EFFECT OF GEOMETRIC DESIGN CONSISTENCY ON ROAD SAFETY: A CASE STUDY OF NAIROBI SOUTHERN BYPASS (UCA-2) ROAD

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Effect of Geometric Design Consistency on Road Safety: A Case Study of Nairobi Southern Bypass (UCA-2) Road

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DECLARATION

This proposal is my original work and has not been presented for a degree in any other University.

Signature: …………………. ……………… Date: …………………………………

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This proposal has been submitted for examination with my approval as University Supervisor

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DEDICATION

I would like to dedicate this research to my family for the support they accorded me during my study.

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LIST OF ABBREVIATIONS AND ACRONYMS

AASHTO: American Association of State Highway and Transportation Officials

NTSA: National Transport and Safety Authority

WHO: World Health Organization

GDP: Gross Domestic Product

HIV: Human Immunodeficiency Virus

ADT: Average Daily Traffic

AADT: Average Annual Daily Traffic

VDLU: Visual demand of unfamiliar drivers

VDLF: Visual demand of familiar drivers

ABSRACT

The National Transport Safety Authority reported that between January and November 2014, about 15 people were involved in fatal accidents along the Nairobi Southern Bypass. This high number of deaths has made this bypass to be declared a high risk road in Nairobi. The safety performance of a road can be significantly improved by identifying and correcting any design inconsistencies present. The main objective of the study was to determine the effect of geometric design consistency on road safety focusing on the Nairobi Southern By-pass (UCA-2) road. To achieve this, two specific objectives were investigated. The first specific objective was to determine the frequency, type and severity of accidents on Nairobi Southern bypass (UCA-2) road in Nairobi County. Primary data was collected from filled questionnaires while secondary data was collected from the accident data recorded at Karen, Langata and Industrial Area Police Stations. From the analysis of the collected data, the results showed that total of 87 accidents had occurred between June 2016 and April 2019.It was also established that driver carelessness was the main cause of accidents that occurred along this road. To achieve the second objective, which was to determine the design consistency measures and evaluate their applicability on road safety along Nairobi Southern bypass (UCA-2) road in Nairobi County, the analysis of the spot speed data, "as-built" drawings and traffic volume data acquired from the Kenya National Highways Authority and the China Road and Bridge Corporation was done. Using the indicated criteria and models developed by other researchers, all the measures of geometric design of the Nairobi Southern Bypass, that is, operating speed, vehicle stability, alignment indices and driver workload were found to be consistent. The study findings indicated a strong positive correlation between speed reduction and accident occurrence. Two-lane highways designed solely on the concept of design speed have proved adequate in several cases. From the results of this study, it is recommended that the operating speed of vehicles (which is more realistic) be used as much as possible for the design of these roads. The results obtained from the study showed that the geometric design was adequate for criteria of a good design and therefore required warning signs to be placed before the transitions especially for the black spots as the criteria of a good design. This therefore indicated that the geometric design of the Nairobi Southern Bypass was sufficient and that the traffic accidents that occurred were mainly cause by reasons other than the geometric design.

CHAPTER ONE

INTRODUCTION

1.1 Background to the Study

In world today, road safety is a big public health problem (Llopis-Castelló, Findley, & García, 2020). Programs aimed at decreasing and eliminating traffic injuries and fatalities must include effective road design and reliable safety studies. To accomplish the above objective, designers utilize various instruments and strategies (Sil, Maji, Nama, & Maurya, 2019). Analyzing the design consistency is one of the ways in which the road's safety can be maintained or enhanced. The geometry of a road is a three-dimensional arrangement which is exhibited in two projections, the horizontal and the vertical arrangement (Cafiso, Montella, D'Agostino, Mauriello, & Galante, 2021) . The horizontal arrangement comprises of three components, the straight, the transitional curve and the circular curve. The vertical arrangement comprises of two components, the straight and the vertical curve (round or parabolic) (Boroujerdian, Seyedabrishami, & Akbarpour, 2016).

Geometric design mainly deals with the dimensions and the visible features of the road (Al-Sahili & Dwaikat, 2019). It should be designed in such a way to provide optimum efficiency in traffic operations with achieving maximum safety at a reasonable cost. It could be possible to design and construct the roads at any point of time based on the requirements or when the road gets deteriorate but it is rather expensive and difficult to improve the geometry at a later date (Castro & De Santos-Berbel, 2015). Geometric design consistency studies can be used to identify inconsistent sections on highways, which can then be targeted for improvement. Generally, this can be accomplished using design speed as a geometry control (Nama, Maji, & Maurya, 2020).

According to studies, bends account for more than half of all fatal collisions on rural roadways (Gemechu & Tulu, 2021). When a motorist meets an unexpected shift in alignment on a roadway, this occurs. Many researches have shown a link between accidents and curve shape (Zhang, Zhang, Zhang, & Hou, 2021). As a result, precise coordination of straight and curved parts is required in a good highway geometry design so that drivers are not shocked by a change in alignment. In other words, any incorrect geometry design causes unwanted speed changes. If the speed variability necessitated by the geometry exceeds safe limitations, the driver may engage in an unsafe maneuver (Vayalamkuzhi & Amirthalingam, 2016). Due to the fact that highway speeds are rather high, any erroneous driving maneuver might result in a serious collision. This kind of road design is often seen as inconsistency. Evaluating geometric design consistency is one of the viable ways for enhancing rural highway safety, since portions with inconsistent design have a high accident rate (Sameen & Pradhan, 2017). Speed-based, vehicle stability-based, alignment indices-based, and driver workload-based approaches are all available for measuring consistency. The operating speed-based strategy is the most efficient and extensively utilized among the various approaches. Because speed is a visual sign of consistency, this is the case. Furthermore, the operating speed and changes may be readily noticed and quantified (Wilches, Burbano, & Sierra, 2020).

The American Association of State Highway and Transportation Officials (AASHTO, 2021) reported that highway design balance can be accomplished by designing safe and economical geometric design components. The plan of roadway bends ought to be based on a suitable connection between the design speeds, super elevation and side friction. Design consistency alludes to highway geometry's conformance with driver anticipation (Castro & De Santos-Berbel, 2015). Drivers will make less mistakes if the geometric design of the road comply with their desires. On the other hand, if there is an irregular geometric design component or a surprising attribute on a road, drivers are likely to make many mistakes and drive dangerously. This circumstance could prompt speed mistakes, wrong driving moves, as well as undesired level of mishaps (Igene & Ogiribo, 2021).

Distinguishing and treating any inconsistency on an expressway can altogether enhance its safety outcome (Mitra, Haque, & King, 2017) .To date, there are many methods that have been used to quantify design consistency and also gauge these quantities. The goals of this study involve exploring and evaluating how design consistency and road safety are related and also to determining the advantages of implementing a reliable design. Design consistency (on the horizontal bend) is usually quantified through the determining the operating speed, speed distribution measures, driver workload and alignment indices (Coakley, Storm, & Neuman, 2016).

In 2019, statistics from World Health Organization (WHO) approximated Kenya's loss to be at lost US$ 4 billion as a result of road carnage fatalities. Road carnage is a disaster to the human kind and is associated with a lot of financial losses and human suffering that lead to unexpected loss of potential income, property or even life. Elfandari and Siregar (2021) predict that by the year 2025, global road traffic fatalities will increase to 2.7 million from the 1.9 million that were recorded in the year 2014. They continue to say that 90% of traffic deaths recorded affect the low and middle-income countries which comprise of less than half of the number of registered vehicles in the world.

Further, considering that Kenya's Gross Domestic Product (GDP) in 2012 amounted to an estimate of $37.23 billion, it lost about 11% of the GDP to the road accidents. Road traffic deaths and serious wounds are, as it were, preventable, since the danger of causing damage in an accident is generally unsurprising and also preventable since there are already existing effective preventable measures (Gemechu & Tulu, 2021). Every year in Kenya, about 3,000 individuals die in traffic related accidents, interpreting to roughly 68 deaths for every 1,000 enrolled vehicles. According to National Transport and Safety Authority (NTSA, 2020) stated that one out of seven street accidents in Nairobi occurred on the three bypass roads (Eastern, Southern and Northern Bypasses). About 133 individuals have died on those bypasses since the opening of the first one in 2014. Between January and November 2014, 37, 31 and 15 individuals were killed on the Eastern Bypass, Northern and Southern bypass roads respectively. These road carnages on the bypasses have made them to be declared high risk roads in Nairobi City County (Bundi, et al., 2017).

1.2 Statement of the Problem

Africa's road network is rapidly increasing, and maintenance standards have increased, resulting in enhanced road safety (Gemechu & Tulu, 2021). Road accidents, on the other hand, are one of our society's issues. However, in Africa, the role of roads and the environment in traffic accidents is undervalued owing to a lack of training in the field. Road accidents claim the lives of 1.2 million people each year and injure between 20 and 50 million more. The majority of accidents occur on rural roads in European nations; for example, around 63 percent of rural road accident deaths occur in Spain, while 57 percent occur in Ireland (WHO, 2018). With 3,000 people killed every year in Kenya as a result of road accidents, road traffic safety is a crucial concept in road building (NTSA, 2019). Previous study has revealed that accidents tend to cluster along certain road segments, implying that road factors, in addition to driver error, play a significant influence in collision incidence. One of the most common causes of accidents is a lack of geometric design consistency (Igene & Ogiribo, 2021).

It has been established that the Nairobi Southern bypass (UCA-2) road has been an accident-prone road since its development. A large number of the accidents’ victims include people on foot, personal cars and light and heavy business vehicles (Mutune, Mang’uriu, & Diang’a, 2017). The real reasons for accidents along this road such as speeding, vehicles losing control and pedestrians misjudging distance have not been resolved**.** Therefore, there is need to carry out a research study on road safety to thoroughly comprehend the reasons why many accidents occur on this road. This study involved use of linear regression models to investigate the connection between road safety and road geometric design consistency of the Nairobi Southern bypass (UCA-2) road and come up with suggestions that will help in limiting the death toll and save money and lives.

1.3 Research Objectives

The study was guided by the following research objectives;

1.3.1 Main Objective

The main objective of the study was to determine the effect of geometric design consistency on road safety focusing on the Nairobi Southern By-pass (UCA-2) road, Kenya.

1.3.2 Specific Objectives

The study was guided by the following specific objectives;

To determine the frequency, type and severity of accidents on Nairobi Southern bypass (UCA-2) road in Nairobi County.

To determine the design consistency measures and evaluate their applicability on road safety along Nairobi Southern bypass (UCA-2) road in Nairobi County, Kenya**.**

1.4 Research Questions

The study sought to be guided by the following questions:

1. What is the frequency, type and severity of accidents along Nairobi Southern bypass (UCA-2) road in Nairobi County?
2. What are the design consistency measures and what is their applicability on road safety along Nairobi Southern bypass (UCA-2) road in Nairobi County?

1.5 Justification of the study

With the 3,000 road accidents- related deaths annually in Kenya, road traffic safety is an essential idea in the planning, design and construction of the road infrastructure. The establishment of safe, practical and moderate methods of transport is a key goal in the design and planning of road traffic systems. However, to the knowledge of the researcher, little work has been done to measure the safety advantages brought by geometric design consistency. The generalized linear regression approach will be utilized in existing models; these models will be utilized as a quantitative instrument for the assessment of the effect of geometric design consistency on road safety in relation to Nairobi Southern Bypass (UCA-2) Road.

1.6 Scope and Limitations

1.6.1 Scope

The study determined the effect of geometric road design consistency on road safety at the Nairobi Southern Bypass (UCA-2). Contextually, the study focused on the geometric design consistency in the Nairobi Southern Bypass (UCA-2). The Nairobi Southern Bypass (UCA-2) road is relatively a new dual carriageway approximately 28.6 Km long. Conceptually, the study focused on the geometric design consistency measures which included operating speed, vehicle stability, alignment indices and driver workload. The applicability geometric design consistency was also investigated on the road safety along Nairobi Southern Bypass (UCA-2). The study was carried out in 2020/2021 academic year.

1.6.2 Limitations

Some of the respondents were unwilling to divulge sensitive geometric design information. This was however mitigated through the use of perceptual measures that had the overall effect of allowing the researcher to infer road safety and behaviour. Such subjective measures are widely used in research in Kenya and world over. Furthermore, the respondents were assured of the confidentiality of their responses. In addition, it is possible there are many other design consistency measures that may affect the road safety along Nairobi-Southern Bypass (UCA-2) road. The current study only considered the operating speed, vehicle stability, alignment indices and driver workload. Further, a longitudinal study collects data over a longer time period. However, the duration allocated for completing the study was insufficient to conduct a longitudinal study. Therefore, a longitudinal study would have revealed whether there were any changes in the assessment of the long term impact of the geometric design consistency on road safety along Nairobi-Southern Bypass (UCA-2) road over a period of time.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter presents the literature review on the geometric design consistency and road safety. It presents the theoretical framework, conceptual framework, review of literature of variables, empirical review, and critique of the existing literature relevant to the study, research gaps, and summary of the literature review.

2.2 Theoretical Framework

Several theories have been proposed wherein the car-following characteristics of a traffic stream have been developed from a variety of considerations. The current study is guided by the tolerancing theory (Chourasia, 2020). The critical importance of correct geometric dimensioning and tolerancing in conveying the designer's functional purpose and regulating the inherent geometric and dimensional fluctuations of mechanical components and assemblies is becoming more acknowledged (Karimi & Kashi, 2018). Three geometric worlds may be distinguished: the ideal world of Euclidian geometry, the world of mechanical components, which uses a geometric model of the physical world, and the virtual world of CAD/CAM, which uses a geometric model of the numerical world. The attributes of these three geometric realms are not entirely consistent. A virtual or real object's geometric model is subjected to a variety of constraints in order to accurately represent the genuine attributes of adjacent items. These constraints primarily apply to the equivalence of all fundamental dimensions, as well as to their symmetry and transitivity (Abebe, 2019).

There is a complete equivalence between all of the model's dimensional descriptions in the Euclidian universe (Butsick, Jovanis, & Wood, 2015). When attempting to represent the actual world, however, things get more complicated. Due to the uncertainty inherent in building, the selection of a series of fundamental dimensions has a significant influence on the quality of the realization. The term "nominal dimensions" refers to the fundamental dimensions used to characterize the model. The research efforts and innovations in the field of tolerancing design, as well as the development of supporting tools, techniques, and algorithms, as well as significant advances in computing software and hardware, have all contributed to its recognition as a viable area for serious scholarly contributions (Ng & Sayed, 2014). The discipline of tolerancing design is effectively maturing, with deeper insights and strong theories providing explanations and trustworthy implementations providing solutions (Tola & Gebissa, 2019). The concept of assigning a lower and upper limit to each dimension, referred to as tolerances, was established. Tolerances were defined to guarantee that mating features work properly. Clearances, location fits, and interference fits were all types of mating feature fits, with different sub-grades within each category given a tolerance value based on the nominal size of the mating features (Gemechu & Tulu, 2021). A part is rejected during the inspection process if a dimension falls outside the specified range. As assembly accuracy standards tightened, designers were forced to evaluate more essential dimensions and assign tolerances to them to assure the assembly's operation (Vayalamkuzhi & Amirthalingam, 2016).

2.2.1. Operating Speed

Operating speed is a typically an obvious marker of inconsistency. This is due to the fact that when a roadway design does not consider a driver's expectation, the driver is likely to reduce the vehicle's speed. Operating speed is an index that represents drivers' speeding behaviors on different highways and shows the comfort and safety levels they experience. This speed is acquired under free flow conditions and is typically the 85th percentile speed (V_{85}) ((Elfandari & Siregar, 2021). According to Cafiso, et al., (2021) the road's design speed V_d may not always be equal to the drivers' operating speed (V_{85}). Geometric design inconsistency can be easily noted from the difference between these two speeds (V_{85}-V_d). On the other hand, inconsistency caused by driver discomfort can be calculated from ΔV_{85}, the speed reduction between two successive points on a road.

Based on design speed and operating speed, there are two sets of evaluation criteria developed that can determine whether or not the geometric design of a road is consistent (Lamm, Psarianos, & Mailander, 1999). They are illustrated in Tables 2.1 and 2.2.

Table 2.1: Design Consistency Evaluation Criteria based on operating speed

Criterion
Good design: V_{85}-$V_d \leq$ 10km/h (Design is consistent)
Fair design: 10 Km/h < V_{85}-V_d $\leq$ 20 Km/h (Minor inconsistency in design; use of traffic warning signs required)
Poor design: V_{85}-V_d > 20Km/h (There is a great design inconsistency; road redesign recommended)
Where;
V_{85}=Operating Speed (Km/h);
V_d = Design speed (Km/h).

