020/21, the Uganda National Revenue Authority (UNRA) was allocated a total budget of UGX 3,918.20 billion, with a meagre portion of UGX 310 billion allocated to the road maintenance program (Integrated transport infrastructure and services program performance report, 2021). This significant imbalance in budget allocation, with road development receiving a larger share while road maintenance is neglected, has resulted in unsustainable development and an increasing backlog of maintenance needs. Consequently, road networks, including issues such as pavement edge drop-offs, bad curves, potholes, and edge failures, are in a deteriorating state, posing risks to road users.

Shifting the focus to the specific case of Kireka in Wakiso District, the road network in this area exhibits diverse road conditions and notable features. Rapid urbanization and growing traffic volume contribute to high levels of congestion, particularly during peak hours, which leads to slower traffic flow and increased stress on the road infrastructure. Additionally, Kireka is characterized by narrow lanes, presenting challenges for smooth traffic movement and potentially contributing to edge break issues. Furthermore, the presence of high-volume intersections, such as the junction of Kampala Jinja Highway and Kamuli road, as well as the junction of Kampala Jinja Highway and Namugongo road, adds complexity to traffic patterns and further escalates the risk of edge break occurrences.

The insufficient budgetary allocation to road maintenance has far-reaching consequences, including delayed or inadequate repairs, which result in deteriorating road surfaces, weakened pavement structures, and increased vulnerability to distresses such as edge breaks. Considering these consequences, it becomes evident that proactive measures to mitigate and prevent edge breaks are essential for ensuring the safety of road users, minimizing maintenance expenses, and maintaining an efficient transportation system.

1.2 PROBLEM STATEMENT

The Uganda Road Fund (URF) has been tasked with allocating funds for maintaining roads throughout Uganda. In the financial year 2020/21, UGX 310 billion was allocated to Kampala Capital City Authority (KCCA) for the maintenance of its existing bituminous and gravel road network. However, KCCA's bituminous roads are plagued with various defects, with cracking, potholes, and edge break being the most prevalent. Many of Uganda's roads have limited right-of-way, and the cost of compensating project-affected persons is often prohibitive. As a result, many bituminous roads in Kampala are narrow, with lane widths ranging from 2.8 to 3 meters. The narrow roads coupled with increasing traffic volumes have resulted in edge break becoming a significant problem on many roads in Kampala.

The damage caused by edge break can result in high maintenance costs for KCCA, as repairs are required more frequently than on roads without edge break because according to a report by the Uganda National Roads Authority), the cost of rehabilitating a paved road shoulder ranges from approximately UGX 20 million per kilometre to UGX 35 million per kilometre, depending on the extent of damage and the type of repair required. This problem is particularly acute on narrow roads with unpaved shoulders, where vehicles frequently travel on and off the pavement edge. Edge break can lead to serious damage to the road, including pavement distress, rutting, and even complete failure. Additionally, edge break can cause safety hazards for road users, as it may create a rough surface that can cause vehicle damage or result in accidents. Therefore, it is crucial to address the issue of edge break on Kampala's roads to improve road safety and reduce maintenance costs.

1.3 OBJECTIVES

1.3.1 Main Objective

The main objective of the study is to investigate the effect of traffic volumes on road edge break along Kampala roads in order to come up appropriate cost-effective strategies.

1.3.2 Specific Objectives

The specific objectives of the study are to;

i. Identify bituminous roads with different road geometric parameters in Kampala.
ii. Measure the different geometric parameters along the bituminous roads.
iii. Estimate the average vehicle speeds to traverse these roads.
iv. Establish the relationship between Annual Average Daily Traffic and Edge Break.

1.4 JUSTIFICATION OF THE STUDY

The aim of the research is to obtain an improved understanding between traffic and edge break loss in order to develop cost-effective methods to reduce or prevent pavement edge failure especially where pavement widening is not an option. Edge break loss due to narrow roads heavily affects the population since it increases accidents and increases maintenace as well as road user costs. Better understanding of the relationship between traffic and edge break loss is necessary to have more safer and better roads.

1.5. SCOPE

1.5.1 Academic Scope

The academic scope was limited to investigating the effect of traffic volume on road edge break in Kampala.

1.5.2 Geographic Scope

The graphical scope of this research was limited to greater Kampala metropolitan area which includes major suburbs surrounding the central business district.

2. LITERATURE REVIEW

2.1 Introduction

According to Smith and Johnson (2018), the deterioration of paved roads is attributed to two primary factors that are traffic volumes and environmental conditions such as climate. The authors emphasize that the paved road network plays a crucial role in accommodating the majority of national freight traffic. As traffic volumes increase over time, the constant flow of heavy vehicles exerts significant stress on the pavement, leading to wear and tear. Additionally, environmental factors, particularly climate, contribute to the degradation of roads. Extreme weather conditions, including temperature variations, precipitation, and freeze-thaw cycles, can accelerate the deterioration process by causing pavement cracking, erosion, and structural damage. The combination of heavy traffic and adverse environmental conditions poses a substantial challenge for road infrastructure maintenance and calls for effective strategies to mitigate the effects of these factors.

2.2 Traffic Surveys

Traffic surveys play a crucial role in the design and management of traffic facilities and infrastructure. Road planners, engineers, and traffic designers rely on accurate and comprehensive information to make informed decisions. Geometric standards and economic analysis are essential components in this process (Smith & Johnson, 2018). Traffic surveys are conducted to determine priorities and justify the need for traffic control devices such as signs, signals, and pavement markings. The collected data is also utilized to assess the effectiveness of implemented schemes, diagnose specific situations, forecast the impacts of proposed strategies, and validate traffic models (Jones et al., 2019).

Traffic surveys serve multiple purposes in traffic engineering. They enable traffic monitoring, control, and management, ensuring efficient and safe traffic flow. The data collected helps in traffic enforcement, aiding in the identification and resolution of traffic violations. Additionally, traffic surveys support traffic forecasting, which is essential for long-term planning and infrastructure development. They also contribute to the calibration and validation of traffic models, ensuring their accuracy and reliability (Smith et al., 2020).

In pavement design, the impact of traffic loading is a well-established factor. Heavy vehicles, with their wheel load, tire pressure, frequency, and duration, significantly influence pavement performance. Environmental factors also play a role, but the axle load of heavy vehicles is considered the most critical parameter (Johnson & Brown, 2017). Light vehicles, such as cars and delivery vans, have a minimal impact on the structural damage of pavements compared to their heavier counterparts (Jones et al., 2019). Proper consideration of traffic loading characteristics is vital in designing durable and resilient pavements that can withstand the stresses imposed by heavy vehicles over time.

2.3 Traffic Volumes

Traffic volumes are needed for highway project development, financing considerations, project cost-benefit comparisons, analysing, monitoring and controlling traffic movement on roads, traffic accident surveillance, research purposes, highway maintenance, public information, highway legislation and for many other purposes.

Traffic volumes vary from location to location. traffic volumes also vary from hour to hour, day to day, month to month and year to year. it is generally believed that traffic volumes on urban roads progressively increase with each passing year due to the increasing population. both location and time elements must be properly identified and elated to one another in order to develop accurate traffic volume data.

2.4 Definitions

A number of important terms and concepts are briefly defined and explained below (Haque, Halder, et al 2009).

