CROSS-INTERSECTION TRAFFIC ANALYSIS: A CASE STUDY OF KYALIWAJJALA-NAMUGONGO

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A FINAL YEAR RESEARCH AND DESIGN PROJECT REPORT SUBMITTED TO THE FACULTY OF ENGINEERING, DESIGN AND TECHNOLOGY, IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF A DEGREE OF BACHELOR OF SCIENCE IN CIVIL AND ENVIRONMENTAL ENGINEERING OF UGANDA CHRISTIAN UNIVERSITY

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ABSTRACT

This research focused on analyzing traffic congestion at cross-intersections using a case study of Kyaliwajjala-Namugongo junction, Wakiso District-Uganda. The main objective of this study was to optimize traffic flow at the Kyaliwajjala-Namugongo intersection using a geometric design.

The study involved carrying out topographic surveys to collect geometric and topographic data and manual traffic counts of the approaches to determine the performance of the intersection. The intersection topography was determined using road profiles generated from the elevation data and Coordinates and performance was assessed from the traffic volumes and traffic flow movements.

A geometric design was then recommended at the end of this study to enhance the intersection to cope with the existing and future expected traffic volume. The proposed design is able to cope with the traffic for a design life of 15 years and installation of road signs, clear road markings and construction of raised islands were made to cater for safety of road users.

DECLARATION

I Nakiganga Lydia, S20B32/015, a Civil and Environmental Engineering student at Uganda Christian University, certify that all the work and information mentioned in this document was done to the best of my acknowledged with all the required supervision. I therefore take full responsibility for all the work contained in this report and declare that it has never been published by any educational institution.

Signature…………………………

NAKIGANGA LYDIA S20B32/015

APPROVAL

This report has been submitted for examination with my approval as the University supervisor of this student.

Signature: …………………………….

NAME: KASUMBA ANDREW.

DEDICATION

This research report is dedicated to my guardians whose unwavering support and encouragement has been a cornerstone of my journey which has enabled me to reach this far. I also dedicate this report to the department of Engineering, Design and Technology, whose guidance, wisdom and expertise have shaped my academic pursuits. Their dedication to education has inspired me to strive for excellence and to never cease in my pursuit of knowledge.

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List of acronyms used in this document

CBD: Central Business District

WHO: World Health Organization

NGO: National Government Organization

MoWT: Ministry of Works and Transport

GDP: Gross Domestic Product

ADT: Average Daily Traffic

AADT: Annual Average Daily Traffic

PHF: Peak Hour Factor

CHAPTER ONE: INTRODUCTION

In both established and emerging nations, traffic congestion has become worse across most of the world and it is especially bad at intersections where many collisions occur as cars try to go to distant areas. Research indicates that traffic will only get worse, posing a clear threat to the standard of living in cities, (Bull A. and Cepal N., 2003). Over the years, traffic congestion in and around the central business district (CBD) of Uganda has been and is still a menace as most routes experience intense traffic congestion during early morning, and evening hours while some of the roads experience it all day long up to late night hours, (Kwikiriza, 2016). According to Uganda Motor Vehicle Sales he number of vehicles in the central business district has highly increased from 770,000 in Dec 2018 to 832,000 in Dec 2019, (Naddumba E, 2001). Due to poorly planned road networks with even the size of some of the roads being narrow and poor traffic management, the end result is traffic congestion. There is often heavy traffic during peak hours, as cars can move at rates of up to 15 km/h and slower, causing a slowdown in the flow of traffic, (Sheila Maria Belgis Putri Affiza, 2022). The situation is often worse around during peak hours.

Kyaliwajjala-Namugongo Junction is located in Wakiso District, neighboring Kira Municipality, and Kyadondo County and is part of central Uganda. The junction is surrounded by Namugongo to the northeast, Bweyogerere to the southeast, and downtown Kira to the northwest. Kyaliwajjala-Namugongo is a non-signalized intersection with four arms and it experiences traffic inflow from Kyaliwajjala-Naalya road, and Namugongo road. Road users mainly use this intersection to acquire access to and from the capital and the business units around Namugongo, Kireka, Kyaliwajjala, Naalya and other places due to the strategic location of the junction. According to research, traffic congestion can also represent the expansion of the economy as this can happen when the population of vehicles increases in tandem with an economy's growth and household real income, which exacerbates traffic congestion in urban areas (Kwikiriza, 2016). According to Uganda Bureau of Statistics, Uganda's population growth rate is 3.1% basing on the population census conducted in 2014 implying that number of people who travel to the great Kampala for different reasons include work, via this junction has also increased yet the road has not changed much to cope up with this increment.

From site survey, there is poor traffic management around this intersection and more so, given the fact that the junction does not have any signalized traffic controls to regulate the flow of traffic. This is impacting undesirable consequences that include impeding vehicle flow, escalating travel time, economic losses and accidents among others. It is due this that this research focused was developed in order to deal away with or greatly reduce this problem mainly in developing countries. As recommended by this research developing countries should equip intersection of this nature with geometric designs that can not only support but also enhance the free flow of traffic at the intersections so as to reduce congestion.

1.1 Problem statement

Since Kyaliwajjala-Namugongo is non-signalized four-legged intersection, the traffic congestion experienced at the intersection gets worse majorly during rush hours when road users are rushing to and from the metropolis of the country. From site survey, traffic congestion is intense at this junction and there is poor traffic management at the junction as once in a while, controlling the flow of traffic is done by traffic officers and these cannot perform to the level of a geometric design.

The junction is strategically located as it provides shorter routes to the capital, Namugongo shrine, learning centers and major highways like the northern by-pass, this results into high usage of the junction. Traffic bottlenecks have been determined to be mostly caused by narrow roads, poor urban design, restricted parking, and the concentration of most social and economic activity in the city centers, (Kwikiriza, 2016). This is impacting undesirable consequences to the users of the junction that include; impeding vehicle flow, escalating travel time, economic losses, high fuel consumption due to the slow speeds during vehicle queuing and others. The cost of annual travel time due to traffic delays, the high expense of treating accident victims and their compensation, and the societal cost of environmental pollution all have an impact on the GDP of the economy as a whole. In addition to impairing corporate operations and lowering productivity, traffic congestion also claims lives and pollutes the environment. This occurs nationwide, not just at the Namugongo-Kyaliwajjala intersection, (Kwikiriza, 2016).

Developing nations should thus prioritize improving the traffic management and control system in addition to building more transportation infrastructure in order to enhance the city's transportation network. This will lower government spending, the number of fatal accidents, and improve productivity in production (GDP) and finally lead to clean and smart mobility which reduces traffic congestion in the towns. Therefore, instead of using traffic officers to manage traffic flow at Kyaliwajjala intersection, the junction should be improved in a way that will enable it to not only accommodate but also regulate traffic congestion and also control traffic flow within the junction arms and this is the main focus of this study.