Table 2.2: Design Consistency Evaluation Criteria Based on Speed Reduction

Criterion
Good design: $\Delta V_{85} \leq 10$ Km/h(Design is consistent)
Fair design: 10 Km/h $< \Delta V_{85} \leq 20$ Km/h (Minor inconsistency in design; use of traffic warning signs required)
Poor design: $\Delta V_{85} > 20$ Km/h (There is a great design inconsistency; road redesign recommended)
ΔV_{85}= Speed Reduction (Km/h)

2.2.2 Vehicle Stability

Another important component of design consistency is vehicle stability. If side friction assumed is insufficient on a horizontal curve, a vehicle is likely to rollover, slide out or cause an accident (Burlet-Vienney, et al., 2021). A highway design that lacks vehicle stability disregards the driver's capacity to safely direct the vehicle. Highways with such design are considered to be design inconsistent. Surveying the stability of vehicle can help recognize such areas. This is done through determining the difference between the assumed side friction and demanded side friction (Δf_R) (Ng & Sayed, 2004). Models used to determine vehicle stability in a highway design are shown below ((Lammet al., 1999).

$$\Delta f_R = f_{RA} - f_{RD} \quad \text{......} 2.1$$

$$f_{RA} = 0.22 - 1.79 \times 10^{-3} V_d + 0.56 \times 10^{-5} (V_d)^2 \quad \text{......} 2.2$$

$$f_{RD} = \frac{(V_{85})^2}{127R} - e \quad \text{......} 2.3$$

$$R = \frac{5729.58}{DC} \quad \text{......} 2.4$$

$$\Delta V_{85} = \exp(4.561 - 0.0058DC) \quad \text{......} 2.5$$

Where;

f_{RA} = Side friction assumed

f_{RD} = Side friction demanded

V_d = Design speed (Km/h)

V_{85} = Operating speed (Km/h)

R = radius of horizontal curve (m)

e = super elevation rate

DC = degree of curve (metric units)

A design consistency evaluation criterion based on vehicle stability has also been developed and it is summarized in Table 2.3 (Lamm et al., 1999) below:

Table 2.3: Design Consistency Evaluation Criteria based on Vehicle Stability

Criterion
Good design: $\Delta f_R \geq 0.01$
Fair design: $+0.01 > \Delta f_R \geq -0.04$
Poor design: $\Delta f_R < -0.04$
Δf_R = difference between side friction assumed and side friction demanded.

2.2.3 Alignment Indices

Geometric design consistency evaluations are a widely used method of determining sections of highways which require alignment improvement. Alignment indices are numerical representations of the overall alignment of a roadway section. A more straightforward method of evaluating design consistency is to use alignment indices. This is based on the alignments and intersections of the horizontal and vertical axes. Use of alignment indices enables one to quantify the behavior of the alignment. Although decrease in speed and stability of the vehicle are important components of design inconsistency, they are an indication of design inconsistency and not the causes. The cause of the inconsistencies is the design itself which involves curves and tangents. A big contrast between average alignment indices and individual alignment indices is one of the indicators of inconsistency (Zhang & Shi, 2015). As depicted by Anderson et al. (1999) and Lamm et al. (1986), numerous alignment indices have been studied. One of them is summarized below:

$$CRR_i = \frac{R_i}{R_{avg}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad 2.6$$

Where

CRR_i = ratio of individual radius to average radius

R_i = radius of horizontal curve on the highway section (m)

R_{avg}= average radius (m)

The design consistency evaluation based on alignment indices have however not been well established (Elfandari & Siregar, 2021).

2.2.4 Driver Workload

Driver workload is defined as the pace at which drivers must complete a certain number of driving activities, which rises in complexity as roadway geometric elements get more complicated (Al-Sahili & Dwaikat, 2019). While the mental strain on drivers caused by irregularities may not be as visible as prior efforts, it may result in an increase in accidents (Chourasia, et al., 2020). Roadway planners should avoid highway segments with a disproportionately high or disproportionately low driving burden. Driver workload seems to represent an appealing method of evaluating design consistency. It measures the actual mental workload on the driver, i.e. the difficulty level that a driver experiences while safely negotiating a section of highway (Abebe, 2019). Changes in this workload could conceivably lead to errors. Since the vehicle, the driver and the road cooperate in a united manner, it is sensible to incorporate driver workload as a measure of design consistency. Using the relationship between driver workload and visual demand, models were developed to estimate the visual demand of drivers familiar with the road and drivers unfamiliar with the road (Woolridge, et al., 2000). They are presented below:

$$VD_{LU} = 0.173 + \frac{43.0}{R} \quad \ldots 2.7$$

$$VD_{LF} = 0.198 + \frac{29.2}{R} \quad \ldots 2.8$$

$$WL = 0.193 + 0.016DC \quad \ldots 2.9$$

Where

VD_{LU} = Visual demand of unfamiliar drivers

VD_{LF} = Visual demand of familiar drivers

Using Table 2.4 VD_{LU} and VD_{LF} can be used to predict accident occurrences between the year 2019 and 2024.

The driver workload depends on the radius of curvature of a road. As such, the developed models represent important tools for accurately evaluating driver workload on complex horizontal alignments.

The driver workload was calculated using the model presented below (Wooldridge et al. 2000):

$$WL = 0.193 + 0.016DC \quad \ldots 2.10$$

Where

DC- Degree of curve (metric units)

WL= Workload

Awatta, et al., (2006) had developed a design consistency evaluation criterion to establish design consistency from driver workload. It is tabulated in Table 2.4.

Table 2.4: Design Consistency Evaluation Criteria based on Driver Workload

Level of Consistency	Workload Value (WL)	Driver Expectation
A	≤ 1	No problem expected
B	≤ 2	
C	≤ 3	Small surprise possible
D	≤ 4	
E	≤ 5	
F	≤ 6	Big problem possible

Source: (Awatta, et al., 2006)

2.2.5 Relationship between Geometric Design Consistency and Road Safety

The drivers' expectation may be violated by a geometric design inconsistency leading to collisions. Lamm et al. (1999) developed a criterion based on collision rate to determine the geometric consistency of a highway. It is presented in Table 2.6. To determine the collision rates, models linking geometric design consistency to road safety were developed. The resulting models predicted collisions that would occur in the next five years based on each design consistency measure (Joanne, 2002). The models are presented in Table 2.6

Table 2.5: Design Consistency Evaluation Criteria based on Collision Rate

Criterion
Good design: $\frac{\text{collisions}}{10^6}\text{veh} - \text{Km} \leq 2.27$
Fair design: 2.27$<$ $\text{mean collision rate}\left(\frac{\text{collisions}}{10^6}\text{veh} - \text{Km}\right) \leq 5.00$
Poor design: $\frac{\text{collisions}}{10^6}\text{veh} - \text{Km} > 5$

Source: (Joanne, 2002)

Table 2.6: Models showing the relationship between each Design Consistency Measure to Road Safety

No.	Model Form		t-ratio	k	Pearson's X^2 (X^2 test) Standard deviation
1	Difference between operating and design speed (V_{85}-Vd) Collisions / 5 years = exp (-3.380) $L^{0.8920}$ × $V^{0.5913}$ exp [0.009091 (V_{85}-Vd)]	$a_0 a_1 a_2 a_3$	-1.904 6.5112.7841.985	1.539	293.24 (357.39) 341.26
2	Speed reduction: (ΔV_{85}) Collisions / 5 years = exp (-3.796) $L^{0.8874}$ × $V^{0.5847}$ exp (0.04828ΔV_{85})	$a_0 a_1 a_2 a_3$	-2.072 6.482 2.742 2.043	1.533	289.19 (357.39) 341.26
3	Difference between side friction demanded and assumed (ΔfR) Collisions / 5 years = exp (-3.303) $L^{0.8733}$ × $V^{0.5680}$ exp (-2.194ΔfR)	$a_0 a_1 a_2 a_3$	-1.851 6.412 2.672 -1.986	1.521	294.01 (357.39) 341.27
4	Ratio of the radius of individual section to the average radius of the alignment (CRR) Collisions / 5 years = exp (-3.159) $L^{0.8898}$ × $V^{0.5906}$ exp (-0.3606CRR)	$a_0 a_1 a_2 a_3$	-1.791 6.514 2.785 -2.016	1.541	294.06 (357.39) 341.27
5	Visual demand of unfamiliar drivers (VDLU) Collisions / 5 years = exp (-4.297) $L^{0.8866}$ × $V^{0.5841}$ exp (3.076 VDLU)	$a_0 a_1 a_2 a_3$	-2.231 6.476 2.735 2.040	1.531	295.34 (357.39) 341.23
6	Visual demand of familiar drivers (VDLF) Collisions / 5 years = exp (-4.679) $L^{0.8873}$ × $V^{0.5841}$ exp (3.076 VDLF)	$a_0 a_1 a_2 a_3$	-2.323 6.481 2.740 2.027	1.533	295.58 (357.39) 341.26

KEY:

L=section length (km); V=annual average daily traffic (vehicles/d); (V_{85}-Vd) =difference between operating and design speed (km/h) of a single element; ΔV_{85} = speed reduction from one element to the next; ΔfR = fRA – fRD, where fRA and fRD,= side friction assumed and demanded; CRR= Ratio of radius of an individual element i to the average radius of the alignment; VDLU = Visual demand of unfamiliar drivers; VDLF = visual demand of familiar drivers; k=a factor relating to each measure.

Source: (Joanne, 2002)

.3 Empirical Literature

Gemechu and Tulu (2021) conducted a study to assess the design consistency of horizontal alignments using design consistency metrics and to build safety functions that use just design consistency metrics. Using design assessment criteria, elements of all road sections included in the research were graded as having an excellent, fair, or bad design. The association between design consistency measures and road safety was examined using Poisson regression and Negative Binomial regression modeling techniques. Using information-theoretic goodness-of-fit criteria, it was determined that Poisson regression models matched the data better than NB regression models. Three distinct crash prediction models were successfully created that explicitly use design consistency metrics.

The research by Llopis-Castelló, Findley, and Garca (2020) examined several approaches for estimating the frequency of collisions on homogenous road segments. This research analyzed a total of 27 two-lane rural road segments in North Carolina, resulting in 59 homogenous road segments comprised of 350 horizontal curves and 375 tangents along a 150-kilometer stretch of road. On the chosen routes, four approaches were applied: the Highway Safety Manual's predictive method, two jurisdiction-specific Safety Performance Functions (SPFs), and an SPF with a consistency parameter. The research discovered that by including a consistency parameter into SPFs, transportation engineers can account for human factor implications on road safety assessments. Additionally, the inclusion of a consistency parameter might aid in the process of crash estimation. Analysis approaches that used just local geometric variables produced incorrect findings because they calibrated only individual road elements rather than their connection to other road components over homogenous road segments.

Al-Sahili and Dwaikat's (2019) research examined the influence of uniformity in geometric design on road safety in the West Bank. On the basis of available data, a total of 118 kilometers of two-lane rural roadways in the West Bank, Palestine, were analyzed. The influence of design consistency measures on road safety was investigated using comprehensive geometric and operational data for the chosen roadways gathered from field surveys, maps, and official sources. A total of 263 crashes from 2008 to 2012 were utilized to create models utilizing the extended linear regression technique. The tested models were 95 percent statistically significant, and the accepted models had an acceptable degree of goodness of fit. The proposed model worked well when new highway sections, extra years of data, algorithm validation, and " percent error" with a good linear correlation were included. The research contributes to the body of data demonstrating that various geometric design consistency factors improve traffic safety.

The research conducted by Abebe (2019) aimed to quantify the effect of road geometry characteristics on traffic safety (case study: Hawassa-Shashemene-Bulbula Rural Two-Lane Highway, Ethiopia). This study's primary purpose was to measure the effect of road geometry factors on road safety. The predicted number of accidents was calculated using the empirical Bayes (EB) approach utilizing historical accident data, traffic data, and road data. The research revealed a negative correlation between the radius of horizontal curves, superelevation, transition curve length, lane and shoulder widths, and predicted accident frequency. Whereas the number of horizontal and vertical curves per segment, the road grade, the presence of left turn horizontal curves with downgrade and right turn horizontal bends with upgrade were all positively connected with the estimated frequency of accidents. As a result, it has been found that road geometry has a considerable impact on the incidence of accidents within the research region.

Vayalamkuzhi and Amirthalingam (2016) examined the effect of geometric design elements on traffic safety in India by analyzing bi-directional data from a split highway operating under diverse traffic circumstances. The investigation was conducted on a split four-lane intercity roadway with flat and undulating terrain. Poisson regression and negative binomial regression were employed to evaluate the safety performance of the vehicle since collisions are random occurrences and to determine the effect of geometric design factors on the crash frequency. Negative binomial regression was shown to be the most appropriate model for identifying the factors associated with road accidents. Additionally, the research demonstrated that operating speed has a substantial role in the overall number of collisions.

Butsick, Jovanis and Wood (2015) study focused on the modeling safety effects of geometric design consistency on two-lane rural roads using mixed effects negative binomial regression. Examination of two conditions is proposed to ensure the free flow. Vehicles meeting both conditions, when tracked from the preceding tangent section till the centre of the horizontal curve, are considered as free flowing. The speed data of such free flowing passenger cars at the centre of eighteen horizontal curves on four-lane divided highways is analyzed to develop a linear operating speed prediction model. The developed model depends on curve radius and preceding tangent length. The operating speed of passenger car in four-lane divided highways is influenced by horizontal curve of radius 360 m or less. Further, longer tangent would yield higher operating speed at the centre of the curve. Finally, two nomograms are suggested for conventional design, consistency based design and geometric design consistency evaluation of four-lane divided horizontal curves.

The research conducted by Ng and Sayed (2014) examined and measured the connection between design consistency and road safety. The influence of different design consistency strategies on road safety was investigated using a large accident and geometric design database for two-lane rural roadways. Numerous accident prediction models were created that use design consistency metrics. Model development was carried out using the extended linear regression technique. The models may be used to quantify the effect of design consistency on road safety. A comparison of the ability of accident prediction models that add design consistency metrics to those that depend on geometric design attributes is offered. It is discovered that models that explicitly address design consistency are more successful at identifying discrepancies and properly reflecting the ensuing consequences on safety than models that do not.

Camacho-Torregrosa et al. (2013) investigated a novel technique for evaluating road safety throughout the design and redesign phases of two-lane rural roadways. This technique was based on an investigation of road geometric design consistency, a value that served as a proxy for the two-lane rural road segment's safety rating. For 33 Spanish two-lane rural road segments, operating speed profiles were created and multiple consistency assessments based on global and local operating speeds were performed. The final consistency model takes into account not only the worldwide dispersion of the operating speed, but also other indices that take into account both local speed decelerations and speeds exceeding posted limits. The accident frequency for each study site was used while developing the consistency model, which enabled calculating the number of collisions on a road segment via the computation of its geometric design consistency. As a result, the given consistency assessment approach is a potential novel tool that can be utilized to determine the safety of a road section using a surrogate measure.

Karimi and Kashi (2018) evaluated the influence of geometric characteristics on the promotion of safety and the reduction of accidents (Case study: Bojnurd-Golestan National Park road). As a result, safety management and accident reduction are seen as critical problems. The first step in preventing road accidents is to understand the accident process and the elements that contribute to it. Numerous studies have been undertaken in recent years to determine the link between the frequency of accidents, traffic volume, road geometry features, and environmental variables using accident prediction models. These models are powerful tools for accident analysis and are being used to identify and analyze accident black spots on suburban roadways. The use of prediction models derived from precise statistical techniques and data on roads and accidents not only helps in the evaluation of managerial and geometric changes to roads, but also facilitates the identification of accident black spots.

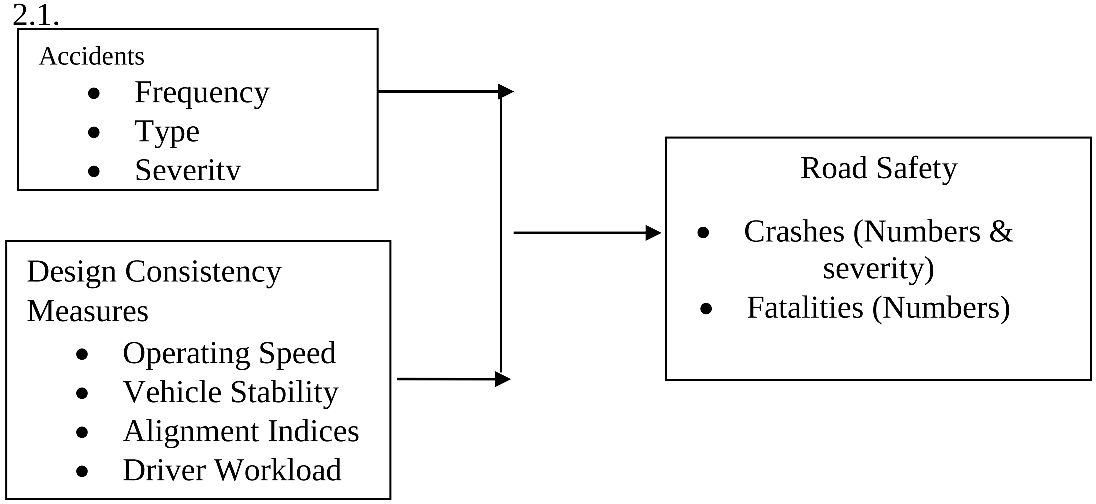
Tola and Gebissa (2019) study assessed the Impacts of Road Geometry and Route Selection on Road Safety: A Case of Mettu-Gore Road, Ethiopia. The objective of the study was a twofold; First, it developed an excel program referring to the governing values of Geometric design manual of Ethiopia in order to identify and quantify inconsistent geometric design on Mettu-Gore road. In order to achieve the first fold of the study, the final As-built geometric design on Mettu-Gore road and the geometric design policy of Ethiopia were used. Second, it assessed the geometric characteristics of police-reported hotspot zones of the road. The result was confirmed that road geometric parameters such as; radius of a curve, superelevation, gradient, and sight distance were the most significant factors affecting road safety on Mettu-Gore road.