2.4.1 Volume and rate of Flow

The volume and rate of flow are important factors in traffic engineering, providing insights into the number of vehicles passing through a specific point or section of a road during a given time interval. Volume refers to the total number of vehicles observed or predicted to pass a particular point or section within a specified time period (Jones & Smith, 2018). It provides an accurate count of the vehicles present on the road. On the other hand, the rate of flow represents the equivalent hourly rate at which vehicles pass through a specific point or section within a time interval shorter than an hour, typically 15 minutes (Johnson et al., 2019).

Accurate measurement and prediction of volume and rate of flow are essential for various traffic engineering purposes. They provide valuable information for traffic planning, infrastructure design, and capacity analysis. Understanding the volume of traffic helps in determining the appropriate road capacity, identifying areas of congestion, and planning for future transportation needs (Smith et al., 2021). The rate of flow is particularly useful in analysing the efficiency and performance of road segments, intersections, and traffic control systems.

Traffic engineers rely on volume and rate of flow data to assess traffic demand, estimate travel times, and optimize traffic signal timings. These parameters are also critical for traffic impact studies, evaluating the effects of proposed developments or changes to the road network. Additionally, volume and rate of flow data are crucial for traffic simulation and modelling, enabling engineers to accurately replicate real-world traffic conditions and evaluate the impacts of various scenarios (Jones & Brown, 2020).

2.4.3 Traffic Counts

Screen line counts are a common method used in traffic engineering to assess traffic volume and flow patterns within a study area. This approach involves dividing the study area into larger sections by placing imaginary lines, known as screen lines, across the region (Smith & Johnson, 2017). These screen lines can be strategically positioned, utilizing natural or manmade barriers such as rivers or railway tracks to create distinct boundaries. At each point where a road intersects a screen line, traffic counts are conducted to determine the number of vehicles passing through.

The purpose of using screen lines is to capture data at specific locations where road networks intersect the lines. By ensuring that each street only crosses a screen line once, the data collected provides a comprehensive understanding of traffic movement and flow direction within the study area (Brown & Jones, 2019). This method allows for the detection of variations in traffic volume and flow patterns resulting from changes in the land-use pattern of the area over time.

Regular data collection at screen-line stations is crucial for monitoring and analysing traffic trends and patterns. It enables transportation planners and engineers to identify shifts in traffic volume, changes in flow direction, and fluctuations in travel patterns within the study area (Davis et al., 2020). By observing these variations, transportation professionals can make informed decisions regarding road design, traffic management strategies, and land-use planning to accommodate the evolving needs of the area and ensure efficient and safe transportation systems.

2.5 Edge Break

2.5.1 Definition

Edge break is the deterioration or wearing away of the pavement surface and adjacent materials along the edge of a road, typically resulting from traffic and environmental factors (Birgisson, Taylor, Galehouse ,2013). They note that this phenomenon is often observed on narrow roads with unsealed shoulders and can negatively impact road safety and performance. The edge break area is typically quantified as the total area of lost bituminous surface material and possibly base materials, expressed in square meters per kilometer. Ideally, three parameters should be considered to accurately define edge break.

2.5.2 Description

Edge break refers to the deterioration that occurs at the edges of pavements, particularly where the pavement meets the shoulder or curb. This phenomenon is extensively discussed in various deterioration manuals and guidelines for pavement management. According to the Manual on Uniform Traffic Control Devices, edge break is considered a type of pavement distress that can compromise the structural integrity and safety of the roadway (Federal Highway Administration, 2009). It is commonly caused by factors such as traffic loading, environmental conditions, and improper pavement design or construction practices.

Deterioration manuals provide insights into the causes, mechanisms, and implications of edge break. The Pavement Maintenance and Rehabilitation Manual by the Federal Highway Administration, highlights that the primary cause of edge break is the repeated wheel loads exerted by vehicles, especially heavy trucks, near the pavement edges (Federal Highway Administration, 2014). As these loads concentrate stress on the edge, the pavement materials gradually weaken and eventually break away, leading to edge deterioration.

In addition to traffic loading, environmental factors can also contribute to the development of edge break. The Maintenance Technical Advisory Guide published by the Federal Highway Administration, recognizes that water infiltration and the subsequent freeze-thaw cycles can accelerate the deterioration of pavement edges (Federal Highway Administration, 2012). This moisture-induced distress is particularly prevalent in regions with cold climates, where the expansion and contraction of water within the pavement materials weaken the edge structure over time.

2.5.3 Measurement of edge break

Recorded length in meters of pavement edge affected at each severity level. The combined quantity of edge cracking cannot exceed the length of the section. Where edge cracking and fatigue or block cracking exist and overlap in the same area, both should be rated.

This study deals with the measurement of distress extent and distress severity to define the condition of road network

2.5.4.1 Severity Level

Table 2.1 Severity Level (Pavement Surface Condition Rating Manual,2020)

Severity level	Description
Low	It is a shallow surface cracks do not cause breaks and loss of materials on the pavement.
Moderate	Moderate cracks are classified when they contain break and loss of materials in the length of up to 10% of the length of the paving of the area affected.
High	It is a deep and many cracks and contains break and loss of materials in the length of more than 10% of the length of the paving of the area affected

The severity levels of cracks in pavement can be classified into three categories. Low severity refers to shallow surface cracks that do not cause any breaks or significant loss of materials. Moderate severity involves cracks that exhibit a break in the pavement and a loss of materials, with the extent of breakage and material loss being up to 10% of the length of the affected paving area. High severity denotes deep and numerous cracks that result in significant breakage and loss of materials, where the length of breakage and material loss exceeds 10% of the length of the affected paving area.

2.5.4.2 Extent Level

The extent of pavement edge conditions is recorded as a percentage of the length of the surveyed segment. Recommended ranges for estimated extent.

Table 2.2 Extent Level of Edge break (Pavement Surface Condition Rating Manual,2020**)**

Extent level	Percentage of the length of the surveyed segment length affected
None	0%
Few	< 10%
Intermittent	10 - 20%
Frequent	20 - 50%
Extensive	50 - 80%
Throughout	80 - 100

The extent level of pavement edge conditions is measured as a percentage of the length of the surveyed segment. According to the Pavement Surface Condition Rating Manual (2020), the recommended ranges for estimated extent are as follows: None, indicating no length of the surveyed segment affected; Few, indicating less than 10% of the length affected; Intermittent, indicating 10-20% of the length affected; Frequent, indicating 20-50% of the length affected; Extensive, indicating 50-80% of the length affected; and throughout, indicating 80-100% of the length affected.

2.6 Possible Causes and Remedies

Table 2.3 Possible Causes and Remedies of Edge Break

No.	Possible Causes	Probable Treatment
1	Inadequate pavement width	Widen the pavement
2	Alignment which encourages drivers to travel on the pavement edge.	Pavement widening and realignment
3	Inadequate edge support	Shoulder strengthening
4	Seepage and heavy rainfall	Proper and efficient drainage

One of the possible causes of edge break is when the pavement width is not sufficient to accommodate the traffic load. This can lead to vehicles frequently driving on the pavement edge, causing stress and damage. To address this issue, widening the pavement is recommended. By increasing the width, there will be more space for vehicles to travel, reducing the strain on the pavement edge and minimizing the risk of edge break.

The alignment of the road plays a crucial role in influencing driver behaviour. If the road alignment encourages drivers to use the pavement edge, it can contribute to edge break over time. To mitigate this problem, a combination of pavement widening and realignment may be necessary. Widening the pavement provides a larger driving area, while realignment helps to redirect drivers away from the edge and onto the main portion of the road, reducing the stress on the pavement edge and preventing edge break.