1.2 Main objective

To optimize traffic flow at the Kyaliwajjala-Namugongo intersection using a geometric design.

1.3 Specific objectives

1. To determine the topography of the intersection.
2. To assess the performance of the intersection in its current state
3. To develop an optimal traffic regulation system for the intersection.

1.4 Research questions

1. What is the topography of the intersection and its arms?
2. What is the current performance of the cross intersection?
3. Which Geometric system can regulate traffic congestion at the intersection?

1.5 Geographical scope

The investigation will consider at least 500meters stretch of all the junction arms and is only limited to Kyaliwajjala-Namugongo junction and its motorized transport.

Figure 1*: Location of Kyaliwajjala-Namugongo Intersection.*

Source: Google maps

1.6 Justification of the study

Despite the fact that traffic management at the Kyaliwajjala-Namugongo junction is currently done by traffic officers, these cannot perform to the level of efficiency as a geometric design. The geometric design that was developed by this study will ensure proper traffic flow as well as reduce traffic congestion and its side effects at the junction.

When the junction geometric design and capacity are improved, the Kyaliwajjala-Namugongo road users will be able to use the junction with limited discomfort, frustration and at a reduced time loss due to decreased delays and traffic queue lengths.

1.7 Significance

One of the primary reasons for upgrading the junction is to enhance safety for all road users. Poorly designed intersections often lead to traffic accidents, especially in areas with high traffic volumes like the Kyaliwajjala-Namugongo junction. Implementing a better geometric design can reduce the risk of collisions, thus safeguarding the lives of pedestrians, cyclists, and motorists.

The current junction suffers from congestion and inefficient traffic flow due to inadequate design therefore upgrading to a better geometric design can optimize traffic movement, reduce delays, and alleviate congestion. This improvement not only enhances the efficiency of transportation but also reduces fuel consumption and emissions associated with idling vehicles.

CHAPTER TWO: LITERATURE REVIEW

2.1 INTRODUCTION

There is no one widely accepted definition of traffic congestion because it is both a physical and a relative phenomenon, according to an Organization for Economic Co-operation and Development [OECD] paper from 2007 on managing urban traffic congestion. As a physical phenomenon, traffic congestion is the result of an excess of demand for available road space, which manifests itself as slower travel times, greater travel distances, and longer lines of moving cars. This issue has a long-term negative impact on health as well as several facets of contemporary life, including time wastage, traffic accidents, economic growth, and greenhouse gas emissions.

2.2 Causes of traffic congestion at junctions

In metropolitan areas, traffic congestion slows down and interferes with the ability of vehicles to move freely. Roads facilitate access to a multitude of resources, including markets, opportunities, people, goods, services, and networks. These advantages can be obtained through increased proximity or faster travel times.

Some of the causes of traffic congestion include:

1. **Narrow of roads or lanes especially towards junctions**: Narrow roads tend to increase traffic congestion and overwhelm the carriageway width and therefore vehicles can't travel with the desired speed because of the interference with the other road users like motorists and pedestrians.

2. **Improper lane management;** Improper Lane management can lead to confusion among road users where some vehicles tend to overtake at points where it is prohibited, others create more lanes in a single lane road, a common mistake is when vehicles use the shoulder section of the carriage way to overtake. This leads to more congestion especially towards junctions.
3. **Poor driving habits:** The already congested junction scenario is made worse by drivers and other road users who are insufficiently taught how to observe lane discipline, particularly at intersections. More traffic congestion results from drivers' frequent erratic behavior, such as running red and yellow lights and blocking junctions (Bull A. and Cepal N., 2003). Illegal parking is another indicator of poor driving behavior. In Uganda, taxis are the primary culprits here; they park there for short periods of time and longer ones, which narrows the road and causes traffic congestion in that area.
4. **Lack of Law Implementation:** The majority of these issues are made worse by the fact that traffic law enforcement is often criticized for not properly enforcing the law, which also encourages illegal parking. Law enforcement should be rigorous as a result hence giving cars a reason to obey the law.

In Other cases, composition and capacity of the road are considered as factors that do affect traffic congestion on a highway or in an area. Heavier vehicles, like trailers and trucks, have a greater influence on traffic congestion than the lighter passenger car units (PCU) since the heavier vehicles may fail to move at the desired design speed for the highway and these gradual delays develop into longer queues in the long run (Jalagat, R. and Jalagat, A, 2016)

2.2.1 Effects of traffic congestion

1. **Traffic congestion affects human and environment:** Millions of people are injured each year, and over 3400 people lose their lives on the roadways every day and the biggest percentage includes the most vulnerable road users such as children, motorcycle riders, pedestrians, cyclists, and the elderly (Razzaghi, A., Soori, H., Kavousi, A., 2019). Speed, drunk driving, the use of motorcycle helmets, seat belts, and child restraints are all key behavior risk factors that can be addressed through good practice by the WHO in conjunction with governmental and nongovernmental (NGOs) organizations around the world in order to reduce their effects.
2. **Traffic Congestion increases travel cost:** (Jalagat, R. and Jalagat, A, 2016), traffic congestion, traffic slows down speed travel speeds which results into high fuel consumption, due to the continuous deceleration of vehicles. Some drivers, when traffic congestion is intense, tend to turn off their car engines to reduce fuel consumption. This rater results into high travel expenditure.
3. **Increased pollution:** The congestion of vehicles in a particular area result into increased pollution inform of air and noise pollution. Air pollution is mainly in form of gas emissions from the vehicle exhaust pipes and the main gases usually emitted by vehicles include; Carbon dioxide (CO_2), Carbon monoxide (CO), Benzene, unburnt hydrocarbons, and others. These not only reduce the quality people's lives but also deplete the ozone layer which later results into long term problems like change of seasons and drought.

2.3 Traffic Management

The planning, directing, and management of both stationary and moving traffic, including bicycles, pedestrians, and other kinds of vehicles, is known as traffic management. Its primary goals are to ensure the safe, efficient, and orderly movement of people and commodities, as well as, whenever feasible, to improve the local environment near and around traffic facilities in order to lessen traffic congestion and the issues that go along with it. In order to achieve this, a collection of management tools and applications known as traffic management systems combine processing, sensor, and communication technology. They gather information on traffic from a variety of sources, including cars, traffic signals, in-road and roadside sensors, and traffic lights. Additionally, by conceiving and utilizing such traffic-related data cooperatively, a number of traffic dangers can be recognized and managed, enhancing overall traffic efficiency and facilitating smooth traffic flow, (Works, 2010a).