2.4 Summary of Literature Reviewed and Research Gap

Academic scholars and transportation agencies continue to debate the influence of road design and route selection on accident rates. Along with 'driving error,' road geometric design elements have an effect on the route's safety in advance. Road geometry, in addition to driver error, contributes to traffic collisions. Consistency in geometric design is a critical aspect of road safety enhancement. Consistency in geometric form is emerging as a critical criterion in highway design. Identifying and resolving roadway inconsistencies may dramatically enhance a route's safety performance (Butsick, et al, 2015; Intini, et al., 2019). Numerous studies have been conducted to investigate this idea, including the identification of prospective consistency metrics and the development of models to assess them (Camacho-Torregrosa, et al., 2013). However, little research has been conducted to assess the safety advantages of consistent geometric design on road performance. Prior study sufficiently addressed the influence of uniformity in geometric design on road safety. However, the linkages between geometric design consistency and road design element safety concerns remain largely unexplored, with a dearth of dedicated experimental investigations (Intini et al., 2019; Butsick et al., 2015; Llopis-Castelló et al., 2020; Camacho-Torregrosa et al., 2013). The research examined a database of run-off-road single-vehicle incidents on the Nairobi Southern Bypass (UCA-2) route. The geometric design consistency data was gathered from traffic police, pedestrians, and drivers on the distance between their residences and the locations of drivers involved in accidents. The present research set out to determine the influence of geometric design consistency on road safety along Kenya's Nairobi-Southern Bypass (UCA-2) motorway.

2.5 Conceptual Framework

The conceptual framework is visual or written output that elucidates essential features of a topic (Berman, 2013; Yin, 2014). The conceptual framework for this study attempts to explain an integrative view of the effect of geometric design consistency on road safety. It is hypothesized that geometric design consistency has significant effect on road safety. Design consistency is defined as the conformance of a highway’s geometry to the driver’s anticipation. Highway design which guarantees that progressive components are facilitated in such an approach to create agreeable and homogeneous driver performances along the road is viewed as safe and reliable. Therefore, the two measures: Accidents (Frequency, type and severity) and Design Consistency Measures (operating speed, vehicle stability, alignment indices and driver workload) are classified as the independent variables, while road safety (Crashes and Fatalities) is classified as the dependent variable and the conceptual framework is demonstrated as shown in Figure 2.1.



Independent Variables **Dependent Variables**

Figure 1.1: Conceptual Framework

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Introduction

This chapter describes the research methodology used in undertaking the study. This study is sought to assess the effect of geometric design consistency on road safety in Nairobi-Southern Bypass (UCA-2) road. The chapter starts by explaining the research design, and then covers the population, sampling techniques, data collection procedures, pilot study (validity and reliability), data processing and analysis.

3.2 Research Design and Approach

The study adopted descriptive research design. The descriptive research design establishes the relationship between two variables (Chelugo, 2017). This approach was adopted so as to enhance study objectives. According to Soro and Wayoro (2018) the descriptive research design involves the use of both qualitative and quantitative approaches. Descriptive research design is concerned with gathering of facts and figures rather than manipulating of variables (Ong'ondo, et al., 2019). Therefore, the application of descriptive research design in the study was adopted mainly for two reasons, first it helps in understanding which variables are the cause, and which variables are the effect and secondly, it aided in determining the nature of the relationship between the causal variables and the effect predicted (Ashraf, et al., 2019). This assisted in the collection and analysis of the data used in this research based on the geometric design parameters, traffic volume, spot speed and crashes recorded on a two-lane rural highway located along Nairobi-Southern Bypass (UCA-2) road.

3.3 Research Site

The study was carried out along Nairobi-Southern Bypass (UCA-2) road in Kenya. The Nairobi Southern Bypass Highway is a road in Kenya, forming a semi-circle through the south-western neighborhoods of the capital city of Nairobi, as shown in Figure 3.1 below. The road allows traffic from Mombasa, destined for western Kenya and Uganda to bypass downtown Nairobi, thereby reducing traffic congestion in the city's central business district. The road starts at the junction of the Nairobi–Mombasa Road and Likoni Road, approximately 10 Kilometres (6 mi) south-east of the city centre. The road then loops through the south-western suburbs of Nairobi, including the northern environs of Nairobi National Park, Uhuru Gardens, Lang'ata and Dagoretti. In Dagoretti, the road enters Kiambu County and then turns northwards, to pass through Muguga and end in the town of Kikuyu, in a suburb known as Gitaru. At that location, the road connects with the Nairobi-Malaba Road (A104). The total length of the Nairobi Southern Bypass Highway is approximately 29.6 Kilometres (18 mi). The road safety is an issue of prime importance in along Nairobi-Southern Bypass (UCA-2) road in Kenya. It has been established that the Nairobi Southern bypass (UCA-2) road has been an accident-prone road since its development (KeNHA, 2020). A large number of the accidents' victims include people on foot, personal cars and light and heavy business vehicles (Mutune, et al., 2017). The road accident results a serious social and economic problems. Studies have focused on geometric design and safety aim to improve highway design and to eliminate hazardous locations. The relationship between geometric design elements and accident rates is complex and not fully understood along Nairobi-Southern Bypass (UCA-2) road in Kenya. Relatively little information is available on relationships between geometric design elements and accident rates.

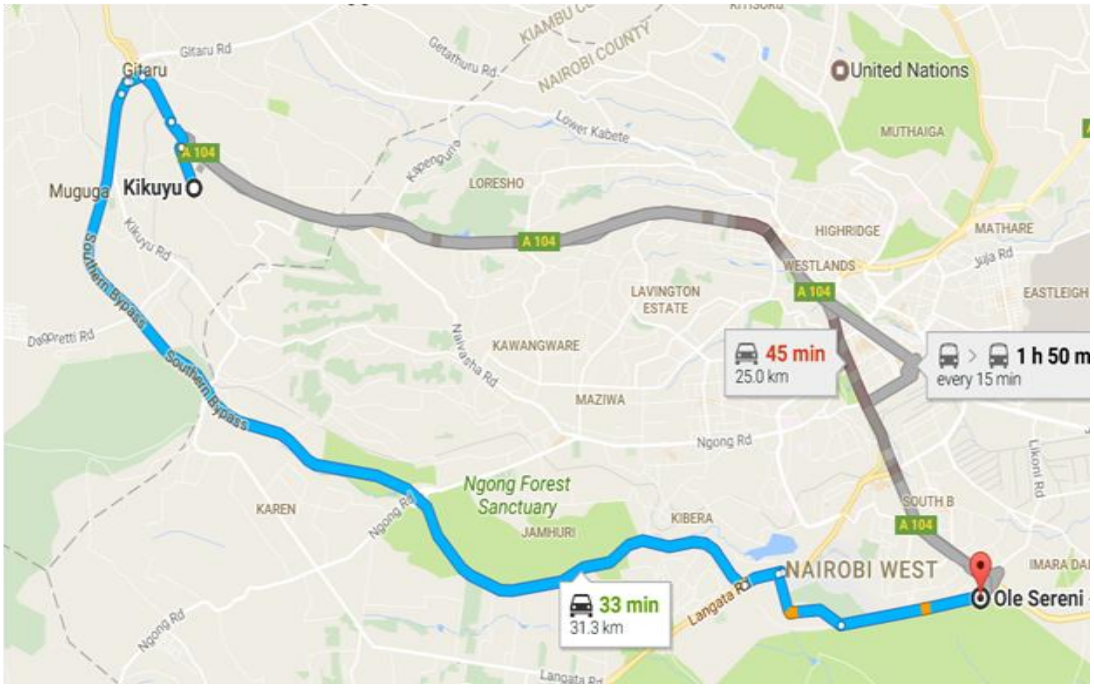


Figure 3.1: Nairobi-Southern Bypass (UCA-2) Road in Kenya.

Source: Kenya Roads Board (2021)

3.4 Study Population

The study population was 8 black spots along Nairobi-Southern Bypass (UCA-2) road. The respondents included the 12 police officers, 2500 motorists and 3,000 pedestrians estimated using the road per day (Kenya Roads Board, 2021). Their hands experience on road safety made them the most suitable target for the study. The study focused on the black spots (according to data by NTSA) in areas along Nairobi-Southern Bypass (UCA-2) road. Road users whose responses to the structured questionnaire in relation to road design variables and accident variables were sought and compared with actual measures and observations of the research team. Random sampling of sections of Nairobi-Southern Bypass (UCA-2) road, which are accident-prone (black spots), and which are mostly used for public transport was carried out. The sampling of the study population and road sections was done to measure the state of affairs of existing variables in the field without an experimenter bias or manipulation of data or responses. The study population is presented in Table 3.1;

Table 3.1: Study Population

Category	**Population**
Police Officers	12
Motorists	2500
Pedestrians	3000
Total	5512

3.5 Sampling Technique

The following formulae was used as recommended by Mugenda and Mugenda (2003) from normal distribution, the population proportion can be estimated by:

$$n = \frac{Z^2 PQ}{\alpha^2}$$

Where:

Z = Standard normal deviation set at 95% confidence level (1.96)

P = Percentage picking a choice or response (0.9)

Q = 1-P α = level of significance = 5% (1)

Therefore,

$$n = \frac{1.96^2 \times 0.9 \times (1 - 0.9)}{0.05^2}$$

n = 138

Table 3.2: Sample Size Distribution

Category	**Population**	**Sample (n)**
Police Officers	12	3
Motorists	2500	55
Pedestrians	3000	80
Total	5512	138

3.6 Research Instruments

Data was collected using structured questionnaires and interview guides which were filled by the respondents along Nairobi Southern Bypass road. They included the Police, motorists and pedestrians. This data was collected from four locations, namely Kibera, Kikuyu, Ngong and Olesereni. Qualitative data was acquired from the Police. Both closed and open-ended questions were prepared for data collection. Closed questions were expected to offer uniformity to respondents in answering the questions while open-ended questions accorded objectivity and freedom to respond to question without personal indulgence or biasness (Chelugo, 2017).

3.7 Data Collection Methods

The study collected both the primary and secondary data. The study research assistants helped to collect accident primary data from the respondents along the Nairobi-Southern Bypass (UCA-2) road and using a checklist observed the road design variables on the sample sections. The questionnaire as a data collection instrument was employed to give relevant information from respondents because of ease of administration, time saving, upholding of confidentiality between the respondents and the researcher as well as being the best source of primary data (Testa & Simonson, 2017). Both closed and open-ended questions were prepared for data collection. Closed questions were expected to offer uniformity to respondents in answering the questions while open-ended questions accorded objectivity and freedom to respond to question without personal indulgence or biasness (Awatta, et al., 2006). Secondary data was collected by use of published documents and government publications.

3.8 Reliability and Validity of Research Instruments

3.8.1 Validity

Validity is the extent to which an instrument actually measures what it is supposed to measure (Bett & Memba, 2017). The questionnaire items were guided by the conceptual framework (Figure 2.1) in order to measure study variables. Amuhaya, et al., (2018) advised that to assure validity, the construct measures and their indicators be taken from several conceptual and empirical literatures, as the current study has done, evidenced from various cited sources. To attain content validity, the questionnaire measurement items were constructed from the conceptual frame work constructs to ensure that only items relating to the study variables are included in the tool. This ensured that the instrument measured as accurately as possible the salient research characteristics that they are intended to measure. To ensure convergent validity, the study used factor loadings. The study tried to identify the fewest number of factors that account for the common variance of a collection of variables and to quantify the amount of variance explained by each component. According to Mandala et al. (2019), factor loadings larger than 0.3 are deemed acceptable. Loadings more than 0.40 are deemed substantial, whereas loadings greater than 0.50 are considered extremely significant. Hence the least factor loading thresh-hold expected was 0.3.

3.8.2 Reliability

Reliability refers to the degree of consistency between two measures of the same thing (Kiende, et al., 2019) and it measures the degree of accuracy in the measurements an instrument provides (Guney, et al., 2021). From the piloted responses, Cronbach Alpha coefficient was calculated on the study variables to determine construct reliability. Mathematically, if there are p sub-items used, Cronbach Alpha coefficient (α) is calculated thus:

$A = \frac{p}{p-1}\left(\frac{S_t^2 - \sum S_i^2}{S_t^2}\right)$, where S_t^2 is the variance of the scores for the summation of the individual sub-items and $\sum S_i^2$ is the sum of the variance of individual items. The Alpha coefficient can take any value from zero (shows that no internal consistency) to one (complete internal consistency).

Larsson (2015) advice the Cronbach Alpha coefficient of the sub – items were expected to yield an acceptable minimum coefficient value of 0.7. Items failing to satisfy this condition were dropped from the scale. This helped to check the suitability and clarity of the questions of the instrument designed, relevance and comprehension of the information being sought, the language being used, logic and content validity of the instruments from the responses given.

3.9 Data Analysis

Upon data collection, the researcher cleaned it to ensure completeness and consistency, then coded and given a unique identifier to aid its traceability.

3.9.1 Frequency, type and severity of accidents on Nairobi Southern Bypass (UCA-2) Road

The data collected for the first objective was analysed as shown below:

Consolidation of Traffic Accident Data

The traffic accident data of Southern bypass road from Karen, Langata and Industrial area police stations collected from the year 2016 to 2019 was consolidated. This is the period between when Southern Bypass started being used and the time when the field data was collected. The raw data was fed in Microsoft excel and classification of the accidents done in terms of location, frequency and severity. A distribution map showing the location, frequency and severity of road accidents from the year 2016 to date was plotted on Microsoft excel.

Road-side interview survey (Traffic Survey Manual, 2009)

Data was collected using structured questionnaires which were filled by the main people who frequently used the Nairobi Southern Bypass. They included the Police, motorists and pedestrians. This data was collected from four locations, namely Kibera, Kikuyu, Ngong and Olesereni. Secondary data was acquired from the Police and analyzed. The sample size was determined as shown in study population above. A sample questionnaire is in Appendix X.

The data obtained was used to establish the main accident causes along the Nairobi Southern Bypass and the possible solutions.

3.9.2 Geometric Design Consistency of Nairobi Southern Bypass (UCA-2) Road

3.9.2.1 Average Annual Daily Traffic (AADT)

The traffic count data was acquired from the Kenya National Highways Authority. This was measured in terms of the Annual Daily Traffic (ADT). The Annual Average Daily Traffic (AADT) was estimated by scaling up the ADT give an annual estimate using adjustment factors as below (Ministry of Works and Transport, 2004):

Table 3.3: Typical traffic conversion factors

Traffic scenarios	Urban	Inter-urban	Recreation
High	1.016	1.115	1.271
Medium	1.000	1.060	1.141
Low	0.989	1.016	0.962

Source: (Ministry of Works and Trasnsport, 2004)

The AADT obtained was used as input in the models for relating geometric design parameters with road safety.

3.9.2.2 Determination of Geometric Design Measures

Spot speed data was acquired from the Kenya National Highways Authority. Using this data, spot speed measurements were plotted on a graph showing the variation of traffic speeds on a simple frequency graph. The operating speed (V_{85}) was acquired from determining the 85th percentile speed on the plotted graph (Traffic Survey Manual, 2009).The obtained operating speed was used to gauge how consistent the geometric design of the Nairobi Southern Bypass was. The data obtained was used in an existing model to illustrate the difference between design speed and operating speed.

Using the model in Equation (2.1) illustrated in the literature review, the difference between side frictions demanded and assumed (Δf_R) was calculated to determine the vehicle stability aspect of the Nairobi Southern Bypass.

The design parameters were scaled off from the "as-built drawings" of Southern bypass road acquired from the Kenya National Highways Authority. The data on alignment indices obtained was used as an input in modeling of the components of geometric design (AASHTO, 2001).

The vehicle stability, alignment indices, and driver workload were determined using the equations below: (Sayed, Ng, & Tarek, 2004).

Vehicle stability

$$\Delta f_R = f_{RA} - f_{RD} \quad \text{……} \quad 3.1$$

$$f_{RA} = 0.22 - 1.79 \times 10^{-3} V_d + 0.56 \times 10^{-5} (V_d)^2 \quad \text{……} \quad 3.2$$

$$f_{RD} = \frac{(V_{85})^2}{127R} - e \quad \text{……} \quad 3.3$$

$$R = \frac{5729.58}{DC} \quad \text{……} \quad 3.4$$

$$\Delta V_{85} = \exp(4.561 - 0.0058DC) \quad \text{……} \quad 3.5$$

Where;

f_{RA} = Side friction assumed

f_{RD} = Side friction demanded

V_d = Design speed (Km/h)

V_{85} = Operating speed (Km/h)

R = radius of horizontal curve (m)

e = super elevation rate

DC = degree of curve (metric units)

Alignment indices

$$CRR_i = \frac{R_i}{R_{avg}} \quad \text{……} \quad 3.6$$

Where;

CRR_i = ratio of individual radius to average radius

R_i = radius of horizontal curve on the highway section (m)

R_{avg}= average radius (m)

Driver workload

$VD_{LU}= 0.173+\frac{43.0}{R}$ …………………………………………………………… 3.7

$VD_{LF} =0.198+ \frac{29.2}{R}$ …………………………………………...…………. 3.8

WL = 0.193+0.016DC……………………….…………………...……...3.9

Where;

VD_{LU} = Visual demand of unfamiliar drivers

VD_{LF} = Visual demand of familiar drivers

CHAPTER FOUR

RESULTS AND DISCUSSIONS

4.1 Introduction

In this chapter, the results of the study are presented and discussed with reference to the main objective of the study, which was to determine the relationship between geometric design consistency and road safety on Nairobi Southern bypass (UCA-2) road in Nairobi County. The first specific objective of the study was to determine the frequency, type and severity of accidents on Nairobi Southern bypass (UCA-2) road in Nairobi County. The second was to evaluate the geometric design consistency of Nairobi Southern bypass (UCA-2) road in Nairobi County.

4.2 Response Rate

Out of the 100 distributed questionnaires, 50 (50% of the questionnaires) were returned. The rate of return was a fair representative and conformed to Mugenda and Mugenda (2003) requirement that a response rate above 50% is adequate for analysis and reporting. Hager et al. (2003) a response rate of 50% is adequate for research studies. This implies that the response rate for this study was adequate.