2.7 Mechanism of Edge Break

The fatigue and damage mechanisms of a road can be classified into five main categories based on their origin (AASHTO, 2021).

2.7.1 Water infiltration and Saturation

Water infiltration occurs when precipitation or other water sources penetrate the soil adjacent to the road edge. This water can saturate the underlying soil layers, particularly if there is poor drainage or the soil has a low permeability

2.7.2 Soil Erosion and Weakening

As water infiltrates the soil, it can cause erosion and weaken the stability of the road edge. The erosive action of water can wash away fine particles, leading to the loss of soil cohesion and strength. This erosion is often more pronounced in areas where the road is exposed to concentrated flow or where the soil composition is susceptible to erosion,

2.7.3 Edge Subsidence and Settlement

As the soil at the road edge weakens and erodes, subsidence and settlement can occur. The loss of support beneath the pavement can cause the road edge to sink or settle, creating a depression or break in the edge. This subsidence is typically more evident in areas with inadequate compaction during construction or where the underlying soil is prone to settlement.

2.7.4 Traffic-induced Stresses and Load Transfer

The presence of a depressed or broken road edge can result in improper load transfer from the pavement to the weakened edge. As vehicles traverse the road, the edge may experience additional stress and loading beyond its design capacity. These traffic-induced stresses can further exacerbate the breakage and deterioration of the road edge.

2.7.5 Edge Failure and Disintegration

Over time, the combination of water infiltration, soil erosion, subsidence, and traffic-induced stresses can lead to edge failure and disintegration. The weakened road edge may progressively deteriorate, resulting in the loss of structural integrity, formation of potholes, or complete collapse of the edge. This edge failure can pose safety hazards for road users and require subsequent repairs or rehabilitation.

2.8 Mechanisms that cause Edge Break

Edge break is a common phenomenon that occurs when material at the edge of the road carriageway is lost or eroded. According to World Bank,

2.8.1 Traffic related factors

there are two main mechanisms due to traffics that cause edge break that is shear failure and attrition.

2.8.1.1 Shear Failure

Shear failure occurs in the upper layers of the pavement due to vertical wheel loads near the edge of the road without lateral support from the shoulder. This mechanism is influenced by several parameters, including the drop height from pavement to shoulder, the strength of the pavement material, and the number of wheel loads passing over the pavement edge.

2.8.1.2 Attrition

On the other hand, attrition occurs when wheels travel on and off the pavement edge, which often happens when vehicles pass on narrow roads or when they park on the shoulder. The extent of material loss due to attrition is influenced by several factors, including the number of wheel passes, edge step, and vehicle speed. Therefore, the management of the shoulders is critical in mitigating the impact of edge break on the pavement.

2.8.2 Rainfall

In addition to traffic-related factors, rainfall is also a significant contributor to edge break, particularly when the water is not properly drained off fast. Surface runoff can rapidly increase the rate of edge break, making it more challenging to maintain road safety and performance. A general rule of thumb is to make the shoulders properly flush with the pavement surface and slope slightly away from the pavement to quickly drain off the water. Proper shoulder management can reduce the occurrence of edge break and improve road performance.

To ensure accurate characterization of edge break, it is essential to consider the impact of various parameters such as the speed of the vehicles, edge step (drop height from pavement to shoulder of the shoulder) and amount of traffic are all critical factors that need to be taken into account when defining edge break. Failure to account for these factors may result in inaccurate or incomplete assessments of edge break.

3.METHODOLOGY

3.1 Introduction

The objective of this research is to investigate the relationship between geometric parameters, vehicle speeds, Annual Average Daily Traffic (AADT), and edge break on bituminous roads in Kampala. To achieve this, a field study will be conducted to identify bituminous roads with different geometric parameters in the study area. The selected roads will then be measured for various geometric parameters, such as lane width, pavement thickness, and shoulder width, among others.

To estimate the average vehicle speeds on the selected roads, a traffic survey will be conducted using appropriate equipment. This will involve capturing data on the number and type of vehicles using the road, as well as their speeds. The data collected will be analysed to determine the average vehicle speeds for each of the selected roads.

To establish the relationship between AADT and edge break, the study will involve collecting data on the AADT of the selected roads The data collected will be analysed to determine the correlation between AADT and edge break. The study will also investigate the factors that contribute to edge break, including rainfall, shoulder management, and other environmental factors. To achieve this, the study will involve conducting a literature review to identify relevant studies and best practices for mitigating edge break.

Overall, this study will contribute to a better understanding of the relationship between road geometry, traffic flow, and edge break. The findings of the study will be useful in developing effective strategies for preventing or mitigating edge break, improving road safety, and reducing maintenance costs. The methodology for this study will involve a combination of field surveys, traffic data collection, and statistical analysis. The data collected will be analysed using appropriate statistical methods to identify patterns and relationships between the various parameters studied. The study will use both descriptive and inferential statistics to summarize and draw conclusions from the data.

In summary, this study aims to investigate the relationship between road geometry, traffic flow, and edge break on bituminous roads in Kampala. The study will involve a field survey to identify roads with different geometric parameters, a traffic survey to estimate vehicle speeds, and data collection on AADT and edge break. The findings of the study will be useful in improving road safety and reducing maintenance costs.

3.2 Research Design

The objective of this research is to investigate the relationship between road geometric parameters, vehicle speed, Annual Average Daily Traffic (AADT), and Edge Break on bituminous roads in Kampala. In order to achieve these objectives, a cross-sectional study design will be utilized. This research design will enable the measurement of different road geometric parameters and the estimation of vehicle speeds on selected bituminous roads. Additionally, AADT data will be collected and analyzed alongside Edge Break measurements to establish the relationship between the two variables.

A purposive sampling technique will be employed to select bituminous roads in Kampala. This technique will ensure that the study roads represent a range of geometric parameters such as road width, shoulder width, and lane width. The sample size will be determined based on the availability of resources and time constraints.

To estimate vehicle speed, a speed gun will be used to record the speed of vehicles as they pass by a designated point on the selected bituminous roads. These speed readings will be recorded in a field notebook and the AADT data will be obtained from the Traffic counts.

3.3 Research Instruments

To measure the geometric parameters of the bituminous roads, a tape measure and a measuring wheel will be used to measure road width, shoulder width, and lane width. These measurements will be recorded in a field notebook.

3.4 Research Procedure

3.4.1 Sample Design

This research was conducted in Kireka, along Kamuli and Ndagire roads, which are heavily affected by edge break. Purposive sampling was employed to select the two roads for the study based on their observed edge break conditions. The selected roads have unpaved shoulders along the entire stretch.

It is impractical and expensive to collect data on the entire population, sampling was necessary to gather information about the selected roads. The sample size was determined based on the availability of resources and time constraints. The data collected will enable the investigation of the relationship between road geometric parameters, vehicle speed, Annual Average Daily Traffic (AADT), and Edge Break on bituminous roads in Kampala.

3.4.2 Data Collection

3.4.2.1 Traffic Counts

Field surveys were conducted to manually count vehicle traffic for the selected roads to estimate traffic volumes. The estimate was the Annual Average Daily Traffic (AADT) and classified into vehicle groups such as cars, light goods vehicles, trucks (heavy goods vehicles), and buses. Counts were taken twice a week. Counts were avoided at times when travel activity was abnormal, such as on public holidays. These counts were done during morning hours from 7:00 am to 9:00 am in the morning and 5:00 pm to 7:00 pm in the evening, based on a pilot traffic count survey establishing these hours as the peak hours for travel. Selection of observation points put into consideration safe points and a clear unobstructed view of the traffic.