2.3.1 Goals of traffic management

The following goals are the goals of traffic management however, they can be revised depending on the situation at hand;

1. **To ensure free flow of traffic.** The primary objective of any traffic management plan is to guarantee traffic flow. Numerous variables, including road form and purpose, adjacent land uses, and traffic volume characteristics, influence how traffic flows. Understanding the daily, monthly, and annual variations in traffic volume is essential. Additionally, knowing the flow direction at any given time is

crucial as it illustrates the point of traffic development and attractiveness. An effective traffic volume study helps with traffic flow management by giving priority to the stream with larger volume.

2. **To reduce traffic congestion and delay:** Traffic congestion typically happens when a road infrastructure cannot accommodate the volume of traffic at an acceptable speed and so there is a conflict between automobile, trucks, buses as well as pedestrians among other road users. Such spots could be referred to as choke points or bottlenecks that could either be on stretch of a road or a crossroads and are frequently caused by street trade, substandard roads, on-street parking, broken or abandoned vehicles.
3. **To increase road capacity:** Every road junction or intersection has a design capacity depending on its purpose. A road may fail to carry the intended volume of traffic that it was designed for as long as the traffic management systems are not put in place. Traffic management systems such as road markings and traffic control signals allow the facility to handle a significant traffic volume within a reasonable period of time.

To reduce road traffic accidents since road accidents are becoming a major problem in the world today.

2.3.2 Methods of traffic management

1. **Parking Restrictions:** This can be achieved by limiting the quantity of public and roadside parking spaces, tightening enforcement measures against unlawful parking, particularly for taxis, limiting the construction of new parks, and

limiting the amount of parking spaces that are permitted for both new and current companies. However, a large percentage of parking spaces are private and non-residential, which frequently limits the efficacy of parking management.

2. **Use of street cameras:** Street cameras aid in the monitoring of vehicle or traffic flow and are able to keep records of bad driving and accident incidences. This system has been picked up by different countries including Uganda and has been effective in the managing of traffic at some of the different intersections.
3. **Control of access:** Uncontrolled access to roadside development, whose primary purpose is to facilitate mobility, increases the risk of accidents, reduces capacity, and causes roadways to age more quickly. Road authorities must apply access control, which limits the right of landowners or occupiers to access, in order to protect roads and keep them at a high degree of traffic control.

Roadways without access control are just as vital as land service facilities, even though access control is one of the most crucial strategies for maintaining the effectiveness and road safety of major roadways.

2.4 Levels of access control

1. **Control of full access:** This means that the authority to control access is exercised to give preference to through traffic by providing access connections with selected public roads only and by prohibiting direct access connections.

2. **Partial access control:** This indicates that the power to regulate access is used to partially favor through traffic in that there may be (some) private access connections in addition to access links with specific public roadways.
3. **Unrestricted access:** This suggests that local traffic is prioritized, and that the route serves the surrounding areas by providing direct access connections. To guarantee proper standards of visibility, surfacing, drainage, etc., the Road Authority shall, nevertheless, approve the precise position and design of the accesses.

However, the traffic control that ought to be enforced at certain roads and highways must be matching the level or traffic class experience that road or junction and must also match with the class of the road. This is because roads of different classes experience different traffic volumes and hence require individual traffic management strategies.

2.5 Different road functional Classes

Based on their primary role in the road networks, Uganda's rural roads are classified into five types.

1. **Class A roads:** The majority of these are international trunk roads that connect internationally significant centers. As a result, they create a link between the national road network and the highways of the surrounding nations. Their primary purpose is to enable mobility.

2. **Class B:** These are often National Trunk Roads that connect major population areas, province capitals, and sites of national significance. Their primary purpose is to facilitate mobility as well.
3. **Class C:** Primary Roads connect provincially significant centers to higher-class roads (urban/rural centers) or to one another. Their primary purpose is to facilitate access and transportation by connecting developing zones and local population centers with higher class roadways.
4. **Class D:** These secondary roads serve as a conduit between locally significant traffic generators and their rural hinterlands. They can connect locally significant centers to one another, to a more significant center, or to a higher class of road (rural/market centers). Similar to the preceding, these roadways' primary purpose is to facilitate access and transportation.
5. **Class E:** These are minor roads that connect to all other motorable roads as well as minor centers, such as marketplaces and local centers. Their primary purpose is to grant access to the property that borders the secondary road networks.

The primary purpose of the highest classes of roads, A and B, is to facilitate movement and have greater trip distances. They must deliver high-quality services at a rapid design speed. In addition to carrying shorter excursions, the roads in Classes C and D also supply the higher classes of roads. An intermediate design speed and quality of service are necessary for these highways. Road Class E's main purpose is to offer access and has a short travel duration. These highways may have low design speeds and service levels, (Fwa, 2006)

The general recommendations for access control level in respect to functional road categorization are provided in table 1 for all-purpose roads:

Table 1: Level of Access Control (Source: Uganda Road Design Manual, 2010)

Functional class	**Level of service control**	
	desirable	**Reduced**
A	Full	Partial
B	Full or partial	Partial
C	Partial or Unrestricted	Partial
D	Partial	Unrestricted
E	Partial or unrestricted	Unrestricted

2.6 Geometric Design of Highways

The visible dimensions of a roadway are the subject of geometric design, which is governed by traffic demands, economic constraints, and design elements such as vertical and horizontal alignment, cross-section components, sight distance, lateral and vertical clearances, intersection treatment, control of access, and others, (Conlin and Conlin, 2004). The two main inputs into the design of a highway are the design speed and the design hourly volume; the former determines the necessary capacity, and the latter controls the design of vertical and horizontal curvatures.

When choosing the design standards for a roadway, the design engineer must take the following factors into account.

1. Safety ought to be integrated into all design components.

2. Faulty geometrics are costly, and in some cases impossible to rectify at a later date and so, due consideration should be given to geometric design at the initial stage itself.
3. Abrupt changes in design should be avoided, and standards suggested for various aspects should be compatible with one another and consistent with one another.
4. When designing a highway facility, appropriate geometric design guarantees that the structure won't become outdated anytime soon. Therefore, the foundation of design should be the amount and makeup of traffic during the design year.
5. The location and design of the roadway should improve rather than worsen the surrounding environment since it is a part of the overall environment.
6. All elements of the road's geometry, such as intersections, signage, markings, and adequate lighting, should be incorporated into the design.
7. The highway should have a pleasing visual appeal. Controlling pollution should be the goal of the design elements.
8. The layout should be chosen to minimize not only the facility's original building costs but also the overall transportation costs, which include upkeep and road user expenses.

The layout should make the facility usable by all users of the road, including automobiles, bicycles, pedestrians, and vehicles drawn by animals. Consideration should be given to how well the vehicles utilizing the facility operate.