4.3 Frequency, type and severity of accidents on Nairobi Southern Bypass (UCA-2) Road

Road traffic Accident Data Collected

To achieve the first objective, results were obtained by analyzing the accident data for the period November 2016 – May 2019 to assist in showing the trend after the construction of the Nairobi Southern Bypass. The study of accidents along the Nairobi Southern Bypass involved collecting extensive statistics of both accident frequency and casualties. Sometimes accidents involved single vehicles (for example a car rolling over) but it more often involved other vehicles or other road users. The following are extensive results that were obtained from the study:

Total Number of Accidents

The data on the number of accidents computed for the whole year over the stated period is as shown in as shown in Figure 4.1. The secondary data from the Kenya Police indicated that there was a total of 87 accidents which occurred between June 2016 and April 2019.The data indicated that the number of accidents occurrence were highest in June, 2016 (12%) and lowest in June, 2018 (2%). From the day of its commissioning (June, 2016), the AADT of the Nairobi Southern Bypass had increased to 37,832 veh/day, Retallack and Ostendorf, 2020) state that the traffic accident occurrence increases with the increased traffic volume traffic volume. The accident occurrences are therefore attributed to the fact that there was an increase in traffic volume. The data also indicated that 26% of the accidents occurred in 2016, 20% occurred in 2017, 36% occurred in 2018 while 18% occurred in 2019.

According to official statistics from the NTSA, more than 12,000 traffic related accidents are reported annually (Muchene, 2013). One of the reasons for the increase in traffic accidents is due to increase of vehicles on the road. Deshpande (2014) suggested that having a properly coordinated official policy to control how vehicles move along a road can minimize accident occurrence on a road. This situation is comparable to accident occurrence along the Nairobi Southern Bypass and implementing the above mentioned policy would assist on minimizing the number of traffic accident occurring on this road.

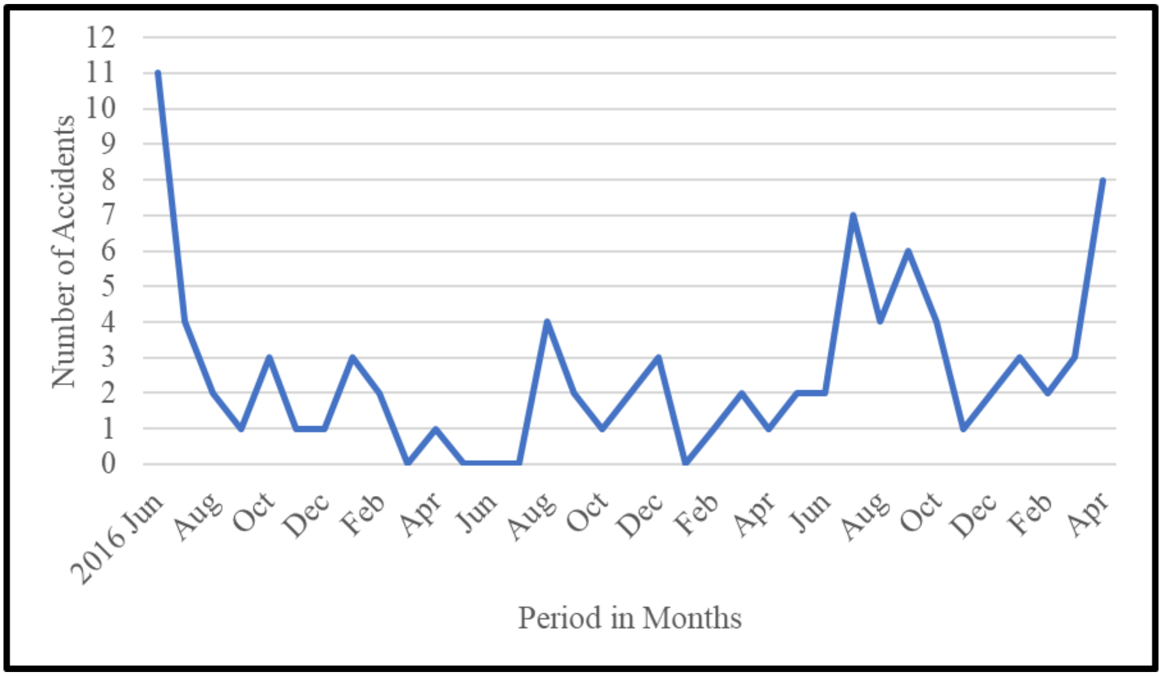


Figure 4.1: Total Number of Accident

4.3.3 Fatality rates

The Secondary data classified accident severity according to how injured the victims were. Each casualty was classified as either slightly injured, seriously injured, or fatally injured as shown in Figures 4.2, 4.3 and 4.4. From the acquired secondary data, 39% of the total recorded accidents were fatal, 47% were seriously injurious while the remaining 14% were slightly injurious as presented in Figure 4.1. In reference and comparison with Indonesia, the slightly injurious accidents were about 30% of the total accidents while about 50% were seriously injurious. These accidents had economic impacts. Using the Human Capital Method, the total accident cost in Purbalingga, Indonesia was estimated to be at US$17,539,274 or 1.27% of the Gross Domestic Product (Sugiyanto & Santi, 2017). This clearly indicates that traffic accidents have negatively affected the economic growth of a country by reducing the market value of goods and services. There would therefore be a need to reduce the accident incidences along the Nairobi Southern Bypass in order to save Kenya’s economy.

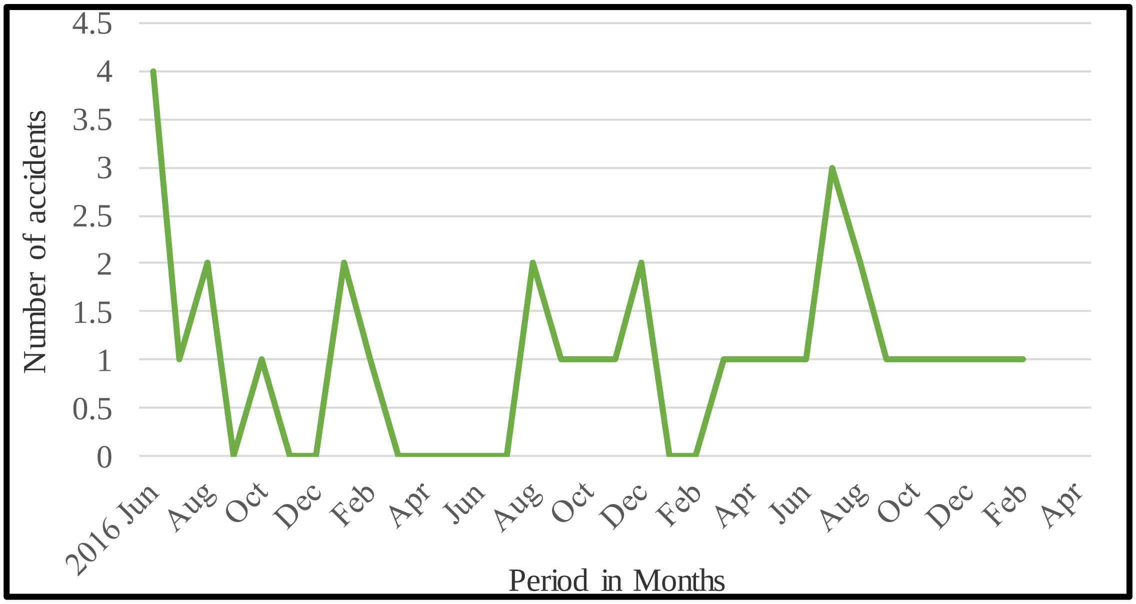


Figure 4.2: Fatal accidents

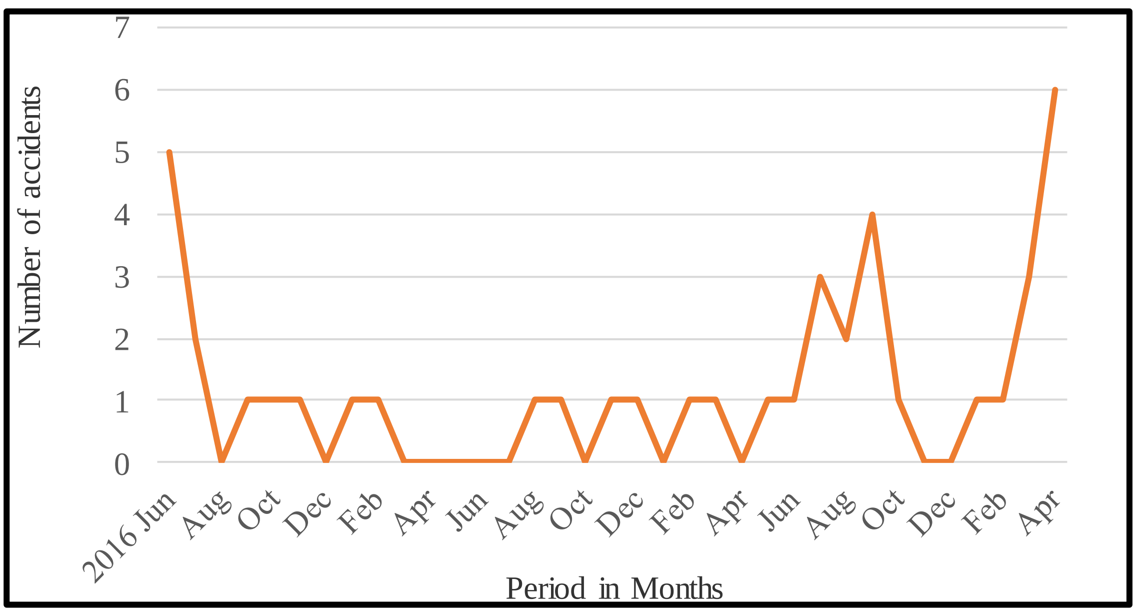


Figure 4.3: Serious injury accidents

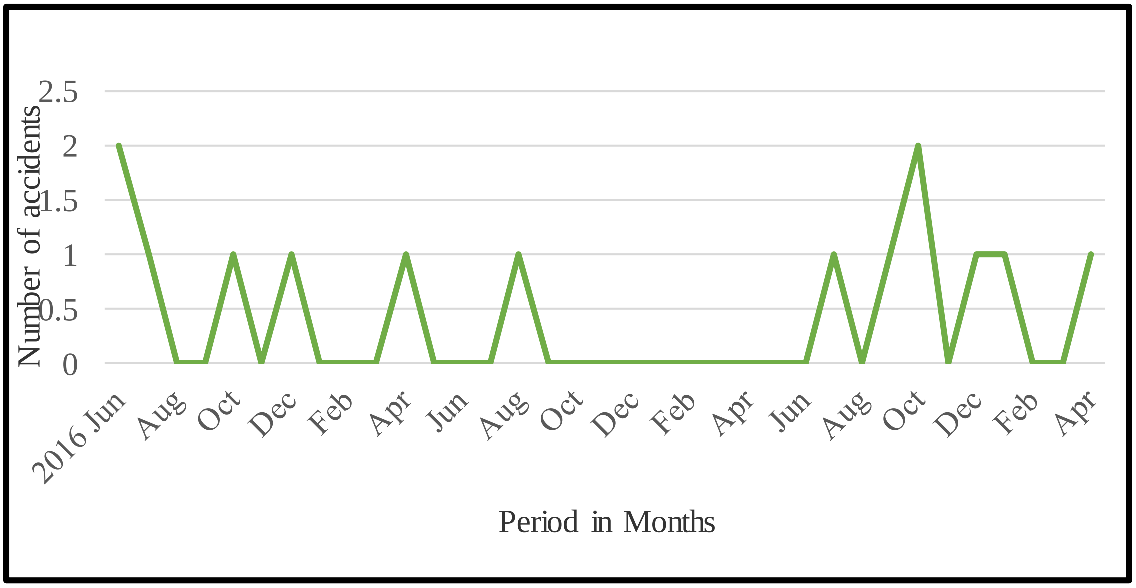


Figure 4.4: Slight injury accident

4.3.4 Victims affected by accidents

From the Secondary data, there were a total of 131 victims affected by the traffic accidents that occurred along the Nairobi Southern Bypass, as illustrated in Figures 4.5 and 4.6 below. It was also established that passengers were the most affected traffic accident victims, composing 35% of all the victims while pedal cyclists were the least affected victims, covering 4% of the total number of victims. According to Peltzer and Rener (2004), passengers and drivers were the most affected traffic related accident victims in South Sudan. In Ethiopia, the most affected traffic accident victims were passengers (Seid , Azazh, Enquselassie, & Yisma, 2015). Between the year 1971 and 1997, 3.5% of the total population in Saudi Arabia was involved in traffic accidents (Ansari, Akhdar, Mandoorah, & Moutaery, 2000). Excessive speeding and/or drivers' disobedience to traffic signals caused 65% of the accidents. Deshpande (2014) suggested the compulsory use of safety seat belts in vehicles corrective measure to reduce the number of traffic accident victims.

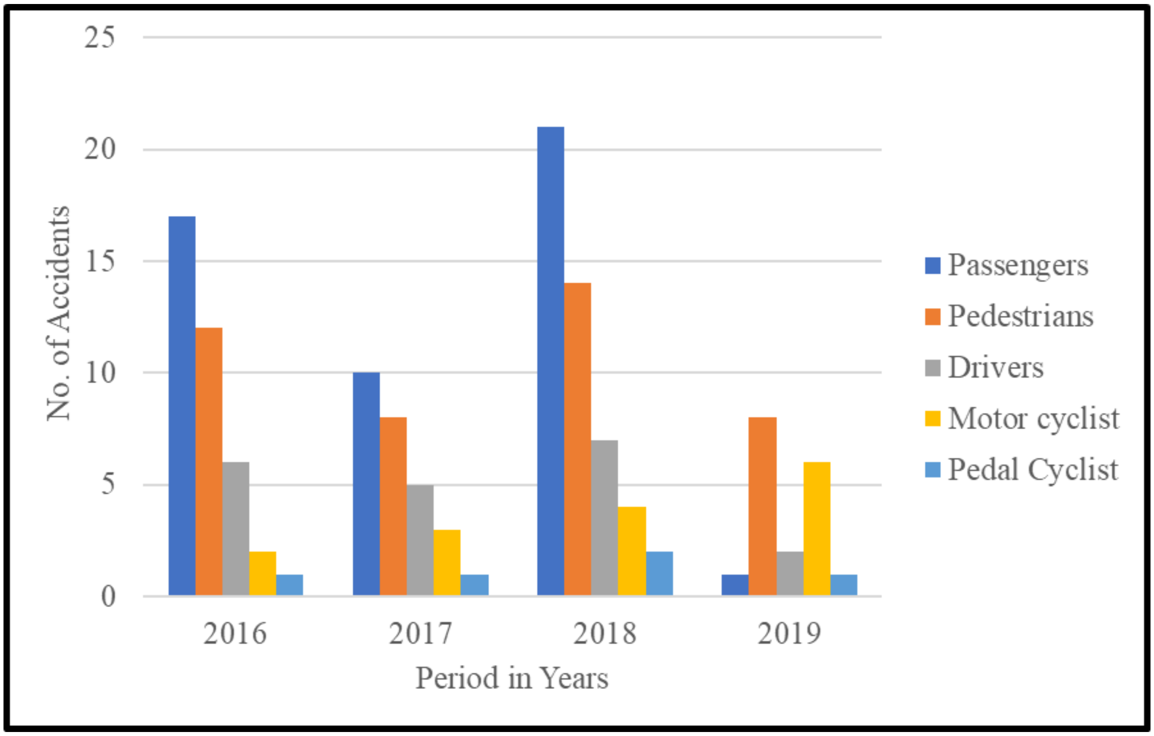


Figure 4.5: Victims affected annually

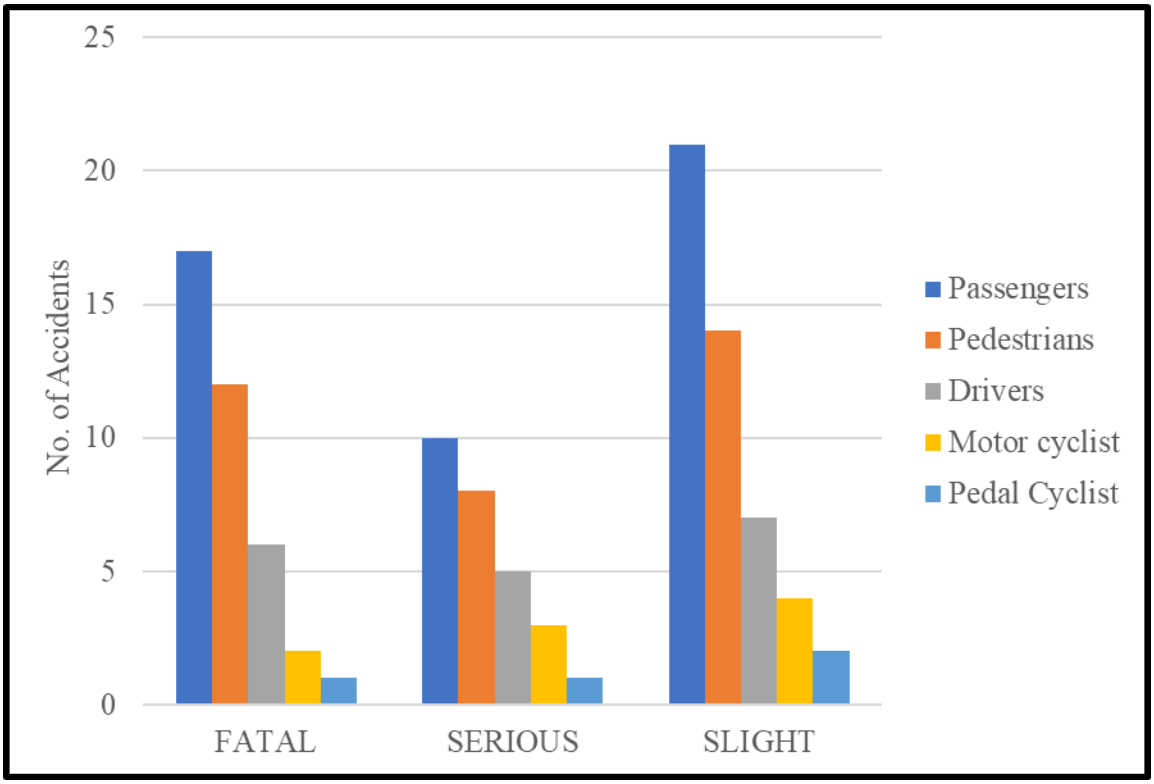


Figure 4.6: Victim affected (accident classes)

4.3.5 Causes of Accidents

The questionnaire data analysis shows that the common causes of accidents are speeding and improper overtaking as shown in Table 4.1 below. The respondents also stated other accident causes that had not been included in the questionnaires. They included: drunk driving, lack of proper road signs due to vandalism, lack of footbridges, animal crossings and pedestrian crossings, inexperience with the road for new road users' distracted driving i.e. using mobile phones while driving and motorists leaving vehicles on the road unattended.