3.4.2.2 Average Carriage Way Width

The average width was determined from measurements taken at six points spaced 50 meters apart for both roads.

3.4.2.3 Average Vehicle Speeds

The time taken for a vehicle to move through 20 meters was recorded for each vehicle category. The values recorded were for both directions for both roads.

3.4.3 Data Collection Procedure

3.4.3.1 Road Carriage Width

Field surveys were conducted to obtain measurements of road carriage width at 6 points spaced 50 meters apart for both roads. These measurements were used to determine the rate of loss of edge material off the paved surfaces of the roads and to carry out the classification of the roads in the study.

3.4.3.2 Average Vehicle Speeds

The average speeds of vehicles were determined using a timer to calculate the average speed for different sections of the roads. This was done by first determining the travelling times of vehicles and then calculating their average speed. The values recorded were for both directions for both roads.

3.4.3.3 Traffic Counts

Manual vehicle traffic counts were conducted twice a week, in the morning from 7:00am to 9:00am and in the evening from 5:00pm to 7:00pm. The counts were conducted on Mondays and Fridays, which were determined as the busiest days of the week. Counts were avoided on public holidays and times when travel activity was abnormal. The traffic counts were used to estimate the Annual Average Daily Traffic (AADT) and classified into vehicle groups such as cars, light goods vehicles, trucks (heavy goods vehicles), and buses. The selection of observation points put into consideration safe points and a clear unobstructed view of the traffic.

3.5 Data Analysis

3.5.1 Road Carriageway Width (CW)

Road carriageway widths were obtained from the conducted field surveys for determining the road classification. The 12-hour counts were counts converted to full day counts in comparison to the 24 hour counts in same weekday or weekend period using the following equation.

$$\text{Estimated Full Day Count} = \frac{\text{Partial Day Count(06.00 to 18.00)} \times \text{(Full 24 hour Count)}}{\text{(Count from 06.00 to 18.00 hours in the 24 hour survey)}}$$

3.5.2 Model for Edge break

The conceptual model presented by Hoban (1987) was used as a starting point in the development of an edge break model for HDM-4. Analysis from Hoof and Overgaard (1995) showed that edge step seemed to be well co related with edge break. Rainfall was added as a parameter to be included in the model to allow for later calibration by users.

The conceptual edge break model has been included in HDM-4

$$\mathrm{dVEB} = \mathrm{K_{eb}a_0PSH(AADT)^2ESTEP(S)^{a1}(a_2 + MMP/1000)\,10^{-6}}$$

Were

$$\mathrm{PSH} = \max\left\{\min\left[\max\left(a_3 + a_4CW, \frac{CW_{max} - CW}{a_5}\right), 1\right], 0\right\}$$

And

dVEB = annual loss of edge material in m^3/km

PSH = proportion of time using shoulder

AADT = annual average daily traffic

ESTEP = elevation difference from pavement to shoulder in mm

S = average traffic speed in km/hr.

CW = Carriageway width in meters

CW_{max}= user definable maximum carriage way width for the occurrence of edge break, in meters (default = 7.2, maximum = 7.5)

K_{eb} = Calibration factor for edge break progression

3.5.2.1 Coefficient Values for edge break model (Hoff and Overgaard (1995))

Table 3.1 Coefficient Values for edge break model (Hoff and Overgaard (1995))

Pavement Type	a_0	a_1	a_2	a_3	a_4	a_5
AMGB	50	-1	0.2	2.65	-0.425	10
AMAB, AMSB, AMAP	25	-1	0.2	2.65	-0.425	10
STGB	75	-1	0.2	2.65	-0.425	10
STAB, STSB, STAP	50	-1	0.2	2.65	-0.425	10

Here are some common abbreviations from the AASHTO (American Association of State Highway and Transportation Officials)

3.5.2.2 AASHTO Pavement Type Abbreviations

Table 3.1 AASHTO Pavement type Abbreviations

Abbreviation	**Pavement Type**
AMGB	Asphalt Mixtures with Gravel Base
AMAB	Asphalt Mixtures with Aggregate Base
AMSB	Asphalt Mixtures with Stabilized Base
AMAP	Asphalt Mixtures with Aggregate Subbase
STGB	Stabilized Mixtures with Gravel Base
STAB	Stabilized Mixtures with Aggregate Base
STSB	Stabilized Mixtures with Stabilized Base
STAP	Stabilized Mixtures with Aggregate Subbase

The abbreviations provided correspond to different pavement types in table 3.2 above, with each abbreviation representing a specific combination of materials used in the pavement.

3.5.2.3 AASHTO Pavement Type Abbreviations

Table 2.3 Coefficient for Edge Break model

Pavement Type	AMGB
a_0	50
a_1	-1
a_2	0.2
a_3	2.65
a_4	-0.425

Since the road type was of type AMGB the parameters chosen were as shown in table 3.3 above

3.6 Data Presentation

Firstly, the relationship between dVEB and ADDT was determined and graphically represented. To determine how the increase in ADDT affects increase in dVEB for each section. Secondly, the relationship between dVEB and ESTEP was graphically represented to determine how each mm increase in ESTEP affects increase in dVEB.

3.7 Ethical Considerations

Ethical considerations were an integral part of this study conducted on investigating the relationship between traffic loading and edge break for flexible roads in Kireka. The study ensured the protection of human subjects' rights and welfare throughout the research process. Informed consent was obtained from participants involved in data collection, and their privacy and confidentiality were strictly maintained. Additionally, the study ensured the responsible use of research findings, with an emphasis on their accurate interpretation and dissemination to contribute to the advancement of knowledge in the field of road engineering and infrastructure development.

3.8 Limitations

Despite the valuable insights gained from the study investigating the relationship between traffic loading and edge break for flexible roads in Kireka, there were certain limitations that need to be acknowledged. Firstly, the study focused solely on a specific geographical area, which limits the generalizability of the findings to other regions. Additionally, the study relied on a limited sample size, which might affect the representativeness of the results. The data collection process itself may have introduced biases or measurement errors, which could have influenced the accuracy of the findings.

Furthermore, the study primarily focused on traffic loading as a contributing factor to edge break, neglecting other potential variables such as environmental conditions or road maintenance practices. Finally, the study had a specific time frame, and the long-term effects of traffic loading on edge break were not extensively explored. Despite these limitations, the study provides valuable insights into the relationship between traffic loading and edge break, laying the groundwork for further research and potential mitigation strategies in road infrastructure planning and maintenance.

4. FINDINGS

4.1 Summary

This study aimed to investigate the relationship between traffic loading on edge break for flexible roads in Kampala. To achieve this objective two roads were surveyed, and the data collected were analyzed using coefficient and regression analysis. The findings are presented below.

4.2 Determination of Road Parameters

4.2.1 Road Carriageway Width

Road carriageway widths were obtained from field surveys for determining the rate of loss of edge material off the paved surfaces of the roads

Table 4.1 shows data collected for the carriageway widths for Kamuli Road and Ndagire road. The measurements were done at 6 points spaced at 50 meters apart for both roads.

Table 4.3 Average Carriageway Width (Source: Field Measurements)

	Carriageway Width (m)	
	Kamuli Road	Ndagire Road
	2.98	3.01
	3.12	3.21
	3.14	3.12
	2.82	3.41
	2.90	2.98
Average	2.99	3.15

4.2.2 Annual Average Daily Traffic (AADT)

The ADT was carried out to simulate the worst possible scenario of traffic experienced on the roads. The traffic counts were carried out for 2-hour peak period. The AM and PM peaks were carried out from 7:00AM to 9:00AM and 5:00PM to 7:00PM respectively, The traffic volumes were then scaled to estimate the worst case possible scenario for both roads under study.