2.6.1 Considerations of a well-designed roadway

1. The geometric arrangement should be chosen to prevent drivers from making potentially dangerous moves. There are several ways to accomplish this, including channelizing and staggering.
2. There should be as few intersections as possible. Before joining a major route, some minor roads may need to be connected to one another.
3. The design should enable the motorist to rapidly choose which path to take and how to merge and diverge based on the layout or traffic signage. A well-planned layout, traffic islands, signage, and road markings can all help achieve this. Safety is increased by clear visibility.
4. It is advisable to reduce the number of conflicting points by dividing some of the numerous cutting, merging, or diverging actions.
5. The design ought to take into account the natural vehicle routes. Smoothness should direct small streams of traffic to stop or slow down, as opposed to abrupt and sharp curves.
6. Sufficient space should be available at the intersection for vehicles that must wait in order to cross a traffic stream.

2.7 Topography

For an economical and sound decision to be made, the different design components should be connected to topographical aspects. This helps in the determination some of the design parameters that will be incorporated in the new design. For example, the minimum passing distance, minimum stopping distance, maximum desirable or absolute gradient, right of way, the minimum horizontal curve radius and others. This is because different terrains are associated with different design parameter mentioned above. Terrain can be flat, rolling, mountainous and others. All these have to be considered in a geometric design of any paved road.

2.7.1 Types of terrain

7. When surveys have been conducted, the results obtained and the field analyses conclusions realized should be compared to the following characters so that to draw the right conclusions of the type of terrain where the given road lies.

    a) **Rolling terrain**

The following characteristics must exist for a paved road to be regarded to have a rolling terrain;

1. The location should be in a hilly or rolling region with generally moderate to gently sloping slopes.
2. Occasional steep slopes must be encountered.
3. There should be restrictions in horizontal and vertical alignment.
4. It should have a transverse terrain slope ranging between 20% and 5%.

    b) **Flat terrain**

For a paved road to be conspired to have a flat terrain, it should have the following characters;

1. It should be in a region that is level or slightly undulating and has few barriers to building a road.
2. There should never be any limitations on the alignments, either vertically or horizontally
3. It should have a transverse terrain slope ranging from of around 5%

c) **Mountainous**

A paved road to be conspired to have a mountainous terrain, it should have the following characters;

1. It should be located in a mountainous, hilly or rugged area with river gorges.
2. There are definite restrictions imposed by this class of terrain in both the horizontal and vertical alignments.
3. Long, steep gradients and constrained sight distances are also involved.
4. The slope of the transverse terrain should range from 20% to 70%.

d) Escarpment

A fourth class was created in addition to the previously listed terrain classes to address the circumstances in which the requirements linked with the aforementioned terrain types cannot be met. Only in escarpment situations, where massive amounts of earth work are needed, it is necessary to change the back road alignment or side hill transverse portions.

These are usually characterized transverse terrain slopes greater than 70%

Table 2 provides a summary of the geometric design parameters for the various paved road terrains.

*Table 2: Design parameters for paved roads (*Source; Ministry of Works)

Design element	**Unit**	**Flat**	**Rolling**	**Mountainous**	**Peri urban/ urban**
Design speed	Km/h	120	100	80	50
Min. stopping sight distance	m	205	260	115	60
Min. passing sight distance	m	795	670	545	345
Min. horizontal curve radius	M	710	415	240	100
Right of way	M	60	60	60	40
Min. desirable gradient	%	4	6.5	8	8
Min. absolute gradient	%	3	4.5	6	6
Shoulder cross fall	%	4	4	4	4

2.8 Characteristics of traffic

Traffic has a direct impact on design's geometric elements, including widths and horizontal and vertical alignments, and it also highlights areas that require repair. As a result, the amount of traffic that a road must handle should be taken into consideration when designing it. Some of the parameters explained below are some of the characteristics and considerations when assessing traffic demand of a road

2.8.1 The design speed

It is the highest safe speed that can be kept on a certain stretch of road when the circumstances dictated by the highway's design are so favorable.

The design speed of a road greatly depends on the terrain and this is why topography surveys are highly important. Different terrains are associated with different design speed for safety purposes. Speed values used are by road designers in the determination of the road alignment (radii of curvatures, sight distances, transition length, and others).

According to Ministry of works, 2010 85th percentile free speed is considered as design speed. 99% percentile could be used but this is expensive, 50% percentile could not be considered as this is unsafe for fastest drivers. It is important to obtain and also refer to typical data previously obtained on similar roads during the determination of the design speed

Design speeds not only rely on terrain because roads in urban and rural areas are designed with different geometric design parameters since, they have different traffic conditions, different development density that is to say; Low development density in rural areas compared to urban areas.

Design speed in urban areas mainly depends on;

- Frontage accesses
- Pedestrians in terms of pedestrian activity and pedestrian crossings

- Junction capacity
- Presence of bus stops

Design speed in rural areas mainly depend on:

- Alignment. This is terms in of the vertical and horizontal alignments of the road. Straight roads generate higher speeds than tortuous ones
- Layout this reflects cross section features such as carriageway widths, verge widths, frequency of accesses. It is a function of access density. The sum of the junction, lay-bay, and commercial access points for each kilometer on both sides of the road can be used to determine the access density.

In all these cases, and rural areas mainly, it is mandatory to include speed limits on the road sides

2.8.2 Traffic volume

Data on traffic volume for road design include volumes for every day of the year and every hour of the day as is collected basing of vehicle types and vehicle weights depending on the purpose for which it is being collected. This data helps to generate information about vehicle trends that the designer might use to project future traffic levels.

In the design year, AADT serves as the design control for low volume roadways. During the busiest months of the design year, ADT serves as the design control for routes with significant seasonal fluctuations.

2.8.3 Design year and design life

The design life can be defined as the period during which the road is will be in position to accommodate the available traffic at a satisfactory level of service without needing further funding in the form of rehabilitation or strengthening the road.

The design life of a road is chosen basing different factors like level of importance of the road sand and level reliability of data collected, mainly the traffic data.

Table 3: Selection design life of a road Source: (Works, 2010a)

Design data reliability	**Level of service or importance**	
	Low	**High**
Low	10-15years	15years
high	10-20years	15-20

2.9 Intersections

An intersection comprises the roadway and roadside design elements that enable orderly traffic flows in the vicinity of a junction or cross between two or more highways. The segment of any highway that extends outside of the intersection's boundaries from an intersection is known as an intersection leg.

Since an intersection is characterized with conflicts between traffic travelling in the various directions. Therefore, an intersection's scientific design can prevent accidents and delays and promote orderly traffic flow.

2.9.1 Types of intersection

Their three primary types of intersections are the four-leg, multi-leg, and T-intersections, sometimes known as three-leg intersections; the size, form, and application of channelization as well as other traffic control devices might differ significantly between each crossing.