Table 4.1: Causes of Accidents

Measures	Strongly agree (5)	Agree (4)	Undecided (3)	Disagree (2)	Strongly disagree (1)	Frequency rating
Over speeding	16	13		1		4.5
Improper overtaking	17	10	1	2		4.4
Driver's failure to obey/ignorance of traffic rules	8	16	4	0	2	3.9
Poor Roadway Maintenance	1	1	4	13	10	1.9
Poor road marking	1	4	3	8	14	1.9
Defective motor vehicles (brakes/other vehicle parts)	5	8	4	11	1	3.2
Lack of roadway identification signs	4	4	6	14	2	2.7
Lack of Speed bumps, raised medians, pedestrian islands	8	8	4	8	4	3.3
Bad weather	3	5	1	10	10	2.4

The Figure 4.7 below shows the recording of accidents along the bypass be the traffic police according to cause codes. Each Cause Code represents a certain cause of traffic accident. Some of the Cause Codes include: Code 7- Driver proceeding with high speed; 8- Driver failing to keep to the proper lane; 10- Driver improperly overtaking;26- Driver losing control of the vehicle; 29- Driver misjudging clearance, distance or speed; 30- Driver's error of judgment or negligence; 68- Pedestrian's error of judgment or negligence and 98- Cause not traced. The traffic accident data indicated that 6% of the accidents that occurred along the Nairobi Southern Bypass could not be traced (Cause Code 98). Most of the accidents that had occurred were as a result of the driver losing control of the vehicle (Cause Code 26). This resulted in 29% of the total accidents. Another 11% of the accidents were caused by speeding while 10% of the accidents were cause by the pedestrians' error of judgment or negligence. Some of the other causes of accidents recorded by the Kenya Police were driver swerving, skidding, failing to comply to the traffic signs or signals, improperly changing the lanes, suddenly stopping, cyclists speeding, pedestrians being heedless to the traffic or mechanical defects or failure.

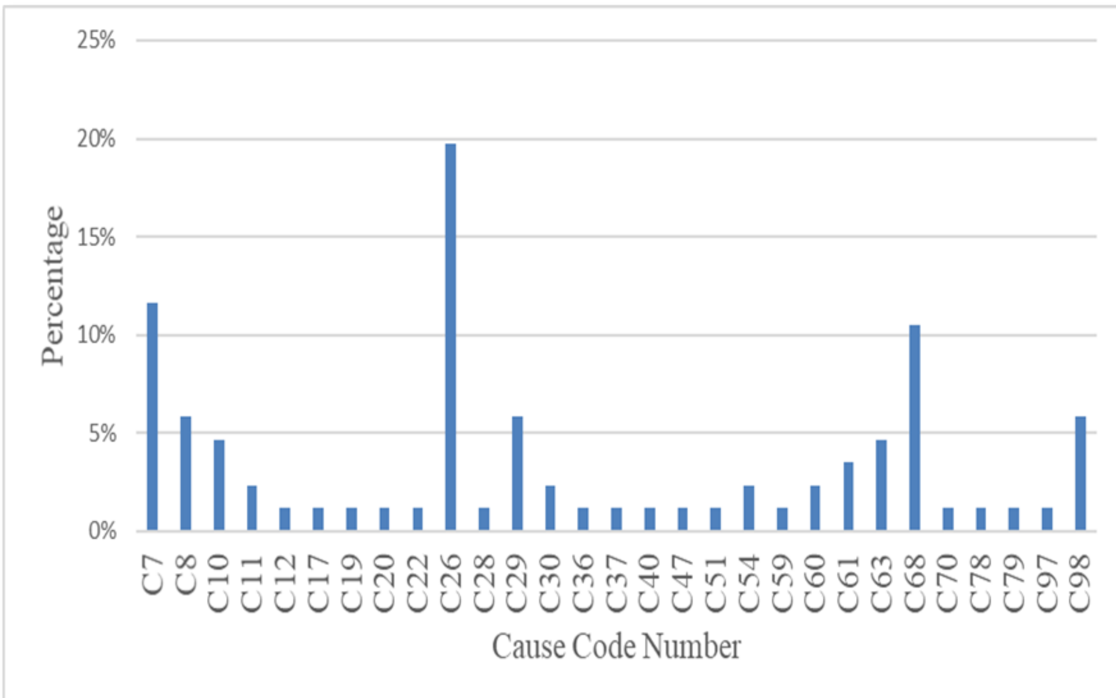


Figure 4.7: Cause codes of the accident occurrences along the Nairobi Southern Bypass between 2016 and 2019

Geometric Design Consistency of Nairobi Southern Bypass (UCA-2) Road

In achieving the second objective which was, to evaluate the geometric design consistency of Nairobi Southern bypass (UCA-2) road in Nairobi County, the following are the results and discussion. The discussions are based on the operating speed, vehicle stability, alignment indices and driver workload.

4.4.1 Operating Speed

From the spot speed data acquired from the Kenya National Highways Authority Weighbridge, the operating speed (V_{85}) of the Nairobi Southern Bypass was found to be

91 Km/h. With a design speed (V_d) of 90 Km/h, the difference between (V_{85}) and (V_d) was found to be 1 Km/h. The speed reduction ΔV_{85} was calculated to be 16.959 Km/h. As far as operating speed was concerned and using the criterion illustrated in Table 2.1, the geometric design of the Nairobi Southern Bypass was found to be consistent. Based on speed reduction as in Table 2.2, the geometric design of the Nairobi Southern Bypass was also found to be fairly consistent.

Using the models, the collision rate based on ($V_{85} - V_d$) was predicted to be 369 collisions per five years. According to Table 2.6, this indicated that the design of the Nairobi Southern Bypass was geometrically consistent. The collision rate based on ΔV_{85} using the model in Table 2.6 was calculated to be 1140 collisions per 5 years. With this value being lower than the one stipulated in table, it was concluded that the Nairobi Southern Bypass had geometric design consistency. To summarize this, it was found that the V_{85} and ΔV_{85} were adequate and they only affected safety of the Nairobi Southern Bypass to a negligible extent. However, Tarris et al. (1995) states that the effect of operating speed on road safety may be overstated or understated since the using speed data acquired from low-speed urban streets reduces the total and nature of variability associated with regression functions of a descriptive statistic that has been acquired from data aggregation, like the 85th percentile speed.

4.4.2 Vehicle Stability

From the computations made in Appendix III, the side friction assumed f_{RA} was found to be 0.104 while the side friction demanded f_{RD} was 0.0734. The difference between the two (Δf_R) was calculated to be 0. 0301. Using the criteria in Table 2.3, the Nairobi Southern Bypass was found to be geometrically consistent when it was based on vehicle stability. From the model used to calculate the collision rate shown in Table 2.6, about 273 collisions were predicted to take place in the next five years based on vehicle stability. From the criterion presented on table, the above predicted collision rate indicated that the design of the Nairobi Southern Bypass was geometrically consistent.

This means that the side friction assumed is sufficient, the super elevation of the road is adequate and no improvement was required. Vehicle stability is not always represented in geometric design due to some reasons. Firstly, the interaction between the longitudinal and side friction as well as the friction distribution on the vehicle's tires is ignored due to the fact that the vehicle is represented by a point mass. Secondly, there is an invalid assumption that all vehicles will travel at a constant speed even when negotiating a curve (Gibreel, Easa, Hassan & El-Dimery, 1999). Lastly, empirical data show that there is an invalid assumption that drivers follow a path with radius identical to the curve radius. For the above reasons, even if a highway design is created according to design standards, vehicle stability may not be guaranteed (Joanne, 2002).

4.4.3 Alignment Indices

From the computations made in Appendix III, the ratio of individual radius to average radius (CRR) was calculated and found to be 0. 4527. On the collision rate predictions, 382 accidents were predicted. Using the criteria on Table 2.6, this value was lower than the minimum number of accidents required to declare a road geometrically consistent. It therefore means that the Nairobi Southern Bypass had a design that was consistent when it came to matters pertaining to alignment. Although alignment indices are the most direct measures of design consistency, they are not the most effective. This is due to the fact that the indices are calculated from a whole alignment and not an individual section. It would be very important to determine how transitions such as tangent to curve or curve to curve violate a driver's expectations (Joanne, 2002).

4.4.4 Driver Workload

From computations in Appendix III, the visual demand of familiar drivers (VD_{LF}) was found to be 0.242 while the visual demand of unfamiliar drivers (VD_{LU}) was 0.238. The average workload (WL) was calculated to be 0. 331. Using the criterion shown in Table 2.4, the driver workload was found to be within the recommended limits and a driver would experience minimal problems while driving along Nairobi Southern Bypass. The

Nairobi Southern Bypass was therefore geometrically consistent when based on driver workload. The collision rate prediction was 274 collisions for VD_{LU} and 275 collisions for VD_{LF}. Using Table 2.5, these values indicated that the Nairobi Southern Bypass was geometrically consistent. According to Joanne (2002), use of very high or low driver workload in designing highway sections should be avoided. This is because in highways with high driver workload, there are complex features put in place with very little time for a driver to decide hence violating the driver's expectation. Highways with very low driver workload are also dangerous since the driver's attention will be lowered for a very long period and this reduces the driver's ability to handle a surprising feature that may arise.

Chapter Summary

The first specific objective of the study was to determine the frequency, type and severity of accidents on Nairobi Southern bypass (UCA-2) road in Nairobi County. Data collected between June, 2016 and June, 2018 was acquired from the Kenya Police and analyzed. The results analysis showed that 87 accidents had occurred between June 2016 and April 2019 with June, 2016 being the month with the highest accident incidences (12%).On the other month, the lowest number of accident occurrences were recorded in June, 2018(2%).

There were 131 traffic accident victims affected with passengers (35%) being the most affected and cyclists (4%) being the least affected.

From the secondary data from the Kenya Police, most of the accidents that had occurred were as a result of the driver losing control of the vehicle (29%). Another 11% of the recorded accidents were caused by speeding while 10% of the accidents were cause by the pedestrians' error of judgment or negligence. Some of the other causes of accidents recorded by the Kenya Police (which are around 1% each) were driver swerving, skidding, failing to comply to the traffic signs or signals, improperly changing the lanes, suddenly stopping, cyclists speeding, pedestrians being heedless to the traffic or mechanical defects or failure. From the responses made by questionnaires respondents, the common accident causes in the included over speeding, improper overtaking and driver ignorance of traffic rules.

The second objective was to evaluate the geometric design consistency of Nairobi Southern bypass (UCA-2) road in Nairobi County. The operating speed (V_{85}) was calculated to be 91Km/h. Using the design speed (V_d) of 90Km/h, $V_{85} - V_d$ was 1 Km/h and ΔV_{85} was 16.959 Km/h. Based on $V_{85} - V_d$ and ΔV_{85}, about 369 and 1140 collisions were predicted to take place by the year 2023 respectively.

On vehicle stability, side friction assumed(f_{RA}) and demanded (f_{RD}) was found to be 0.104 and 0.0734 respectively. The difference between the two (Δf_R) was calculated to be 0. 0301. From the criteria in Table 2.3, a value of Δf_R above 0.01 indicates that a roadway is geometrically consistent. Using the model used to calculate the collision rate (Table 2.6), 273 collisions were predicted to take place by 2023.

On alignment indices, the ratio of individual radius to average radius (CRR) was calculated to be 0. 4527 and about 382 accidents were predicted to have occurred between the year 2018 and 2023.

From calculations in Appendix III, the visual demand of familiar (VD_{LF}) and unfamiliar drivers (VD_{LU}) was 0.242 and 0.238 respectively. The average workload (WL) was calculated to be 0. 331. From the criterion shown in Table 2.4, the driver workload was found to be within the recommended limits (1-5). The predicted collision rates by 2023 were 274 and 275 for VD_{LU} and VD_{LF} respectively.

From the criterion presented on Table 2.6, predicted collisions less than 2.27×10^6 indicate that road is geometrically consistent. Basing the collision rate predictions on the four geometric design components of the Nairobi Southern Bypass Road, all the predicted collision rates were below 2.27×10^6, therefore the Nairobi Southern Bypass (UCA-2) Road is geometrically consistent.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The study investigated the effect of geometric design consistency on road safety focusing on the Nairobi-Southern bypass (UCA-2) road. The specific objectives were: To determine the frequency, type and severity of accidents on Nairobi Southern bypass (UCA-2) road in Nairobi County. To determine the design consistency measures and evaluate their applicability on road safety along Nairobi Southern bypass (UCA-2) road in Nairobi County, Kenya**.** The discussions were based on the operating speed, vehicle stability, alignment indices and driver workload.

5.1.1 Frequency, Type and Severity of Accidents

It was established that a total of 87 traffic accidents had occurred along Nairobi Southern Bypass during the period between June 2016 and April 2019. About 26% occurring in 2016, 20% in 2017, 36% in 2018 and 18% in 2019 and from the total accident incidences, 39% of them were fatal, 47% seriously injurious while 14% were slightly injurious. The victims were drivers, passengers, pedestrians, pedal cyclists and motor cyclists. Out of the 131 victims recorded, passengers led with 35%. The major cause of the traffic accidents from the road users' point of view was over speeding with a frequency rating of 4.5 out of 5. With a frequency rating of 2.4 out of 5, bad weather was recorded as the least contributor to traffic accidents along the Nairobi Southern Bypass.

5.1.2 Geometric Design Consistency Measures and their Applicability

The analysis of the spot speed data, "as-built" drawings and traffic volume data acquired from the Kenya National Highways Authority and the China Road and Bridge Corporation was done. Using the indicated criteria and models, all the measures of geometric design of the Nairobi Southern Bypass, that is, operating speed, vehicle stability, alignment indices and driver workload, were found to be consistent. This therefore indicated that the geometric design of the Nairobi Southern Bypass was adequate and that the traffic accidents that occurred were mainly cause by reasons other than the geometric design. Such reasons may have included road user carelessness, poor road maintenance, vehicle equipment failure and bad weather (odero et al. 2003; Muchene et al. (2018).

5.2 Recommendations

5.2.1 Recommendations from the Study

From the study, it was concluded that the geometric design of Nairobi Southern Bypass (UCA-2) Road is consistent and there are no further adjustments or improvement that should be done on the geometric design features to improve on safety on the road. Speeding is one of the major causes of accidents identified, it is therefore recommended that the operating speed of vehicles is considered during the design of roads.

5.2.2 Areas for Further Study

The current study focused on the effect of geometric design consistency on road safety along Nairobi-Southern Bypass (UCA-2) road. The effect of vehicles defects and human errors were considered to be constant for this study, and thus should be considered in future road safety studies. It is also noted that although alignment indices are the most direct measures of design consistency, they are not the most effective. This is due to the fact that the indices are calculated from a whole alignment and not an individual section. It would be important to determine how transitions such as tangent to curve or curve violet a driver's expectations (Joanne, 2002).