4.2.2.1 Summary of Traffic counts

Table 4.4 Summary of Traffic Counts (Source: Traffic count)

	Wk1		Wk2		Wk3	
Road	Mon	Fri	Mon	Fri	Mon	Fri
Kamuli	5403	5107	5610	4990	5116	5211
Ndagire	4157	3907	3818	4071	4365	4025

Generally, more vehicle traffic was experienced on Kamuli road in comparison to Ndagire road. The average AADT for Kamuli and Ndagire roads was 5240 and 4058 respectively hence traffic on Kamuli road was 1.3 times greater than that of Ndagire road.

4.2.3 Average Vehicle Speeds

The time taken for a vehicle to move through 20 metres for various sections were measured and was done for vehicles from categories available. Values for both directions of traffic for both Kamuli and Ndagire roads as shown Table 4.3 below.

Table 4.5 Average Vehicle Speeds (Source: Traffic Counts)

Average Vehicle Speed, (S) - Kamuli Road						
	Vehicle Type					
Section	Motor-Cycles	Cars & Taxis	Pickups & St. Wagon	Minibuses (<25 Seats)	Small Trucks (2-Axles, <5 Ton)	Medium Trucks (2-Axles, >5 Ton)
0-100 m	00:05:02	00:06:30	00:05:55	00:07:04	00:08:09	00:08:15
400-500 m	00:05:01	00:06:27	00:05:54	00:07:02	00:07:59	00:08:32
1400-1500 m	00:05:02	00:06:34	00:06:05	00:06:43	00:08:09	00:08:27
Average time	00:05:02	00:06:30	00:05:58	00:06:56	00:08:06	00:08:24
time in seconds	5.03	6.30	5.97	6.94	8.09	8.41

speed in m/s	7.96	6.35	6.70	5.76	4.94	4.76
Sped in km/hr	28.64	22.86	24.12	20.75	17.79	17.13
Average speed	21.88					

Average Vehicle Speed, (S) – Ndagire Road						
	Vehicle Type					
Section	Motor-Cycles	Cars & Taxis	Pickups & St. Wagon	Minibuses (<25 Seats)	Small Trucks (2-Axles, <5 Ton)	Medium Trucks (2-Axles, >5 Ton)
0-100 m	00:02:28	00:02:41	00:03:55	00:05:22	00:05:23	00:05:09
400-500 m	00:02:30	00:02:56	00:04:22	00:05:34	00:05:43	00:05:16
1400-1500 m	00:02:32	00:03:08	00:05:30	00:05:32	00:05:54	00:05:43
Average time	00:02:28	00:02:47	00:04:56	00:05:33	00:05:48	00:05:29
time (s)	2.47	2.79	4.93	5.55	5.81	5.49
speed in m/s	8.08	7.18	4.05	3.60	3.44	3.64
Sped in km/hr	29.09	25.83	14.60	12.98	12.40	13.11
Average speed	18.00					

From Table 4.3, it can be observed that the average vehicle speeds on Kamuli Road and Ndagire road vary significantly across different vehicle types and sections. On Kamuli Road, the average speed for motor-cycles is 7.96 m/s (28.64 km/hr), while for cars and taxis it is 6.35 m/s (22.86 km/hr). The speeds gradually decrease for larger vehicle types such as pickups, minibuses, small trucks, and medium trucks. The average speed for all vehicle types combined on Kamuli Road is 6.70 m/s (24.12 km/hr). In contrast, on Ndagire road, the average speed for motor-cycles is higher at 8.08 m/s (29.09 km/hr), followed by cars and taxis at 7.18 m/s (25.83 km/hr). The average speeds for larger vehicle types on Ndagire road are considerably lower compared to Kamuli Road. The average speed for all vehicle types combined on Ndagire road is 4.05 m/s (14.60 km/hr).

The difference in average speeds between the two roads can be attributed to the road conditions. It is mentioned that Kamuli road is potholed, indicating the presence of numerous potholes along the road. This condition likely leads to vehicles, especially motorcycles, maneuvering and dodging the potholes, resulting in reduced speeds. On the other hand, Ndagire road does not mention any specific road conditions, suggesting a smoother road surface, which allows for higher average speeds.

4.2.4 Elevation Difference from Pavement to Shoulder (ESTEP)

The two roads were surveyed and measurements were taken at 100-meter intervals along the road segments. The data collected were analyzed using descriptive statistics. The findings are presented below.

Table 4.6 Elevation Difference

	ESTEP (mm)	
Section (m)	Kamuli road	Ndagire road
0 - 100	21	14
100 - 200	19	13
200 - 300	18	15
300 - 400	18	15
400 - 500	19	15
500 - 600	16	14
600 - 700	16	13
700 - 800	20	14
800 - 900	22	12
900 - 1000	15	15
Mean	18.4	14

The Table 4.4 presents the elevation difference between road sections of two different roads The section length is 100 meters, and the data is given in meters. The mean elevation difference for Kamuli road is 18.4 mm, and for Ndagire road is 14 mm.

4.2.5 Mean Monthly Precipitation (MMP)

The yearly precipitation was obtained and mean monthly precipitation derived for each of the 12 months and found to be 120 mm of rain.

4.3 Pavement Edge Break, dVEB analysis

Pavement edge break defined as loss of edge material, in m3 per km per year off a bituminous road pavement surface and is given by the formula.

$$dVEB = K_{eb}a_0PSH(AADT)^2ESTEP(S)^{a1}(a_2 + MMP/1000)\,10^{-6}$$

Were

$$PSH = \max\left\{\min\left[\max\left(a_3 + a_4CW, \frac{CW_{max} - CW}{a_5}\right), 1\right], 0\right\}$$

And

dVEB =annual loss of edge material in m^3/km

PSH =proportion of time using shoulder

AADT =annual average daily traffic

ESTEP =elevation difference from pavement to shoulder in mm

S = average traffic speed in km/hr.

CW = Carriageway width in meters

CW_{max} = user definable maximum carriage way width for the occurrence of edge break, in meters

K_{eb} =Calibration factor for edge break progression

4.3.1 Parameters for the each of the road

Table 4.7 Geometric Parameters

Road	CW	PSH	CW_{max}	K_{eb}	S	MMP
Kamuli Road	3	1	3.5	15	21.88	231.14
Ndagire Road	3.5	1	3.5	15	18.00	231.14

From Table 4.5, it can be observed that both Kamuli Road and Ndagire road have similar geometric parameters in terms of Carriage Way Width (CW), proportion of time using shoulder (PSH), maximum carriage way width (CWmax), and edge break coefficient (Keb). Both roads have a CW of 3 meters, indicating a standard width for the carriageway. The PSH is 1, suggesting that vehicles rarely utilize the shoulder of the road. The CWmax is also 3.5 meters for both roads, indicating the maximum width of the carriageway. The edge break coefficient (Keb) is 15 for both roads, representing the rate at which the road edge deteriorates due to various factors.

Both Kamuli Road and Ndagire road have an MMP of 231.14 mm, indicating a similar rainfall pattern. This data suggests that both roads experience similar weather conditions in terms of monthly precipitation.