Intersections can however be further categorized into at-grade intersections and grade separated intersections.

1. **At-grade intersections:** Depending on the traffic volume, flow velocity, and site constraints, several at-grade intersection types are deemed suitable in various situations.

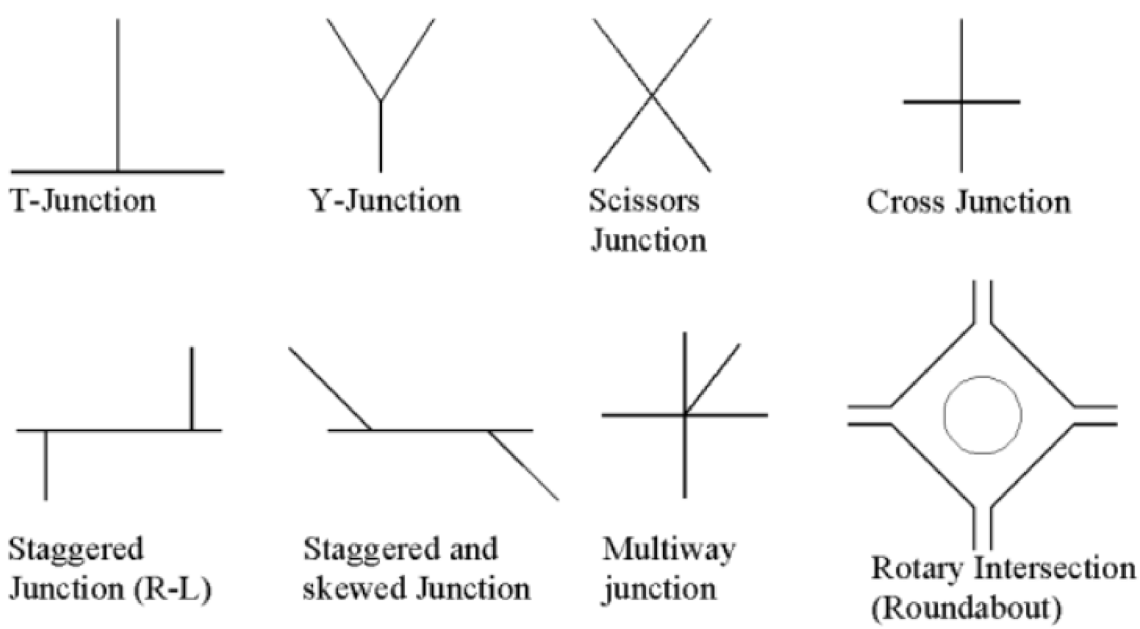

Figure 2: Types of junctions

There two main intersection categories into which At-grade intersections can be classified and these are based on the type of control used.

*Table 4: Types of At-grade intersections (*Source: (Works, 2010b))

Intersection category	**Traffic control**		**Intersection types**
	Major road	Minor road	
Priority intersection	Priority	Stop or give way sign	A. unchannelised T-intersection B. Partly channelized T-intersection C. Channelized T-intersection
Control intersection			A. Round about B. Signalized intersection

2. Priority Intersections

In most rural contexts, these crossings are seen as sufficient. There are several varieties of T-intersections, such as

a. Unchannelised T-intersection

This is the simplest design with no traffic islands and is suitable for intersections that experience very small turning traffic volumes.

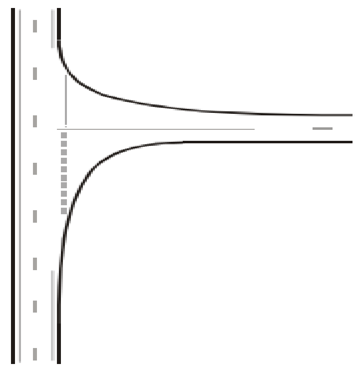

Figure 3: Unchannelised T-intersection

b. **Partly Channelized T-intersection**

The design of T-intersections is mainly recommended for intersections that have moderate volumes of turning traffic and it contains a traffic island only in the minor road arm.

If this design is to be used in urban areas, the traffic island is usually kerbed so as to provide a refuge for pedestrians crossing the road.

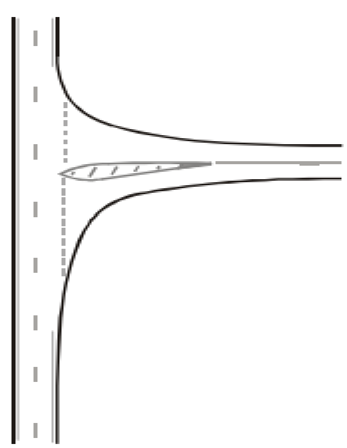

Figure 4: Partly channelized T-intersection

c. **Channelized T-intersection**

This design is recommended for intersections having high volumes of turning traffic or high –speeds. It contains traffic islands both in the minor road and the main road.

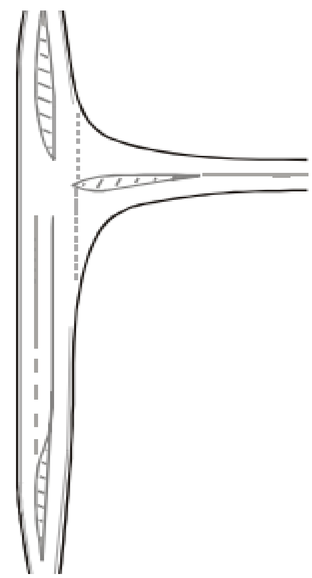

Figure 5: Typical channelized T-intersection

2.9.1.1.1 Control intersections

Control intersections are typically found in metropolitan areas while roundabouts are typically utilized at junctions with significant traffic volumes or between important roads in rural areas.

Types of control intersections are listed below;

a. **Roundabout**

The regulation that all entrance traffic must yield to circulation traffic governs roundabouts. Preferably, there should be at least 10 to 15% of minor road incoming traffic relative to all incoming traffic, (Works, 2010a)

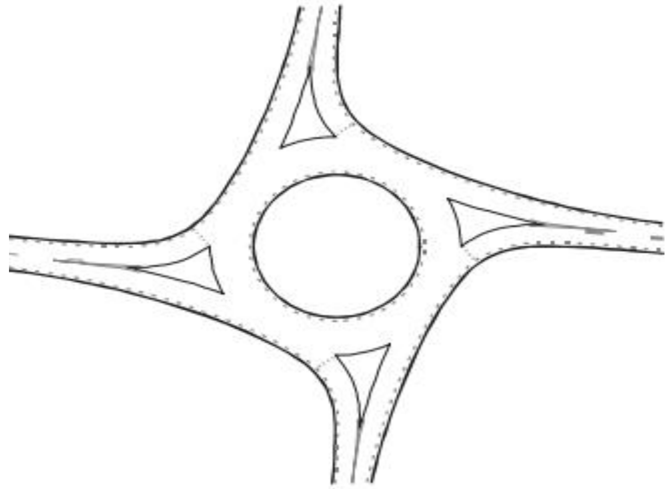

Figure 6: Round about

b. **Signalized intersection**

There are conflicts at these crossroads that are separated by traffic signals, but there are no conflicts between movements of straight-through traffic.