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APPENDICES

Appendix I: AADT CALCULATIONS

TRAFFIC COUNT ALONG NAIROBI SOUTHERN BYPASS (UCA2) ROAD AT THE VIRTUAL WEIGH BRIDGE																			
Station Name:		No. of Vehicles																	
Date:		7th October, 2018 To 13th October, 2018																	
						Buses					TRUCKS							Others eg:Tractors	
Vehicle Type		M/Cycles and B/Cycles	Cars KB	Cars MB	Picups,Jeeps,4 WD,Van	Minibus (<25 seats)KB	Minibus (<25 seats)KB	Minibus (25-40 seats)KB	Minibus (25-40 seats)MB	(>40 seats)	Light Trucks (3-6 Tonnes)KB	Light Trucks (3-6 Tonnes)MB	(2 axles,7-10 Tonnes)	Heavy (3 axles)KB	Heavy (3 axles)MB	4-7 axles KB	4-7 axles MB	KB	MB
10/7/2018 0:00			91	0				8	0		0	0		0	0	17	0	3	0
10/7/2018 1:00			53	0				6	0		1	0		0	0	15	0	0	0
10/7/2018 2:00			50	0				10	0		1	0		0	0	13	0	1	0
10/7/2018 3:00			46	0				3	0		1	0		0	0	16	0	2	0
10/7/2018 4:00			58	0				7	0		0	0		4	0	41	0	5	0
10/7/2018 5:00			106	0				11	0		1	0		1	0	62	0	4	0
10/7/2018 6:00			157	0				17	0		2	0		2	0	80	0	3	0
10/7/2018 7:00			211	0				38	0		2	0		3	0	50	0	7	0
10/7/2018 8:00			269	0				37	0		5	0		8	0	56	0	8	0
10/7/2018 9:00			434	0				29	0		3	0		7	0	58	0	7	0
10/7/2018 10:00			440	0				46	0		4	0		4	0	61	0	6	0
10/7/2018 11:00			488	0				29	0		2	0		5	0	63	0	7	0
10/7/2018 12:00			515	0				36	0		3	0		2	0	78	0	12	0
10/7/2018 13:00			552	0				37	0		3	0		4	0	90	0	13	0
10/7/2018 14:00			653	0				38	0		4	0		9	0	65	0	14	0
10/7/2018 15:00			570	0				30	0		0	0		4	0	75	0	10	0
10/7/2018 16:00			365	0				22	0		2	0		0	0	22	0	2	0
10/7/2018 17:00			317	0				18	0		0	0		0	0	7	0	0	0
10/7/2018 18:00			293	0				17	0		0	0		0	0	2	0	2	0
10/7/2018 19:00			362	0				28	0		0	0		1	0	46	0	2	0
10/7/2018 20:00			284	0				12	0		1	0		2	0	30	0	7	0
10/7/2018 21:00			199	0				2	0		0	0		2	0	34	0	5	0
10/7/2018 22:00			124	0				11	0		0	0		1	0	25	0	0	0
10/7/2018 23:00			68	0				3	0		0	0		0	0	10	0	0	0
10/8/2018 0:00			24	0				2	0		0	0		0	0	13	0	2	0
10/8/2018 1:00			12	0				5	0		0	0		0	0	6	0	2	0
10/8/2018 2:00			12	0				4	0		0	0		0	0	17	0	0	0
10/8/2018 3:00			20	0				2	0		0	0		0	0	19	0	1	0
10/8/2018 4:00			52	0				9	0		1	0		1	0	20	0	2	0
10/8/2018 5:00			192	0				17	0		1	0		7	0	49	0	1	0
10/8/2018 6:00			419	0				42	0		4	0		9	0	38	0	5	0
10/8/2018 7:00			715	0				74	0		6	0		9	0	23	0	5	0
10/8/2018 8:00			650	0				71	0		6	0		17	0	32	0	8	0
10/8/2018 9:00			583	0				94	0		10	0		27	0	55	0	7	0
10/8/2018 10:00			541	0				89	0		8	0		17	0	47	0	15	0
10/8/2018 11:00			497	0				99	0		3	0		20	0	58	0	11	0
10/8/2018 12:00			553	0				98	0		6	0		15	0	68	0	15	0
10/8/2018 13:00			563	144				99	11		9	4		18	5	59	12	10	3
10/8/2018 14:00			522	585				86	82		7	1		16	17	31	74	8	27
10/8/2018 15:00			558	689				38	78		0	5		5	19	18	64	4	27
10/8/2018 16:00			783	880				54	83		3	11		8	13	17	62	4	16
10/8/2018 17:00			1100	996				100	72		2	1		11	14	43	44	12	12
10/8/2018 18:00			809	807				82	81		11	1		13	13	63	72	9	9
10/8/2018 19:00			641	579				90	38		3	3		9	9	55	60	3	7
10/8/2018 20:00			410	401				70	38		3	1		3	5	42	48	3	3
10/8/2018 21:00			261	210				27	15		3	0		5	5	44	38	4	4
10/8/2018 22:00			112	103				23	20		1	0		3	1	23	38	4	3

10/8/2018 23:00			57	54				12	12		1	1		1	4	7	31	1	3
10/9/2018 0:00			22	21				4	12		1	0		0	2	10	17	0	0
10/9/2018 1:00			7	23				9	8		0	1		0	1	12	10	1	1
10/9/2018 2:00			9	14				3	15		0	0		0	2	8	19	1	0
10/9/2018 3:00			19	9				0	8		1	0		0	0	4	19	2	2
10/9/2018 4:00			32	44				6	14		1	0		2	4	14	33	2	4
10/9/2018 5:00			107	185				5	35		0	0		0	10	10	48	3	5
10/9/2018 6:00			296	755				22	58		0	6		3	7	13	76	14	12
10/9/2018 7:00			548	1318				43	69		7	3		4	12	18	62	6	23
10/9/2018 8:00			574	1120				60	71		4	3		14	9	43	65	8	23
10/9/2018 9:00			452	829				75	95		2	6		25	22	39	89	5	21
10/9/2018 10:00			403	669				41	85		5	2		10	22	13	59	15	27
10/9/2018 11:00			415	582				56	76		1	2		3	28	33	63	17	22
10/9/2018 12:00			419	565				62	72		3	6		6	19	25	53	9	13
10/9/2018 13:00			441	605				50	97		3	7		2	15	18	57	19	16
10/9/2018 14:00			469	618				44	70		1	3		7	12	14	86	6	34
10/9/2018 15:00			624	726				74	86		5	11		7	18	43	71	14	18
10/9/2018 16:00			738	810				54	91		4	5		13	10	25	91	19	20
10/9/2018 17:00			857	1091				48	98		2	7		6	17	16	60	12	23
10/9/2018 18:00			116	38				6	0		1	0		3	1	3	1	2	2
10/9/2018 19:00			511	506				56	58		2	5		3	14	16	61	11	9
10/9/2018 20:00			351	434				61	44		5	1		8	8	40	72	6	7
10/9/2018 21:00			269	273				39	35		3	0		3	6	34	53	5	5
10/9/2018 22:00			159	118				13	27		0	0		5	3	31	29	2	2
10/9/2018 23:00			99	62				6	8		1	0		0	4	19	27	0	1
10/10/2018 0:00			62	49				14	9		0	0		1	2	8	17	0	1
10/10/2018 1:00			44	27				11	5		0	1		2	0	19	13	0	0
10/10/2018 2:00			32	20				7	6		1	0		0	0	10	14	1	3
10/10/2018 3:00			27	17				8	6		0	0		1	2	20	24	1	3
10/10/2018 4:00			33	50				11	9		0	0		3	4	21	36	0	4
10/10/2018 5:00			79	91				6	15		2	2		2	6	27	43	4	9
10/10/2018 6:00			154	155				23	25		2	2		8	10	12	67	4	13
10/10/2018 7:00			190	228				25	45		0	2		8	9	19	65	2	16
10/10/2018 8:00			256	260				28	34		4	2		14	11	17	62	5	8
10/10/2018 9:00			226	151				24	29		0	3		10	10	15	27	6	3
10/10/2018 10:00			454	448				57	55		4	1		11	20	45	61	6	10
10/10/2018 11:00			425	466				42	46		1	2		9	26	45	39	6	14
10/10/2018 12:00			489	485				36	48		1	6		9	14	73	97	11	11
10/10/2018 13:00			510	52				61	3		7	0		17	2	72	5	11	1
10/10/2018 14:00			440	0				26	0		1	0		6	0	18	0	10	0
10/10/2018 15:00			406	286				19	25		0	2		4	9	6	26	8	7
10/10/2018 16:00			361	529				18	51		0	2		2	13	9	65	5	19
10/10/2018 17:00			434	592				36	54		0	2		5	17	44	64	7	10
10/10/2018 18:00			457	593				27	46		3	1		8	6	60	49	3	16
10/10/2018 19:00			372	539				21	39		1	4		3	0	54	70	5	8
10/10/2018 20:00			288	324				22	33		3	0		0	6	31	49	2	4
10/10/2018 21:00			186	229				14	29		1	0		1	7	28	48	0	2
10/10/2018 22:00			125	106				8	13		0	0		1	1	37	31	4	6
10/10/2018 23:00			61	62				9	14		0	0		1	2	27	25	3	1
10/11/2018 0:00			41	20				13	11		1	0		1	2	16	19	1	3
10/11/2018 1:00			21	19				5	9		0	0		0	1	9	23	1	0
10/11/2018 2:00			19	17				6	10		0	0		0	0	15	17	0	1
10/11/2018 3:00			22	16				9	9		1	0		2	0	20	24	3	4
10/11/2018 4:00			40	50				7	17		1	0		4	8	31	25	2	3
10/11/2018 5:00			166	176				31	37		3	1		5	13	62	43	2	9
10/11/2018 6:00			407	798				43	82		4	2		25	8	55	74	2	19
10/11/2018 7:00			715	1313				62	79		5	3		21	22	52	60	10	34
10/11/2018 8:00			676	1167				66	71		11	3		15	24	38	68	14	29
10/11/2018 9:00			312	461				42	41		3	4		25	15	29	33	6	6
10/11/2018 10:00			388	341				66	41		4	3		11	16	48	36	10	15
10/11/2018 11:00			517	593				99	79		8	9		20	23	78	67	13	25
10/11/2018 12:00			545	563				97	77		3	7		28	32	80	47	7	17
10/11/2018 13:00			456	587				83	80		5	7		19	17	42	43	7	22
10/11/2018 14:00			530	588				59	75		2	4		8	27	33	68	5	16
10/11/2018 15:00			672	231				92	24		3	0		17	6	70	25	11	11

10/11/2018 16:00			978	0				119	0		6	0		29	0	57	0	11	0
10/11/2018 17:00			1174	0				116	0		6	0		18	0	73	0	7	0
10/11/2018 18:00			935	0				104	0		4	0		8	0	87	0	8	0
10/11/2018 19:00			542	0				90	0		2	0		16	0	44	0	7	0
10/11/2018 20:00			397	0				63	0		4	0		6	0	26	0	6	0
10/11/2018 21:00			244	0				25	0		1	0		4	0	34	0	3	0
10/11/2018 22:00			109	0				18	0		1	0		2	0	17	0	2	0
10/11/2018 23:00			72	0				13	0		0	0		4	0	11	0	0	0
10/12/2018 0:00			25	0				9	0		0	0		1	0	6	0	0	0
10/12/2018 1:00			12	0				1	0		0	0		1	0	2	0	0	0
10/12/2018 2:00			11	0				0	0		0	0		2	0	0	0	0	0
10/12/2018 3:00			23	0				10	0		2	0		0	0	18	0	1	0
10/12/2018 4:00			37	0				6	0		0	0		0	0	3	0	2	0
10/12/2018 5:00			131	0				20	0		2	0		4	0	23	0	5	0
10/12/2018 6:00			381	0				44	0		3	0		13	0	38	0	5	0
10/12/2018 7:00			545	0				50	0		3	0		13	0	28	0	6	0
10/12/2018 8:00			459	0				48	0		12	0		4	0	9	0	6	0
10/12/2018 9:00			528	0				60	0		2	0		14	0	11	0	13	0
10/12/2018 10:00			563	0				84	0		4	0		19	0	20	0	7	0
10/12/2018 11:00			476	0				59	0		2	0		8	0	10	0	6	0
10/12/2018 12:00			471	0				34	0		6	0		8	0	7	0	20	0
10/12/2018 13:00			572	0				60	0		3	0		9	0	33	0	8	0
10/12/2018 14:00			683	0				88	0		3	0		17	0	116	0	18	0
10/12/2018 15:00			774	0				71	0		9	0		17	0	85	0	18	0
10/12/2018 16:00			916	0				107	0		5	0		24	0	59	0	11	0
10/12/2018 17:00			1176	0				136	0		11	0		10	0	90	0	11	0
10/12/2018 18:00			963	0				121	0		9	0		22	0	86	0	15	0
10/12/2018 19:00			649	0				112	0		1	0		10	0	92	0	14	0
10/12/2018 20:00			485	0				58	0		1	0		7	0	63	0	7	0
10/12/2018 21:00			276	0				26	0		1	0		2	0	36	0	5	0
10/12/2018 22:00			161	0				20	0		0	0		0	0	33	0	2	0
10/12/2018 23:00			118	0				15	0		0	0		2	0	28	0	5	0
10/13/2018 0:00			75	0				14	0		0	0		0	0	18	0	0	0
10/13/2018 1:00			57	0				10	0		1	0		1	0	13	0	1	0
10/13/2018 2:00			49	0				6	0		0	0		0	0	30	0	0	0
10/13/2018 3:00			58	0				24	0		0	0		3	0	34	0	3	0
10/13/2018 4:00			78	0				18	0		3	0		2	0	43	0	3	0
10/13/2018 5:00			146	0				23	0		3	0		4	0	69	0	5	0
10/13/2018 6:00			318	0				53	0		5	0		18	0	82	0	7	0
10/13/2018 7:00			380	0				53	0		6	0		21	0	70	0	6	0
10/13/2018 8:00			467	0				60	0		1	0		36	0	63	0	15	0
10/13/2018 9:00			583	0				88	0		4	0		23	0	69	0	11	0
10/13/2018 10:00			623	0				103	0		1	0		20	0	78	0	8	0
10/13/2018 11:00			678	0				91	0		7	0		19	0	68	0	13	0
10/13/2018 12:00			709	0				97	0		3	0		15	0	105	0	20	0
10/13/2018 13:00			885	0				106	0		6	0		29	0	102	0	20	0
10/13/2018 14:00			651	0				50	0		1	0		6	0	47	0	7	0
10/13/2018 15:00			540	0				38	0		3	0		5	0	18	0	8	0
10/13/2018 16:00			464	0				36	0		3	0		2	0	18	0	6	0
10/13/2018 17:00			476	0				32	0		2	0		0	0	20	0	8	0
10/13/2018 18:00			496	0				44	0		4	0		1	0	47	0	7	0
10/13/2018 19:00			456	0				39	0		1	0		2	0	34	0	4	0
10/13/2018 20:00			307	0				23	0		2	0		5	0	19	0	3	0
10/13/2018 21:00			247	0				15	0		1	0		4	0	19	0	3	0
10/13/2018 22:00			216	0				9	0		0	0		1	0	8	0	1	0
10/13/2018 23:00			127	0				9	0		0	0		1	0	52	0	0	0
TOTAL			60338	29562				6780	3143		420	171		1236	742	6130	3433	1021	787
PASSENGER CAR EQUIVALENT			1	1				2	2		2.5	2.5		3.5	3.5	3.5	3.5	3.5	3.5
ADT(Veh/day)			8620	4223				1937	898		150	61		618	371	3065	1717	511	394
TOTAL ADT(Veh/d)			22564																
														.					
Station Name:		**No. of Vehicles**																	
Date:		**25th March, 2019 To 31st March, 2019**																	

								Buses				TRUCKS						Others eg:Tractors	
Vehicle Type		M/Cycles and B/Cycles	Cars KB	Cars MB	Picups,Jeeps,4 WD,Van	Minibus (<25 seats)KB	Minibus (<25 seats)KB	Minibus (25-40 seats)KB	Minibus (25-40 seats)MB	(>40 seats)	Light Trucks (3-6 Tonnes)KB	Light Trucks (3-6 Tonnes)MB	(2 axles,7-10 Tonnes)	Heavy (3 axles)KB	Heavy (3 axles)MB	4-7 axles KB	4-7 axles MB	KB	MB
10/7/2018 0:00			42	36				13	6		0	0		1	4	9	1	0	1
10/7/2018 1:00			21	24				5	16		0	0		0	3	12	1	1	0
10/7/2018 2:00			29	22				9	16		0	0		0	1	14	55	0	11
10/7/2018 3:00			29	27				10	19		2	2		1	7	14	40	0	8
10/7/2018 4:00			79	75				12	21		4	4		4	4	27	44	0	7
10/7/2018 5:00			183	262				32	45		2	2		4	11	59	48	1	11
10/7/2018 6:00			402	1027				49	69		3	3		16	7	21	67	4	27
10/7/2018 7:00			765	1643				78	73		7	7		25	7	44	75	6	36
10/7/2018 8:00			688	1286				85	77		0	0		25	28	57	79	9	38
10/7/2018 9:00			556	867				88	92		4	4		28	24	45	80	8	28
10/7/2018 10:00			564	733				115	92		2	2		28	28	52	68	14	29
10/7/2018 11:00			573	591				120	72		1	1		14	23	81	56	10	26
10/7/2018 12:00			556	590				102	69		3	3		20	15	63	62	6	24
10/7/2018 13:00			571	583				105	78		2	2		21	22	80	69	5	19
10/7/2018 14:00			660	593				90	82		3	3		25	23	54	45	10	16
10/7/2018 15:00			834	666				121	67		2	2		35	19	83	63	10	26
10/7/2018 16:00			1110	861				127	89		8	8		19	17	68	66	19	35
10/7/2018 17:00			1285	951				126	76		9	9		17	19	69	46	14	26
10/7/2018 18:00			1052	759				123	73		5	5		27	21	53	50	17	23
10/7/2018 19:00			621	501				103	56		2	2		12	5	47	56	12	9
10/7/2018 20:00			472	327				63	38		1	1		3	11	50	37	4	7
10/7/2018 21:00			266	252				37	31		0	0		1	7	39	42	2	6
10/7/2018 22:00			141	106				33	24		0	0		1	6	22	33	2	4
10/7/2018 23:00			84	66				21	10		0	0		2	2	35	32	1	6
10/8/2018 0:00			41	40				17	14		1	1		1	3	11	43	5	4
10/8/2018 1:00			18	21				12	17		0	0		0	2	17	19	1	4
10/8/2018 2:00			15	19				13	13		1	1		3	1	23	29	1	3
10/8/2018 3:00			29	15				23	18		0	0		1	5	22	23	1	2
10/8/2018 4:00			50	53				36	26		2	2		4	5	26	26	1	6
10/8/2018 5:00			166	224				51	54		0	0		9	11	41	56	4	10
10/8/2018 6:00			341	1041				62	61		7	7		19	8	43	67	4	23
10/8/2018 7:00			704	1546				76	83		2	2		14	16	49	76	5	36
10/8/2018 8:00			729	1198				88	79		1	1		14	13	47	69	9	30
10/8/2018 9:00			604	944				107	114		11	11		29	15	53	71	9	35
10/8/2018 10:00			637	716				112	83		4	4		20	21	65	64	15	22
10/8/2018 11:00			566	656				128	95		4	4		21	21	71	48	21	92
10/8/2018 12:00			671	578				107	77		3	3		26	25	71	65	12	43
10/8/2018 13:00			621	547				128	85		3	3		19	17	73	53	18	17
10/8/2018 14:00			706	614				104	91		4	4		22	13	74	54	49	24
10/8/2018 15:00			894	672				132	100		1	1		15	18	99	79	10	22
10/8/2018 16:00			1117	779				130	94		4	4		16	23	78	61	15	22
10/8/2018 17:00			1446	925				130	95		5	5		21	36	83	80	22	20
10/8/2018 18:00			1138	840				131	69		7	7		8	17	93	74	24	24
10/8/2018 19:00			694	570				97	53		1	1		12	10	67	88	11	12
10/8/2018 20:00			468	351				56	31		1	1		7	9	35	50	2	13
10/8/2018 21:00			275	272				39	29		0	0		4	10	38	65	3	5
10/8/2018 22:00			152	117				23	32		1	1		3	4	35	38	6	6
10/8/2018 23:00			94	59				24	19		0	0		2	3	35	28	0	5
10/9/2018 0:00			43	27				13	16		0	0		0	3	15	42	1	1
10/9/2018 1:00			23	24				11	18		0	0		1	1	20	28	0	4
10/9/2018 2:00			32	13				19	19		0	0		1	6	20	26	2	7
10/9/2018 3:00			17	15				19	9		0	0		7	5	28	15	1	0
10/9/2018 4:00			50	64				38	19		2	2		1	8	35	37	0	9
10/9/2018 5:00			169	237				54	33		3	3		9	10	49	54	2	15
10/9/2018 6:00			342	1009				62	47		6	6		22	10	54	69	5	28
10/9/2018 7:00			726	1529				73	86		3	3		14	13	68	60	9	30
10/9/2018 8:00			662	1129				71	94		5	5		19	22	43	85	16	30
10/9/2018 9:00			694	872				100	114		4	4		32	22	70	78	11	28
10/9/2018 10:00			654	654				103	105		2	2		25	25	73	74	10	24
10/9/2018 11:00			615	632				104	70		5	5		15	31	97	48	16	25
10/9/2018 12:00			617	621				110	71		6	6		34	23	74	66	13	26