In terms of average speed (S), Kamuli Road has a higher average speed of 21.88 km/hr compared to Ndagire road, which has an average speed of 18.00 km/hr. This indicates that vehicles on Kamuli Road tend to travel at a faster pace on average compared to Ndagire road. By comparing the percentage differences between the two roads, it can be observed that Kamuli Road has approximately 21% higher average speed than Ndagire road. However, in terms of geometric parameters and MMP, both roads have identical values.

4.4 Results

4.4.1 Summary of Variations of Traffic Volume with Edge Break Loss

4.4.1.1 Kamuli Road

The edge break loss was compared to both traffic volume and shoulder to pavement difference as shown. Figure 4.1 below shows the variation of annual edge break loss with traffic volume.

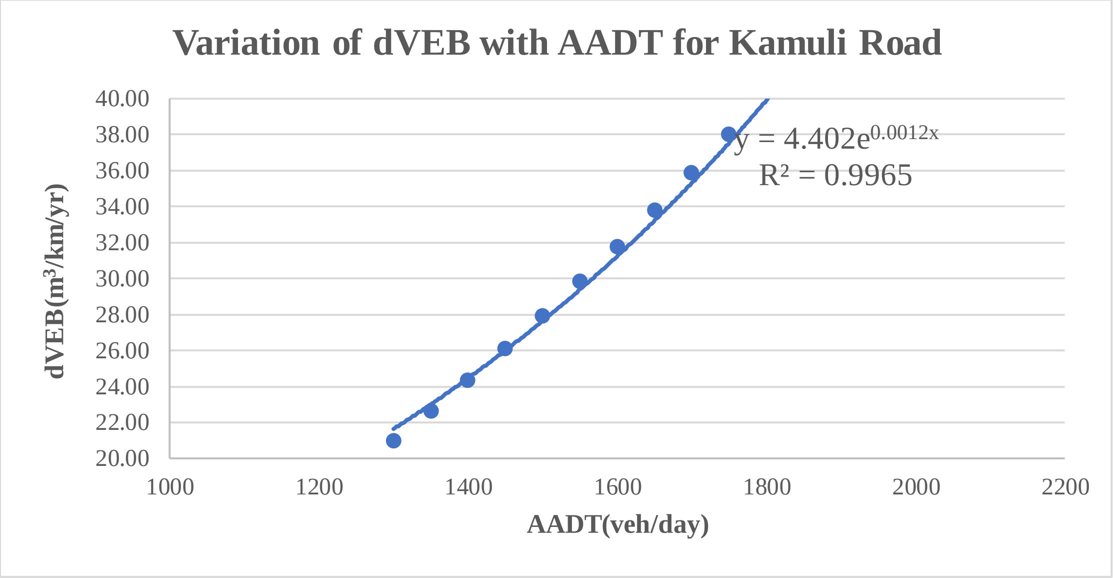

Figure 4.1 Variation of VEB with AADT for Kamuli Road

From the data for Kamuli Road shown in Figure 4.1, there is an increase in AADT from 1,500 to 1,800, with a corresponding increase in dVEB from 27.93 m^3/km to 40.22 m^3/km. By calculating the difference in dVEB for this range, there is an average increase of 11.29 m^3/km per year.

Based on this observation, for every additional increase of 100 vehicles in AADT, there is an average increase in dVEB of approximately 1.13 m^3/km per year. This calculation is derived by dividing the average increase in dVEB (11.29 m^3/km per year) by the corresponding AADT increase (300 vehicles, from 1,500 to 1,800).

For Kamuli Road, the coefficient of AADT is 0.0012. This means that for every unit increase in AADT, dVEB increases by a factor of $4.402e^{0.0012}$, which is approximately 1.0. This indicates that even small increases in traffic volume can lead to significant increases in edge material loss on Kamuli Road, making it more vulnerable to edge break in terms of AADT.

Figure 4.2 below shows variation of edge break loss with shoulder to pavement difference

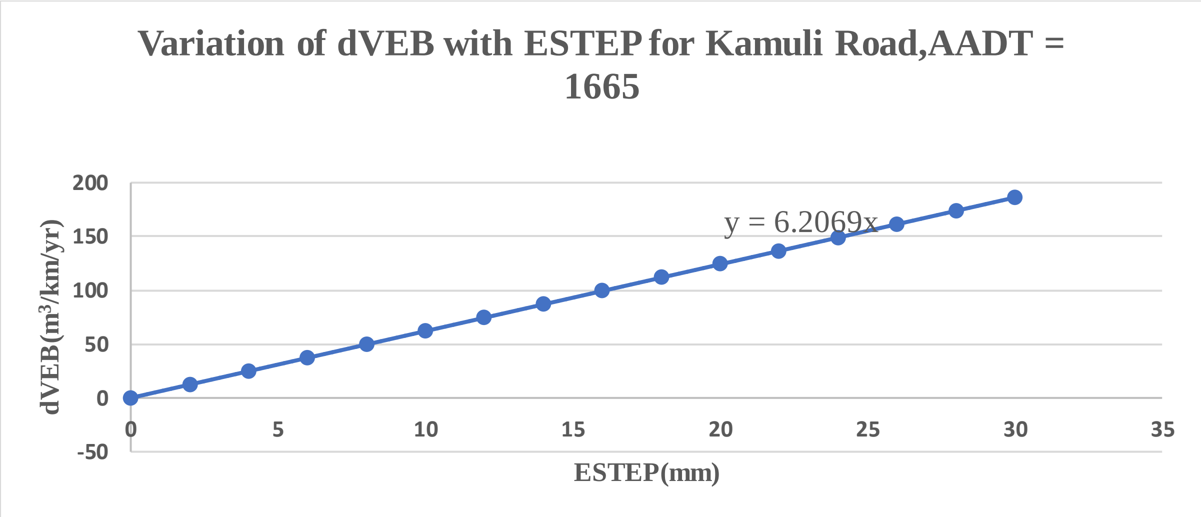

Figure 4.2 Variation of dVEB with ESTEP for Kamuli Road

By analyzing the data of Kamuli Road, there is a clear linear relationship between the Average Annual Daily Traffic (AADT) and the Elevation Step (ESTEP). The equation y = 6.2069x accurately represents this relationship, indicating that for every unit increase in AADT, there is a corresponding increase of 6.2069 units in ESTEP.

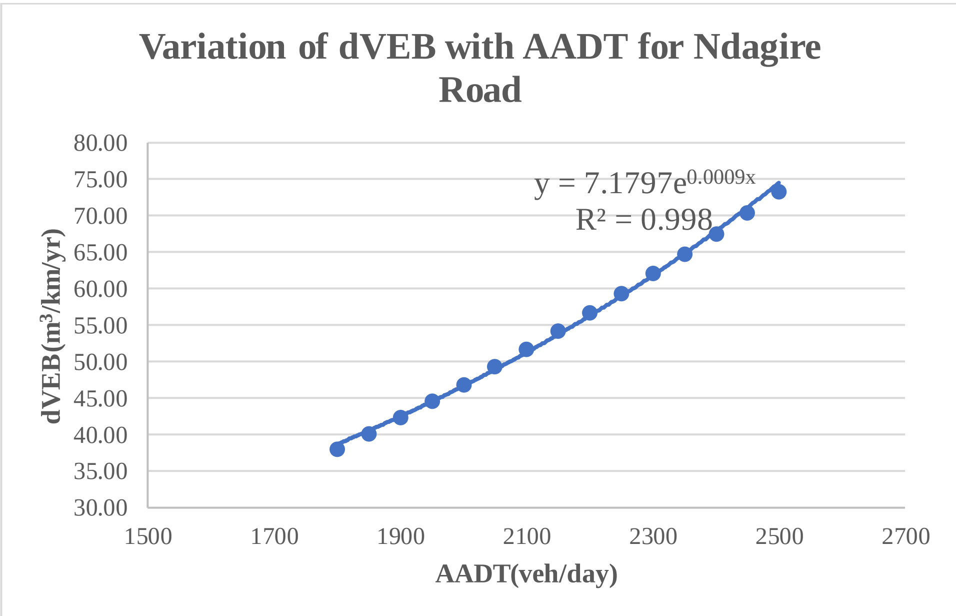

Figure 4.3 Variation of dVEB with AADT for Ndagire Road

From Figure 4.3 the data provided, there is an increase in dVEB from 26.41 to 30.05 as the AADT increases from 1,500 to 1,600. This indicates an increase of 3.64 in dVEB for a 100-vehicle increase in AADT.