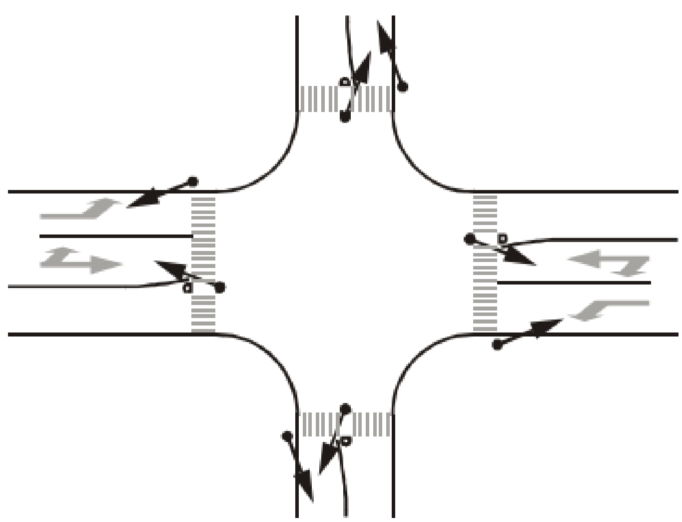

Figure 7: Signalized intersection

2.9.1.2 Design Requirements of at-grade intersections and junctions

When designing at-grade junctions, the following requirements must be put under consideration:

1. Safety and operational comfort

A junction is considered to be safe if it is, perceptible, comprehensible, and maneuverable. These standards can be met by making sure that the following rules are followed in accordance with

i. **Comprehension**
   - Road furniture such as traffic islands, road markings, and plainly visible curbs are utilized to provide optical guidance to the road users.
   - The junction kinds utilized over the entire road network ought to be as comparable or similar as feasible.
   - The layout of the intersection should logically and naturally allow drivers to follow the right of way.

ii. **Perception**
   - This can be improved by expansion of the junction approaches.
   - The intersection needs to be positioned such that the main road approaches are easily noticeable.
   - The use of early and eye-catching traffic signs.
   - Installing visibility splays along the main route to provide clear sight lines to the left and right.

- Traffic islands in the minor road can be used to enhance the "yield" or "stop" requirement.

iii. **Maneuverability**

- The width of the lanes of traffic should be of adequate to enhance appropriate vehicle turning.
- The turning radii should not be less than 15m in order to enable junction to accommodate truck traffic, (Works, 2010c).
- The traffic lane edges must be indicated clearly by use of road markings.

2. **Capacity**

Uncontrolled intersections operate mostly based on how frequently there are gaps between moving cars on the main route. In order to allow vehicles from the smaller road to merge or cross the flow of the major road, these spaces must be long sufficient.

3. **Economy**

- A junction design needs to be cost-effective, primarily by reducing the expenses related to construction, operation, and maintenance.
- In order to guarantee time savings, it is imperative to take into account delay as a significant operational component. Delays result into expensive grade-separated junctions since they increase operating expenses.
- Operational costs like fatalities, serious injuries, and vehicle damage from intersection accidents. These should all be taken into consideration.

Selection of intersection control types for intersections.

When choosing the designs to employ, different intersection control types are used in different contexts. Different intersections are reconfigured with the intersection types and categories chosen depending on priority or control.

The choice of category is mostly based on capacity and safety, for example when considering the intersection category selection for T-intersections, T-intersections primarily offers designing alternatives based on the sort of channelization that is advised to be used in the new design.

2.9.2 Selection of control type for cross-intersections

Provided there is sufficient space, roundabouts are generally appropriate in virtually all circumstances. Roundabouts are appropriate for both low and medium traffic flows and have been found to be safer than signalized crossings. However, they frequently become jammed at extremely high traffic volumes when cars disobey the priority regulations. Well-designed roundabouts reduce traffic, which is advantageous when entering a built-up region or when there is a major change in the standard of the road, like going from a dual carriageway to a single carriageway, however these are better suited for use in rural areas, (Works, 2010b).

The preferred solution in the larger urban areas is traffic signals. Coordinated signal networks have the potential to significantly reduce delays and stoppages while also improving traffic flow. In some traffic patterns, such as heavy traffic on the main thoroughfare, the overall wait time at a signalized intersection may be less than that of a roundabout.

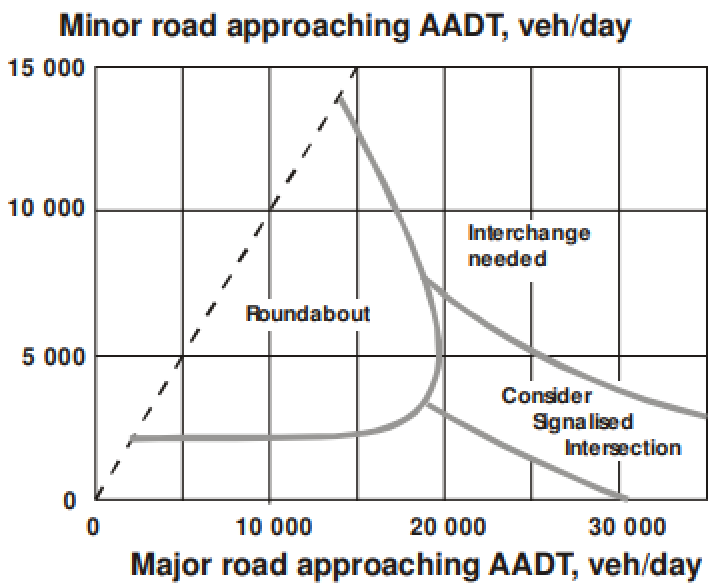

Figure 8: Selection of intersection control type

CHAPTER THREE: METHODOLOGY

3.1 INTRODUCTION

This chapter represents the methodology that was used in achieving the study objectives. The methodology emphasizes the procedure and details on how this research was carried out, and this is elaborated herein. It constitutes the methods that were used, the material sampling and preparation, the data collection, processing and analysis procedures. Below is the list of the methodology that was proposed to be carried out on each objective;