10/9/2018 13:00			635	566				103	73		2	2		19	16	83	59	18	21
10/9/2018 14:00			748	591				129	94		4	4		30	14	87	53	11	22
10/9/2018 15:00			855	685				105	99		4	4		33	21	98	45	10	22
10/9/2018 16:00			1124	848				112	83		9	9		29	32	85	59	8	18
10/9/2018 17:00			1382	969				120	93		7	7		15	19	94	68	24	33
10/9/2018 18:00			1044	806				122	66		6	6		18	23	98	54	13	20
10/9/2018 19:00			629	602				98	55		2	2		7	16	86	98	11	18
10/9/2018 20:00			454	369				76	45		5	5		3	17	65	59	9	8
10/9/2018 21:00			280	271				44	33		0	0		5	6	54	60	6	8
10/9/2018 22:00			162	132				25	28		0	0		5	7	43	50	1	10
10/9/2018 23:00			105	78				24	26		0	0		0	3	31	35	2	3
10/10/2018 0:00			51	27				11	22		0	0		1	4	21	34	0	1
10/10/2018 1:00			16	19				11	9		0	0		0	3	27	22	6	3
10/10/2018 2:00			29	18				19	10		0	0		0	4	23	26	0	5
10/10/2018 3:00			39	26				18	15		0	0		5	4	21	24	1	0
10/10/2018 4:00			70	55				31	20		2	2		3	7	41	20	4	8
10/10/2018 5:00			172	207				45	41		1	1		9	15	54	69	4	17
10/10/2018 6:00			369	937				90	73		8	8		24	9	41	54	6	18
10/10/2018 7:00			703	1462				92	79		5	5		24	17	62	70	6	33
10/10/2018 8:00			753	1190				92	92		2	2		25	23	67	58	12	28
10/10/2018 9:00			682	922				98	103		3	3		27	22	71	91	8	31
10/10/2018 10:00			585	710				115	98		1	1		16	27	89	86	11	25
10/10/2018 11:00			573	626				112	90		9	9		30	15	82	62	6	21
10/10/2018 12:00			601	607				116	92		5	5		31	25	86	55	15	23
10/10/2018 13:00			694	608				120	64		2	2		23	25	115	71	13	19
10/10/2018 14:00			639	576				101	103		4	4		27	21	78	57	17	23
10/10/2018 15:00			867	717				128	90		3	3		26	23	88	63	38	23
10/10/2018 16:00			1046	869				117	110		10	10		28	21	109	61	25	24
10/10/2018 17:00			1329	925				129	85		10	10		19	35	110	59	24	26
10/10/2018 18:00			1026	780				131	81		4	4		15	21	110	50	17	22
10/10/2018 19:00			694	545				102	55		3	3		14	12	89	37	13	15
10/10/2018 20:00			451	391				49	43		3	3		3	17	43	77	11	14
10/10/2018 21:00			334	268				46	36		1	1		4	14	65	72	8	18
10/10/2018 22:00			169	131				22	29		0	0		2	4	53	61	2	9
10/10/2018 23:00			125	79				19	27		0	0		3	3	22	35	1	5
10/11/2018 0:00			58	41				24	17		0	0		1	1	26	31	1	2
10/11/2018 1:00			43	27				17	23		1	1		1	1	23	29	0	2
10/11/2018 2:00			28	25				17	16		0	0		2	3	23	30	0	2
10/11/2018 3:00			45	20				21	15		1	1		4	5	32	31	1	5
10/11/2018 4:00			84	70				28	27		1	1		4	6	41	40	0	5
10/11/2018 5:00			255	261				53	47		1	1		12	14	71	84	3	20
10/11/2018 6:00			445	947				82	73		7	7		23	10	58	62	1	17
10/11/2018 7:00			826	1439				94	99		7	7		17	24	83	86	16	45
10/11/2018 8:00			781	1189				102	110		2	2		19	29	64	84	11	37
10/11/2018 9:00			640	860				113	105		9	9		22	20	80	63	7	25
10/11/2018 10:00			678	737				117	102		3	3		13	26	83	60	15	19
10/11/2018 11:00			703	700				118	106		1	1		28	23	78	51	11	26
10/11/2018 12:00			750	627				95	77		4	4		16	18	69	55	9	30
10/11/2018 13:00			768	669				102	84		1	1		19	24	91	55	9	22
10/11/2018 14:00			863	550				123	71		1	1		24	16	107	44	15	27
10/11/2018 15:00			1054	688				121	70		3	3		29	17	96	41	16	23
10/11/2018 16:00			1211	901				119	72		8	8		25	22	103	50	24	16
10/11/2018 17:00			1268	922				133	76		6	6		13	34	90	43	19	28
10/11/2018 18:00			994	907				94	81		5	5		15	24	68	34	10	25
10/11/2018 19:00			912	693				135	70		3	3		21	13	137	92	16	15
10/11/2018 20:00			589	531				82	65		1	1		6	8	85	68	10	11
10/11/2018 21:00			412	394				49	57		1	1		4	4	40	36	10	7
10/11/2018 22:00			232	229				42	40		1	1		5	4	39	33	3	4
10/11/2018 23:00			169	112				23	20		1	1		1	4	38	31	1	4
10/12/2018 0:00			95	88				10	17		0	0		0	1	27	26	0	2
10/12/2018 1:00			66	61				22	14		0	0		2	2	32	24	1	3
10/12/2018 2:00			65	45				14	13		0	0		1	0	25	28	1	5
10/12/2018 3:00			74	51				19	11		0	0		2	6	28	23	1	4
10/12/2018 4:00			115	59				21	21		0	0		2	9	29	29	2	5
10/12/2018 5:00			191	140				33	40		0	0		6	11	61	52	6	13

Date:

							Buses			TRUCKS							Others eg:Tractors	
Vehicle Type	M/Cycles and B/Cycles	Cars KB	Cars MB	Picups,Jeeps,4 WD,Van	Minibus (<25 seats)KB	Minibus (<25 seats)KB	Minibus (25-40 seats)KB	Minibus (25-40 seats)MB	(>40 seats)	Light Trucks (3-6 Tonnes)KB	Light Trucks (3-6 Tonnes)MB	(2 axles,7-10 Tonnes)	Heavy (3 axles)KB	Heavy (3 axles)MB	4-7 axles KB	4-7 axles MB	KB	MB
10/12/2018 6:00		**305**	**260**				**51**	**48**		**2**	**2**		**22**	**14**	**87**	**69**	**4**	**19**
10/12/2018 7:00		**434**	**507**				**74**	**74**		**1**	**1**		**34**	**17**	**77**	**82**	**9**	**24**
10/12/2018 8:00		**567**	**687**				**87**	**57**		**3**	**3**		**25**	**12**	**52**	**56**	**13**	**27**
10/12/2018 9:00		**639**	**795**				**95**	**93**		**2**	**2**		**21**	**18**	**66**	**67**	**9**	**42**
10/12/2018 10:00		**645**	**761**				**95**	**90**		**4**	**4**		**16**	**20**	**70**	**58**	**11**	**25**
10/12/2018 11:00		**820**	**695**				**102**	**77**		**1**	**1**		**21**	**9**	**103**	**58**	**13**	**32**
10/12/2018 12:00		**827**	**779**				**95**	**80**		**9**	**9**		**19**	**18**	**72**	**61**	**6**	**16**
10/12/2018 13:00		**958**	**806**				**98**	**68**		**1**	**1**		**21**	**22**	**98**	**50**	**22**	**24**
10/12/2018 14:00		**964**	**730**				**104**	**58**		**5**	**5**		**22**	**23**	**100**	**50**	**11**	**19**
10/12/2018 15:00		**975**	**725**				**98**	**76**		**10**	**10**		**26**	**16**	**136**	**57**	**23**	**20**
10/12/2018 16:00		**679**	**701**				**83**	**47**		**4**	**4**		**17**	**18**	**109**	**64**	**22**	**15**
10/12/2018 17:00		**649**	**662**				**90**	**72**		**5**	**5**		**16**	**21**	**97**	**74**	**13**	**34**
10/12/2018 18:00		**633**	**731**				**75**	**61**		**4**	**4**		**10**	**11**	**72**	**50**	**19**	**18**
10/12/2018 19:00		**541**	**634**				**49**	**39**		**2**	**2**		**4**	**22**	**74**	**47**	**3**	**17**
10/12/2018 20:00		**431**	**562**				**34**	**35**		**3**	**3**		**3**	**2**	**36**	**49**	**5**	**10**
10/12/2018 21:00		**374**	**401**				**31**	**29**		**2**	**2**		**1**	**9**	**58**	**76**	**4**	**8**
10/12/2018 22:00		**261**	**289**				**16**	**17**		**1**	**1**		**4**	**3**	**23**	**43**	**0**	**7**
10/12/2018 23:00		**184**	**177**				**12**	**17**		**0**	**0**		**2**	**3**	**21**	**28**	**3**	**5**
10/13/2018 0:00		**105**	**103**				**10**	**6**		**0**	**0**		**4**	**2**	**33**	**24**	**0**	**5**
10/13/2018 1:00		**65**	**66**				**14**	**14**		**0**	**0**		**2**	**3**	**14**	**17**	**1**	**3**
10/13/2018 2:00		**62**	**38**				**12**	**13**		**0**	**0**		**4**	**2**	**21**	**16**	**1**	**1**
10/13/2018 3:00		**67**	**37**				**13**	**18**		**1**	**1**		**2**	**2**	**23**	**20**	**4**	**2**
10/13/2018 4:00		**63**	**39**				**10**	**15**		**0**	**0**		**0**	**4**	**36**	**26**	**2**	**4**
10/13/2018 5:00		**101**	**83**				**19**	**11**		**0**	**0**		**5**	**3**	**52**	**54**	**2**	**8**
10/13/2018 6:00		**134**	**125**				**20**	**15**		**1**	**1**		**4**	**4**	**75**	**47**	**6**	**7**
10/13/2018 7:00		**226**	**185**				**24**	**22**		**1**	**1**		**9**	**8**	**64**	**76**	**6**	**20**
10/13/2018 8:00		**377**	**331**				**41**	**22**		**3**	**3**		**8**	**11**	**56**	**56**	**11**	**15**
10/13/2018 9:00		**453**	**377**				**42**	**26**		**0**	**0**		**3**	**6**	**67**	**64**	**5**	**12**
10/13/2018 10:00		**437**	**383**				**46**	**27**		**0**	**0**		**4**	**4**	**79**	**55**	**4**	**9**
10/13/2018 11:00		**529**	**483**				**41**	**28**		**1**	**1**		**6**	**7**	**105**	**51**	**5**	**11**
10/13/2018 12:00		**535**	**499**				**42**	**35**		**1**	**1**		**12**	**3**	**86**	**58**	**10**	**15**
10/13/2018 13:00		**533**	**581**				**43**	**25**		**1**	**1**		**5**	**5**	**87**	**67**	**10**	**15**
10/13/2018 14:00		**687**	**619**				**42**	**39**		**2**	**2**		**7**	**2**	**103**	**73**	**6**	**14**
10/13/2018 15:00		**664**	**634**				**43**	**31**		**1**	**1**		**3**	**6**	**85**	**60**	**6**	**15**
10/13/2018 16:00		**624**	**717**				**43**	**37**		**2**	**2**		**3**	**2**	**83**	**44**	**8**	**28**
10/13/2018 17:00		**577**	**790**				**48**	**28**		**0**	**0**		**1**	**3**	**65**	**55**	**10**	**14**
10/13/2018 18:00		**514**	**867**				**34**	**32**		**0**	**0**		**3**	**9**	**62**	**77**	**14**	**28**
10/13/2018 19:00		**435**	**711**				**41**	**25**		**1**	**1**		**2**	**10**	**53**	**46**	**13**	**9**
10/13/2018 20:00		**410**	**557**				**22**	**25**		**1**	**1**		**2**	**12**	**34**	**71**	**2**	**9**
10/13/2018 21:00		**296**	**312**				**14**	**22**		**1**	**1**		**0**	**3**	**31**	**49**	**2**	**7**
10/13/2018 22:00		**204**	**213**				**8**	**23**		**0**	**0**		**1**	**3**	**27**	**41**	**2**	**5**
10/13/2018 23:00		**108**	**100**				**12**	**24**		**0**	**0**		**0**	**1**	**16**	**28**	**1**	**1**
TOTAL		**81344**	**84818**				**11038**	**8826**		**418**	**418**		**2033**	**2096**	**9919**	**8806**	**1390**	**2792**
PASSENGER CAR EQUIVALENT		**1**	**1**				**2**	**2**		**2.5**	**2.5**		**3.5**	**3.5**	**3.5**	**3.5**	**3.5**	**3.5**
ADT(Veh/day)		**11621**	**12117**				**3154**	**2522**		**149.2857143**	**149**		**1016.5**	**1048**	**4959.5**	**4403**	**695**	**1396**