From the provided data points, the average increase in dVEB is approximately 3.67 m^3/km per year. This suggests that for every additional increase of 100 vehicles in AADT on Ndagire Road, there is an expected increase in dVEB of 3.67 m^3/km per year.

For Ndagire Road, the coefficient of AADT is 0.0009. This means that for every unit increase in AADT, dVEB increases by a factor of $7.1797e^{0.0009}$, which is approximately 1.0. This indicates that the rate of increase in edge material loss with respect to AADT is lower for Ndagire Road than for Kamuli Road, making Ndagire Road less vulnerable to edge break in terms of AADT.

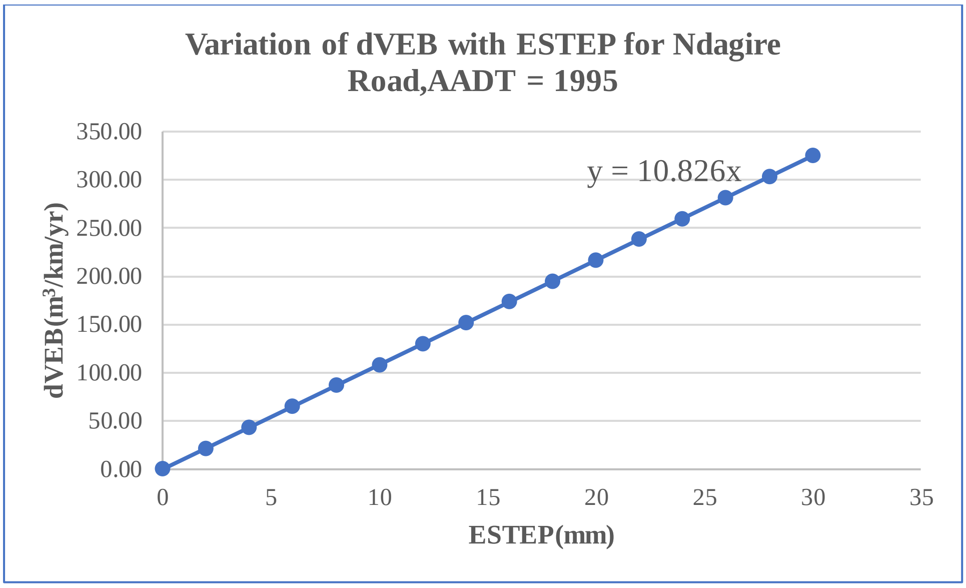

Figure 4.2 Variation of dVEB with ESTEP for Ndagire Road

By analyzing the data for Ndagire road, there is a consistent pattern in the relationship between the Average Annual Daily Traffic (AADT) and the Elevation Difference from pavement to shoulder (ESTEP). The equation y = 10.82x indicates that for every increase of 100 vehicles in AADT, there is an average increase of 10.82 mm in ESTEP. This implies that as the traffic volume increases, there is a corresponding rise in the elevation difference from the pavement to the shoulder.

4.4.2 Descriptive statistics

The mean AADT for Kamuli Road which is lower than the mean AADT for Ndagire road. This indicates that Kamuli Road is less busy road than Ndagire road. The mean dVEB for Kamuli Road is higher than the mean dVEB for Ndagire road indicates that Kamuli road is experiencing less edge material loss compared to Ndagire road.

The standard deviation of AADT for Kamuli road is lower than the standard deviation of Ndagire road This indicates that the traffic on Kamuli road has a smaller variation compared to Ndagire road meaning roads with higher traffic variation may require more frequent maintenance and inspection to ensure that they can handle the fluctuating traffic demands without deteriorating too quickly. The standard deviation of dVEB for Kamuli road which is lower than the standard deviation of dVEB for Ndagire road This indicates that the amount of edge material loss on Kamuli Road has a smaller variation compared to Ndagire Road meaning the edge break of Kamuli is less sensitive to changes compared to Ndagire which requires more attention or control to manage its impact or mitigate its risks.

5. CONCLUSION

Ndagire road is more vulnerable to edge break in terms of shoulder to pavement difference compared to Kamuli road even for small increases in traffic evidence by the higher coefficient of Ndagire Road (10.82) compared with Kamuli road (6.21). Kamuli road is more vulnerable to edge break interms of traffic compared to Ndagire Road evidenced by the the higher coefficient attached to the Average Annual Daily Traffic (AADT) for Kamuli road (0.012) compared to Ndagire Road (0.009).

The directional traffic for both Kamuli and Ndagire road for the left side have a significant amount of traffic thus more edge break was found on the left side compared to the right of about 10% that has significantly impacted the amount of edge break on the left side. Kamuli road has a smaller variation in traffic compared to Ndagire road with a significant difference of about 72% although Kamuli road has more traffic than Ndagire road of about 18% and in addition there is a significant mean difference of traffic between both roads of about 24% which due to the fact that Kamuli road is linked directly to the Kampala Jinja Highway hence higher levels of traffic thus higher edge break compared to Ndagire road.

It is observed that the traffic volume, as represented by AADT, follows an exponential pattern in relation to edge break loss. This means that the impact of traffic volume on edge break is more pronounced for higher volumes of traffic and becomes less significant for smaller volumes. In other words, as the traffic volume increases, the potential for edge break loss increases at a greater rate. On the other hand, the Elevation Difference from pavement to shoulder, represented by ESTEP, shows a linear relationship with edge break. This implies that the impact of the shoulder to pavement difference on edge break is consistent within a given range of difference. Regardless of the specific value of the difference, it has a proportional impact on edge break, assuming other factors remain constant. These insights suggest that while both traffic volume and shoulder to pavement difference play a role in edge break, their impact differs in nature. The traffic volume, being exponential, has a more significant influence on edge break for higher volumes, while the shoulder to pavement difference, being linear, has a consistent impact within a certain range.

6. RECOMMENDATIONS

For Ndagire Road, where the vulnerability to edge break is more closely related to the shoulder to pavement difference, it is advisable to focus on interventions that target this aspect. Regular monitoring and maintenance of the shoulder to pavement difference should be implemented to minimize the risk of edge break. This may involve measures such as ensuring proper shoulder support and stability, addressing any erosion or degradation issues, and implementing appropriate drainage systems to manage water runoff. On the other hand, for Kamuli Road, where the vulnerability to edge break is more influenced by traffic volume, it is important to prioritize strategies that mitigate the impact of increased traffic. This may include traffic management measures such as implementing traffic calming measures, improving road infrastructure to accommodate higher traffic volumes, and considering alternative transportation options to reduce congestion and traffic load.