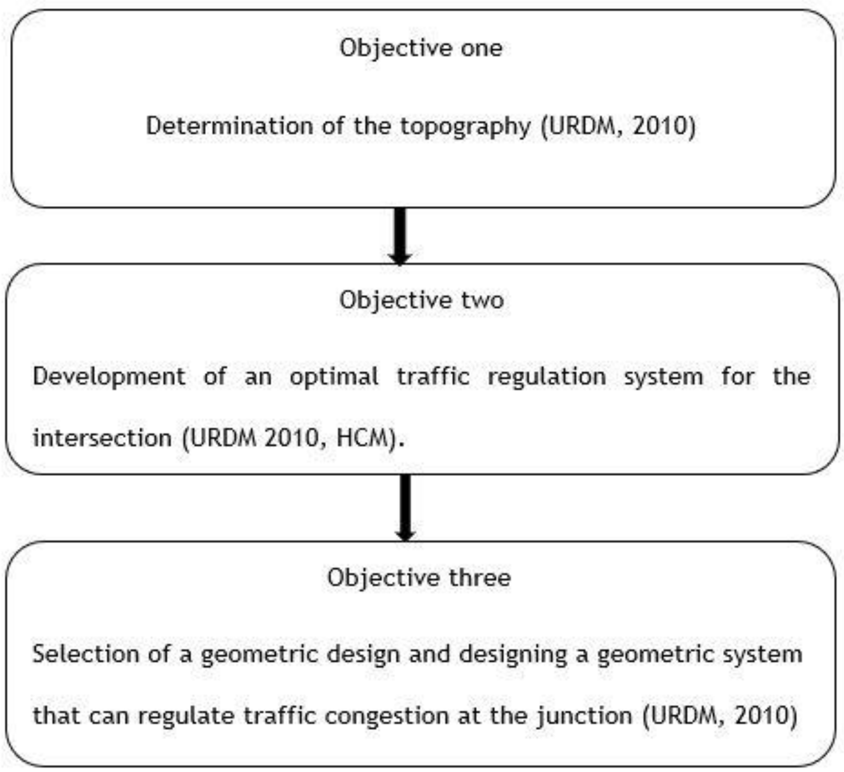

Figure 9: Research Design

3.2 Topographic surveys

Topographic surveys were done to come up with the topographic map of the road from which road profiles were generated and these aided in the determining the nature of the slopes from which conclusions were about the terrain were drawn. This methodology was done with reference to (Works and Transport, 2010) and this aided in determining the terrain in which the intersection lies. This involved contouring and determination of road elevations

3.2.1 Instruments used

- Computer; This was used to develop the profiles of the different arms of the junction which were later used to determine the topography of each arm
- RTK: This survey instrument was used in the field to pick coordinates of the elevations of the different points and the spot heights

3.2.2 Procedure

- A Global positioning system was used to accurately determine and record the geographic coordinates of points on the earth's surface.
- These coordinates were then used to create a detailed topographic map. Software for example; Surfer software and GPS Visualizer was used for analysis to create topographical maps of the area.

- Profiles were then developed from the surface, and these aided in the determination if the terrain of the place, depending on the sloppiness of the junction its arms.

Figure 10: Topographic survey with the RTK GPS

3.3 Determining the performance of the intersection in its current state

3.3.1 Manual traffic counts

- Manual Traffic counts which were done in accordance to the procedure elaborated in the Geometric Road Design Manual, 2010. This was done in order to determine traffic volumes, flow and composition at the junction

This was done only on normal days implying that no traffic analysis was carried out on public holidays, visitation days of the nearby schools, or school reporting days, as this would result into unrealistic data (Ministry of Works and Transport, 2010).

- Directional traffic counts were also conducted in order to analyze the turning movements, and conflicting volumes.
- Using stop watches, queueing time was also determined for the different vehicles which was used to determine the delays of the vehicles and que lengths

The information obtained from these counts was used to determine performance of the intersection.

3.3.2 Instruments used

- Traffic tally forms
- Stop watch
- Note book
- Pen

3.3.3 Procedure

- The location and time period for the traffic count was determined based on the time period when traffic was most likely to be at its busiest or peak.
- The counting equipment like manual tally forms, clipboards, pens, and/or other equipment needed for data collection were set up or arranged.

- Individuals or enumerators were trained and assigned the different vehicle categories such as saloon cars, trucks, bicycles, or pedestrians and others. This was done to ensure that all vehicle categories are counted accurately.
- The data was later transformed from tallies to figures and analyzed.

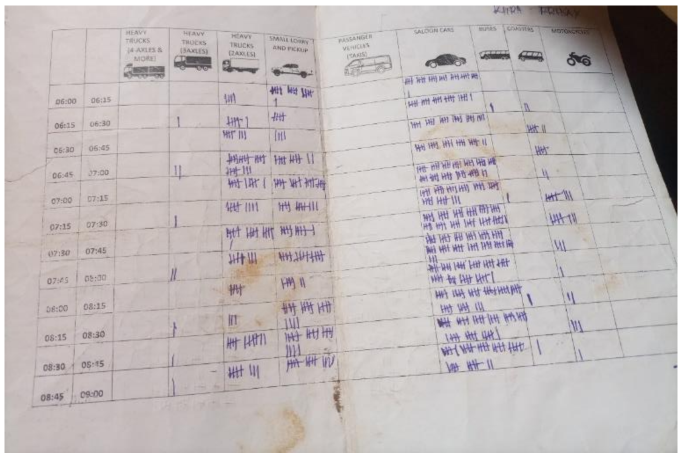

Figure 11: Manual traffic data form

3.4 Selection of a geometric design and designing a geometric system that can regulate traffic congestion at the junction.

The geometric design was selected using the graphs illustrated in the Geometric Road Design Manual, (Ministry of Works, 2010).

This design parameters for the new geometry were determined using the traffic volumes, and following procedure in the Uganda Road Design Manual, 2010 (section 8.4.3). These design parameters included the carriageway width, entry radius, circulatory carriage way, and others.

Drafting tools or softwares like AutoCAD Civil 3D, Simulation of Urban Mobility (SUMO) and twin motion were be used in order to come up with the required models, (Moller, D., 2014).

CHAPTER FOUR: RESULTS AND DISCUSSION

4.1 INTRODUCTION

This chapter discusses a number the outcomes of the activities that were done during the course of studying and analyzing traffic congestion at Kyaliwajjala-Namugongo intersection. These results present a basis to assist in coming up with an effective solution so as to regulate the problem of traffic congestion and enhance better traffic flow at the intersection. From the data that was picked from the field using an RTK, the terrain of the junction was determined. Traffic counts were then done to assess the performance of the intersection and finally, design parameters were determined which were used to generate the layout of the solution.

4.2 Topographic surveys

From the topographic surveys conducted, the road section was found to have a minimum slope of 0.77% and a maximum slope of 18.94%, indicating that it lies in a rolling country since it has a transverse terrain slope ≤20% which is characterized by gently rising and falling slopes along Naalya and Kira arms and occasional steep slopes along Kireka and Namugongo arm.