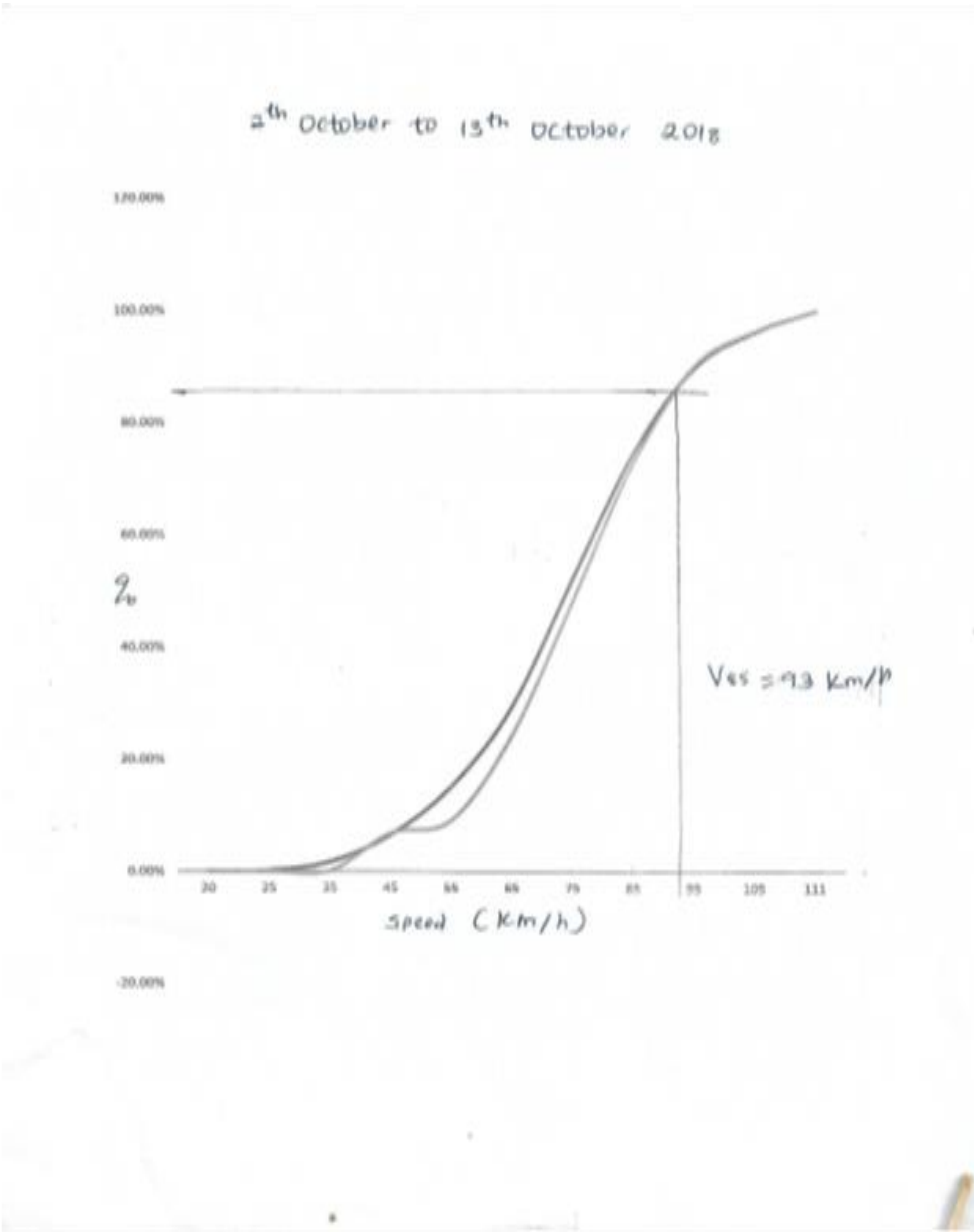
TOTAL ADT(Veh/d) **43229**

SEASONAL CONVERSION FACTOR **1.15**

AADT(Veh/d) **37832**

Vehicle Type	M/Cycles and B/Cycles	Cars KB	Cars MB	Picups,Jeeps,4 WD,Van	Minibus (<25 seats)KB	Minibus (<25 seats)KB	Minibus (25-40 seats)KB	Minibus (25-40 seats)MB	(>40 seats)	Light Trucks (3-6 Tonnes)KB	Light Trucks (3-6 Tonnes)MB	(2 axles,7-10 Tonnes)	Heavy (3 axles)KB	Heavy (3 axles)MB	4-7 axles KB	4-7 axles MB	KB	MB
10/7/2018 0:00		91	0				8	0		0	0		0	0	17	0	3	0
10/7/2018 1:00		53	0				6	0		1	0		0	0	15	0	0	0
10/7/2018 2:00		50	0				10	0		1	0		0	0	13	0	1	0
10/7/2018 3:00		46	0				3	0		1	0		0	0	16	0	2	0
10/9/2018 2:00		9	14				3	15		0	0		0	2	8	19	1	0
10/9/2018 3:00		19	9				0	8		1	0		0	0	4	19	2	2
10/9/2018 4:00		32	44				6	14		1	0		2	4	14	33	2	4
10/9/2018 5:00		[illegible]	[illegible]				5	35		0	0		0	10	10	48	3	5
10/9/2018 6:00		296	755				22	58		0	6		3	7	13	76	14	12
10/9/2018 7:00		548	1318				43	69		7	3		4	12	18	62	6	23
10/9/2018 8:00		574	1120				62	71		4	3		14	9	43	65	8	23
10/9/2018 9:00		452	829				75	95		2	6		25	22	39	89	5	21
10/9/2018 10:00		403	669				41	85		5	2		10	22	13	59	15	27
10/9/2018 11:00		415	582				56	76		1	2		3	28	33	63	17	22
10/9/2018 12:00		419	565				62	72		3	6		6	19	25	53	9	13

Appendix II: Spot speed data and Operating speed determination



Appendix III: Calculations

Design speed V_d = 90 Km/h

e = 2.5%

Radii from the curves at the Lang'ata interchange, R_i = 300 m

Annual Average Daily Traffic, AADT = 37832 veh/day

Operating speed, V_{85} = ($\frac{93+89}{2}$) Km/h

= 91 Km/h

Difference between operating speed and design speed, (V_{85}-V_d) Km/h = (91-90) Km/h

=1 km/h

Speed reduction (ΔV_{85}) Km/h = (3.30+1.58DC) Km/h

V_{85} = exp (4.561-0.0058DC)

91 = exp (4.561-0.0058DC)

In 91 = 4.561-0.0058DC

DC = $\frac{4.561 - In91}{0.0058}$

= 8.6449 metric units

ΔV_{85} = (3.30+1.58×8.6449) Km/h

= 16.959 Km/h

Difference between side friction assumed and side friction demanded, Δf_R = f_{RA} - f_{RD}

Side friction assumed, f_{RA} = 0.22 $-1.79\times10^{-3}V_d$ + $0.56\times10^{-5}(V_d)^2$

$= 0.22 - 1.79\times10^{-3}\times90+0.56\times10^{-5}\times90^{2}$

$= 0.104$

Side friction demanded, $f_{RD} = \frac{(V_{85})^2}{127R} - e$

Average radius, R = $\frac{5729.58}{DC}$

$= \frac{5729.58}{DC}$

$= \frac{5729.58}{8.6449}$

$= 662.77$ m

$f_{RD} = \frac{(V_{85})^2}{127R} - e$

$= \frac{(91)^2}{127\times662.77} - 0.025$

$= 0.0734$

$\Delta f_R = 0.104 - 0.0734$

$= 0.0301$

Ratio of individual radius to average radius (CRR) = $\frac{R_i}{R_{avg}}$

$= \frac{300}{662.77}$

$= 0.4527$

$VD_{LU} = 0.173 + \frac{43.0}{R}$

$= 0.173 + \frac{43.0}{662.77}$

$= 0.238$

$$VD_{LF} = 0.198 + \frac{29.2}{R}$$

$$= 0.198 + \frac{29.2}{R}$$

$$= 0.198 + \frac{29.2}{662.77}$$

$$= 0.242$$

$$WL = 0.193 + 0.016DC$$

$$= 0.193 + 0.016 \times 8.6449$$

$$= 0.331$$

Difference between operating and design speed ($V_{85} - V_d$)

$$\text{Collisions / 5 years} = \exp(-3.380)\ L^{0.8920} \times V^{0.5913} \exp[0.009091\ (V_{85} - V_d)]$$

$$= \exp(-3.380)\ 28.6^{0.8920} \times 37832 \exp[0.009091\ (91 - 90)]$$

$$= 369 \text{ collisions}$$

Speed reduction: (ΔV_{85})

$$\text{Collisions / 5 years} = \exp(-3.796)\ L^{0.8874} \times V^{0.5847} \exp(0.04828 \Delta V_{85})$$

$$= \exp(-3.796)\ 28.6^{0.8874} \times 37832^{0.5847} \exp(0.04828 \times 16.959)$$

$$= 1140 \text{ collisions}$$

Difference between side friction demanded and assumed (Δf_R)

$$\text{Collisions / 5 years} = \exp(-3.303)\ L^{0.8733} \times V^{0.5680} \exp(-2.194 \Delta f_R)$$

$$= \exp(-3.303)\ 28.6^{0.8733} \times 37832^{0.5680} \exp(-2.194 \times 0.0301)$$

$$= 273 \text{ collisions}$$

Ratio of the radius of individual section to the average radius of the alignment (CRR)

Collisions / 5 years = exp (-3.159) $L^{0.8898} \times V^{0.5906}$ exp (-0.3606CRR)

= exp (-3.159) $28.6^{0.8898} \times 37832^{0.5906}$ exp (-0.3606×0.4527)

= 382 collisions

Visual demand of unfamiliar drivers (VD_{LU})

Collisions / 5 years = exp (-4.297) $L^{0.8866} \times V^{0.5841}$ exp (3.076VD_{LU})

= exp (-4.297) $28.6^{0.8866} \times 37832^{0.5841}$ exp (3.076×0.238)

= 274 collisions

Visual demand of familiar drivers (VD_{LF})

Collisions / 5 years = exp (-4.679) $L^{0.8873} \times V^{0.5841}$ exp (3.076VD_{LF})

= exp (-4.679) $28.6^{0.8873} \times 37832^{0.5841}$ exp (3.076×0.242)

= 275 collisions

SUMMARY OF CALCULATIONS

Speed reduction (ΔV_{85}) Km/h	16.959 Km/h
Difference between side friction assumed and side friction demanded, $\Delta f_R = f_{RA} - f_{RD}$	0.0301
Ratio of individual radius to average radius (CRR) = $\frac{R_i}{R_{avg}}$	0.4527
Difference between operating and design speed ($V_{85} - V_d$)	369 collisions
No. of collisions/5 years	

Speed reduction: (ΔV_{85}) No. of collisions/5 years	1140 collisions
Difference between side friction demanded and assumed (Δf_R) No. of collisions/5 years	273 collisions
Ratio of the radius of individual section to the average radius of the alignment (CRR) No. of collisions/5 years	382 collisions
Visual demand of unfamiliar drivers (VD_{LU}) No. of collisions/5 years	274 collisions
Visual demand of familiar drivers (VD_{LF}) No. of collisions/5 years	275 collisions

Appendix IV: Accident data from Kenya Police

Accident Classes		Fatal	Serious	Slight	Total
2016 Jun	2016	4	5	2	**11**
Jul	2016	1	2	1	**4**
Aug	2016	2	0	0	**2**
Sep	2016	0	1	0	**1**
Oct	2016	1	1	1	**3**
Nov	2016	0	1	0	**1**
Dec	2016	0	0	1	**1**
2017 Jan	2017	2	1	0	**3**
Feb	2017	1	1	0	**2**
Mar	2017	0	0	0	**0**
Apr	2017	0	0	1	**1**
May	2017	0	0	0	**0**
Jun	2017	0	0	0	**0**
Jul	2017	0	0	0	**0**
Aug	2017	2	1	1	**4**
Sep	2017	1	1	0	**2**
Oct	2017	1	0	0	**1**
Nov	2017	1	1	0	**2**
Dec	2017	2	1	0	**3**
2018 Jan	2018	0	0	0	**0**
Feb	2018	0	1	0	**1**
Mar	2018	1	1	0	**2**
Apr	2018	1	0	0	**1**
May	2018	1	1	0	**2**
Jun	2018	1	1	0	**2**
Jul	2018	3	3	1	**7**
Aug	2018	2	2	0	**4**
Sep	2018	1	4	1	**6**
Oct	2018	1	1	2	**4**
Nov	2018	1	0	0	**1**
Dec	2018	1	0	1	**2**
2019 Jan	2019	1	1	1	**3**
Mar	2019		3	0	**3**
Apr	2019	1	6	1	**8**
Total		**34**	**41**	**14**	**87**

Appendix V: Fatality rates

Accidents&victims	2016	2017	2018	2019	Total	Percentage
Fatal	8	10	12	2	**32**	**37**
Serious	11	6	14	10	**41**	**47**
Slight	4	2	5	3	**14**	**16**
	25	**18**	**31**	**15**	**87**	**100**

Source: Police

Appendix VI: Victims affected annually

	2016	2017	2018	2019	Total	Percentage
Passengers	17	10	21	1	**49**	**38**
Pedestrians	12	8	14	8	**42**	**32**
Drivers	6	5	7	2	**20**	**15**
Motor cyclists	2	3	4	6	**15**	**11**
Pedal cyclists	1	1	2	1	**5**	**4**
	38	**27**	**48**	**18**	**131**	**100**

Source: Police

Appendix VII: Victims affected (accident classes)

	Fatal	Serious	Slight	Total	Percentage
Drivers	6	9	5	**20**	**15**
Motor cyclist	2	12	1	**15**	**11**
Pedestrians	12	8	14	**34**	**26**
Pedal cyclist	4	4	5	**13**	**10**
Passengers	6	27	16	**49**	**38**
	34	**60**	**42**	**131**	**100**

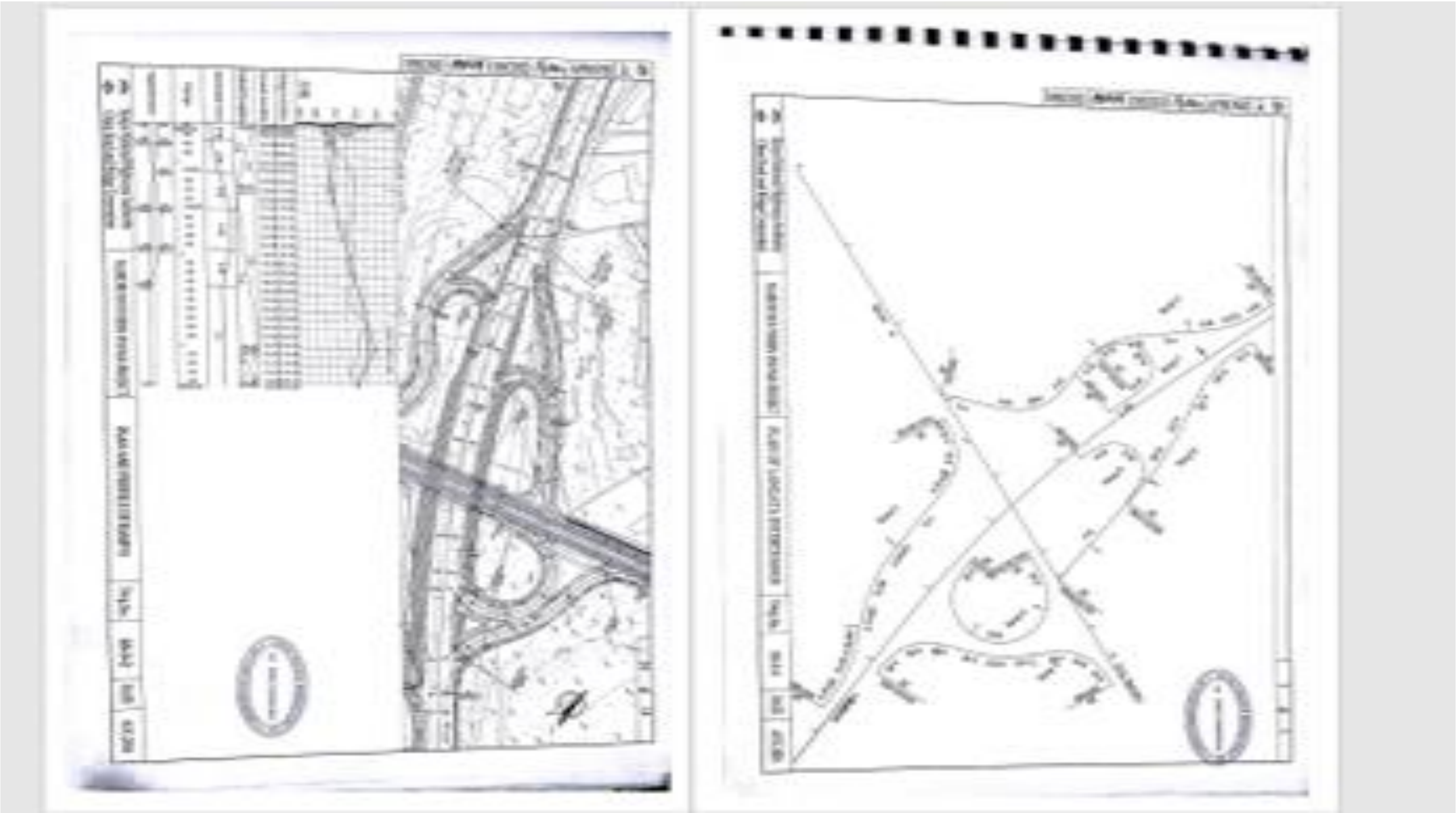
Source: Police

Appendix VIII: Cause codes from Kenya Police

Cause code	C7	C8	C10	C11	C12	C17	C19	C20	C22	C26	C28	C29	C30	C36	C37
Accidents	10	5	4	2	1	1	1	1	1	17	1	5	2	1	1
Percentage	12%	6%	5%	2%	1%	1%	1%	1%	1%	20%	1%	6%	2%	1%	1%

Cause code	C40	C47	C51	C54	C59	C60	C61	C63	C68	C70	C78	C79	C97	C98	TOTAL
Accidents	1	1	1	2	1	2	3	4	9	1	1	1	1	5	86
Percentage	1%	1%	1%	2%	1%	2%	3%	5%	10%	1%	1%	1%	1%	6%	100%

Appendix IX: As-built drawings from Kenya National Highways Authority (KeNHA)



Appendix X Questionnaire

QUESTIONNAIRE

OBJECTIVE TO BE ACHIEVED: Main objective of the project is to determine the relationship between geometric design consistency and road safety.

1. **IDENTIFICATION**
   i. Name…………………………………………………………(optional)
   ii. Age ……………………………..……………………………………..
   iii. Gender ……………………………..………………………………….
   iv. Occupation …………………..…………………………………(optional)
2. **Road safety**

i. Have you witnessed a road accident on the Nairobi Southern Bypass road before?

€ Yes

€ No

ii. If your answer to (i) is yes, how many accidents have you witnessed for the past one year?

€ Less than 5

€ 5-10

€ More than 10

iii. On a scale of 1-5 with 5 being “strongly agree” and 1 being “strongly disagree” please indicate (using a tick) the extent to which you feel the following are the main causes of accidents on Nairobi Southern Bypass.

MEASURES	**5- strongly agree**	**4- agree**	**3- undecided**	**2- disagree**	**1- strongly disagree**
Over speeding					
Improper overtaking					
Driver’s failure to obey/ignorance of traffic rules					
Poor Roadway Maintenance					
Poor road marking					
Defective motor vehicles(brakes/other vehicle parts)					
Lack of roadway identification signs					
Lack of Speed bumps, raised medians, pedestrian islands					
Bad weather					

3. Driver workload

Please describe what your experience was while driving/being driven on the Nairobi Southern Bypass road……

……

……

……

…………………………

THANK YOU FOR YOUR PARTICIPATION