Due to the significant traffic on the left side of both roads, measures should be taken to mitigate edge break in this area, such as strengthening the pavement and implementing regular maintenance. Additionally, it is crucial to prioritize left-side edge break mitigation, considering the observed 10% difference between the left and right sides. Moreover, variations in traffic should be addressed, with specific strategies for managing fluctuations and optimizing traffic flow. For Kamuli Road, which experiences higher traffic levels and exhibits a significant mean difference in traffic compared to Ndagire road, prioritizing maintenance, repairs, and potential road upgrades is recommended. By implementing these measures, the occurrence of edge break can be minimized, ensuring the longevity and safety of both roads.

In the case of an exponential relationship between traffic from pavement to shoulder and edge break. The exponential nature of time in relation to edge break emphasizes the need for timely maintenance and repair actions. Neglecting edge break can result in faster deterioration, safety risks, and increased repair costs. Regular inspections and maintenance, along with preventive measures like sealants and proper drainage, can extend the life of pavement edges. Road authorities should invest in durable materials, robust designs, and monitoring programs to address edge break proactively. By taking timely measures and planning for long-term maintenance, the negative effects of exponential time on edge break can be reduced, ensuring safer and resilient roads.

In the case of a linear relationship between Elevation Difference from pavement to shoulder and edge break, it is important to understand the consistent impact of time on edge break volume. As time progresses, the edge break volume tends to increase at a relatively steady rate. To mitigate the impact of linear time on edge break, regular monitoring and maintenance are crucial. Conducting frequent inspections and assessments of the pavement edges can help identify any signs of edge break early on. Implementing timely repairs, such as filling cracks and addressing shoulder support issues, can prevent further deterioration. Furthermore, considering the cumulative effect of linear time, implementing proactive measures like routine resurfacing and applying protective coatings can help prolong the lifespan of the pavement edges. Regular maintenance practices, such as seal coating and periodic reevaluation of the shoulder support, can mitigate the impact of time and maintain the integrity of the road infrastructure.

Future studies could expand the geographical scope by including multiple regions or even different countries to provide a more comprehensive understanding of the relationship. Additionally, it would be beneficial to conduct longitudinal studies that track the effects of traffic loading on edge break over an extended period of time, allowing for a more accurate assessment of the long-term impacts. Moreover, considering the limitations of the current study, future research should aim to increase the sample size to enhance the representativeness of the findings.

Furthermore, exploring the influence of other variables such as environmental factors (e.g., temperature, rainfall) and road maintenance practices on edge break would provide a more holistic understanding of the phenomenon. Lastly, incorporating advanced data collection techniques, such as remote sensing or continuous monitoring systems, could provide real-time data on traffic loading and its effects on edge break

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8.APPENDIX

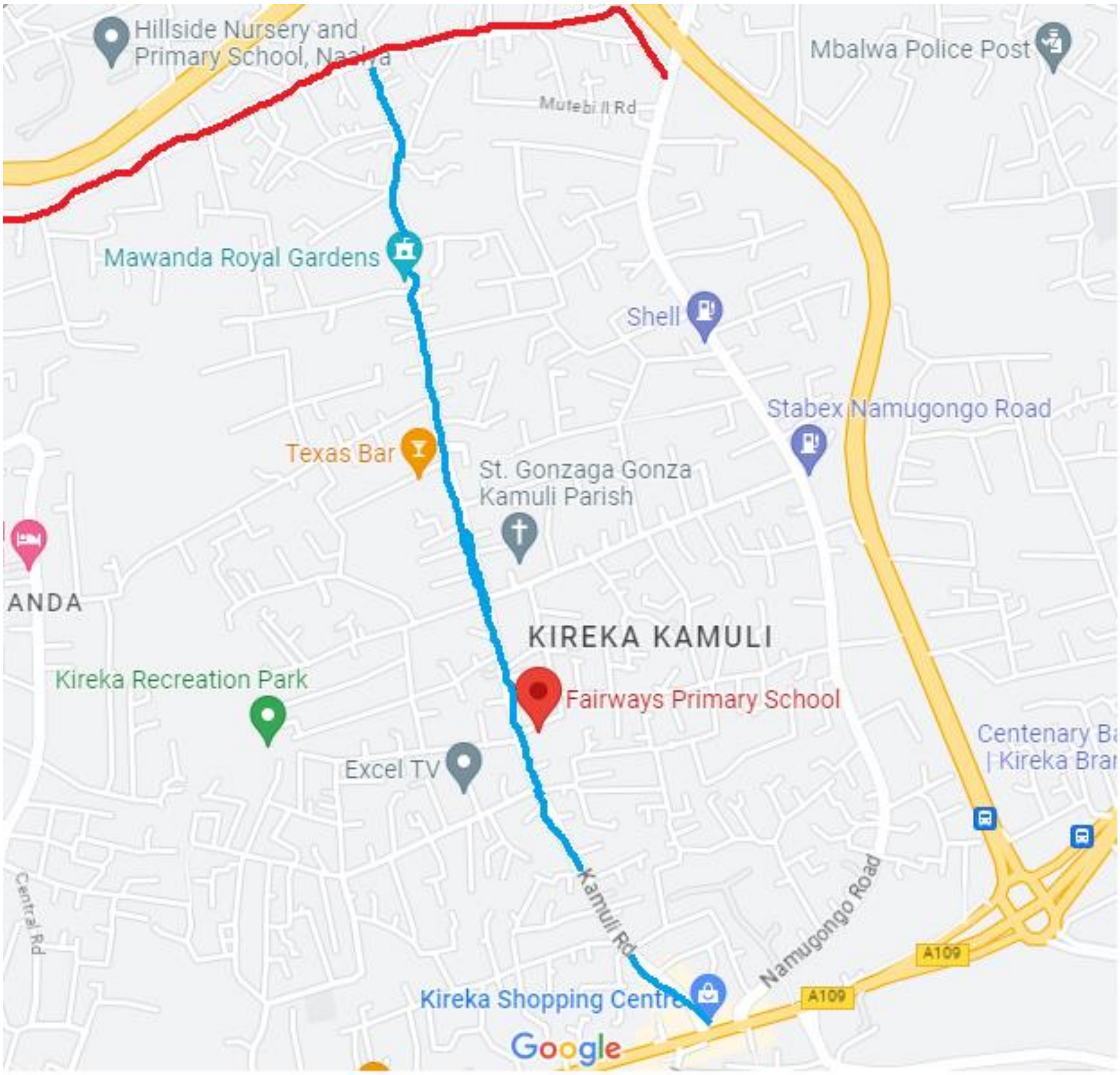
8.1 APPENDIX 1A: MOWT TRAFFIC COUNT FORM

CLASSIFIED TRAFFIC COUNT FORM

ROAD: .... LOCATION: .... TRAFFIC TOWARDS: .... ENUMERATOR: .... DATE: ....

TIME	CARS & TAXIS	PICKUPS & ST. WAGON	MINIBUSES (<25 seats)	LARGE BUSES (>25 seats)	SMALL TRUCKS (2-AXLES, <5 TON)	MEDIUM TRUCKS (2-AXLES, >5 TON)	HEAVY TRUCKS (3-AXLES OR MORE)	SEMI-TRAILERS	TRUCK TRAILERS	MOTOR-CYCLES	OTHERS	TOTAL
TOTAL												

8.2 APPENDIX 1B; MAP OF NDAGIRE AND KAMULI ROAD



KEY

NDAGIRE ROAD

KAMILI ROAD