Due to the gentle and steep slopes encountered, vehicles approaching from Kira and Naalya arms tend to move at a relatively higher speed than the speed at which they move when leaving the intersection due to the unfavorable change in the slopes. This leads to more congestion and delays. These gentle slopes which result into higher approach speed of vehicles also lead to an increased number of the approaching vehicles from these 2 arms contributing to more congestion.

The low speeds at which the approaching vehicles from Kireka and Namugongo move leads to increased time lag experienced as they overcome the steep slopes hence increasing congestion at the intersection.

During site surveys, it was also observed that Naalya-Namugongo has a high commercial land use compared to other roads. This leads to regular road side parking of vehicles, which narrows the available space hence more congestion

The existing road geometric parameters for the different arms were also established and these are summarized in table 5;

Existing road geometric parameters for;

i. **Kireka and Kira arms**

Table 5: Existing Road geometric parameters for Kireka and Kira

ARM	**Lane width**	**Width of the shoulder**
Namugongo	3	2
Naalya	1.8	Absent
Kireka	2.9	0.8
Kira	2.1	1.3

Table 6: Road Geometric standard parameters

Parameter (m)	STANDARD (m)
Lane width	3.35
Width of the traffic island	
Width of the shoulder	2.5
Distance of the building from the road centerline	15

From the above analysis, it was noted that most of the junction arms do not comply with the standard parameters. This could be one other possible cause of congestion creating a need for the intersection to be provided with a geometry.

4.3 Determining the performance of the intersection in its current state.

4.3.1 Peak hour traffic counts

This mainly involved field traffic counts for the peak hours. This survey was undertaken for one week where the number of vehicles using each approach were recorded for every fifteen-minute interval. The traffic volume data collected was converted into passenger car units (PCUs) using passenger car equivalent values.

The morning and evening peak hours considered were 7 – 8am and 6-7pm respectively since they had the highest volumes throughout the days and from the field analysis, the summery of the peak traffic volumes was obtained as shown Table 7. Basing on these peak traffic volumes, Naalya-Namugongo was taken to be the major road. This implies that this road is the most contributor towards the traffic congestion experienced at the intersection, followed by other arms.

Table 7: Summary of peak traffic volumes for each intersection arm

Arm	Traffic volumes (veh/h)
Naalya	1432
Kireka	1112
Kira	1136
Namugongo	1396

4.3.2 Turning movements

The high volumes of right and left turns from the minor arms and through traffic from the major arm result into high congestion at the intersection.

From this information, the following parameters were determined and these indicate the performance of the intersection;

Table 8: Total turning traffic

TURN	VOLUME (veh/h)			
	KIRA	KIREKA	NAMUGONGO	NAALYA
Left turns	936	563	812	1330
Through	712	1045	1339	1543
Right turns	1475	1174	474	447

4.3.3 The peak hour factor

$\text{PHF} = \frac{V}{4\,V_{15}}$

Where:

- $V = Peak\ hour\ volume$, which is the highest hourly volume within a 24-hour period
- V_{15} = Highest fifteenth volume of the peak hour

The LOS was determined from;

$SFi = 2800\ x\ (\frac{v}{C})\ x\ F_d\ x\ F_w\ x\ F_T$

Where;

- SF = Total service volume for the level of service in vehicles per hour.
- $\frac{v}{C}$ = Flow to capacity ratio for level of service
- F_d = Directional factor
- F_w = Lane width factor.
- F_T = Truck factor.
- $FT = \frac{1}{1+P_T\ (E_T - 1) + P_B(E_B - 1)}$

Where;

- P_T = proportion of trucks in the traffic stream, expressed as a decimal
- E_T = passenger car equivalent for trucks
- P_B = proportion of buses in the traffic stream, expressed as a decimal
- E_B = passenger car equivalent for buses.

The above analysis the following conclusions were made;

1. The intersection was experiencing long delays of approximately 10minutes and not only leads to long waiting periods but also leading to escalating travel time. This was also evidenced from the long queue lengths experienced.
2. It also has high Peak Hour Factors indicating high peak hour volumes experienced at the intersection.
3. The intersection was found to have an average flow to capacity ratio of 1.89 indicating a LOS of E. This LOS is characterized by congested traffic under forced flow,(*HIGHWAY CAPACITY MANUAL*, no date). This level of service can easily turn from E to F

Table 9: Existing performance of the intersection

ARM	DELAY (s)	PHF	V/C	LOS	Que length (Veh/h)
Namugongo	480	0.92	0.92	E	55
Naalya	588	1.23	1.06	E	64
Kireka	360	0.92	0.89	D	45
Kira	306	0.91	0.79	D	32

From the data obtained through traffic count, the daily traffic volumes were summarized in figures 11 to 14, and these were used to determine the traffic composition of the different vehicle categories.

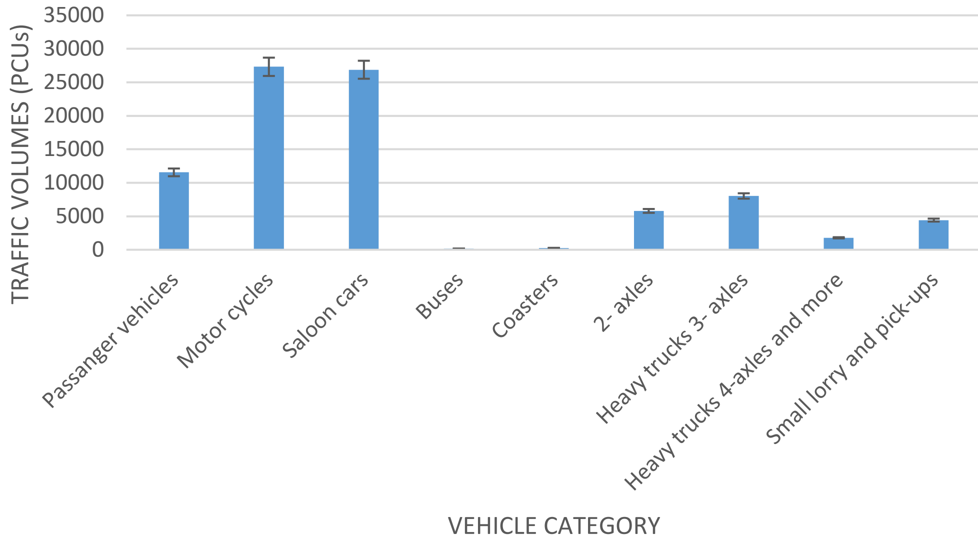

Figure 12: Traffic composition for Naalya arm

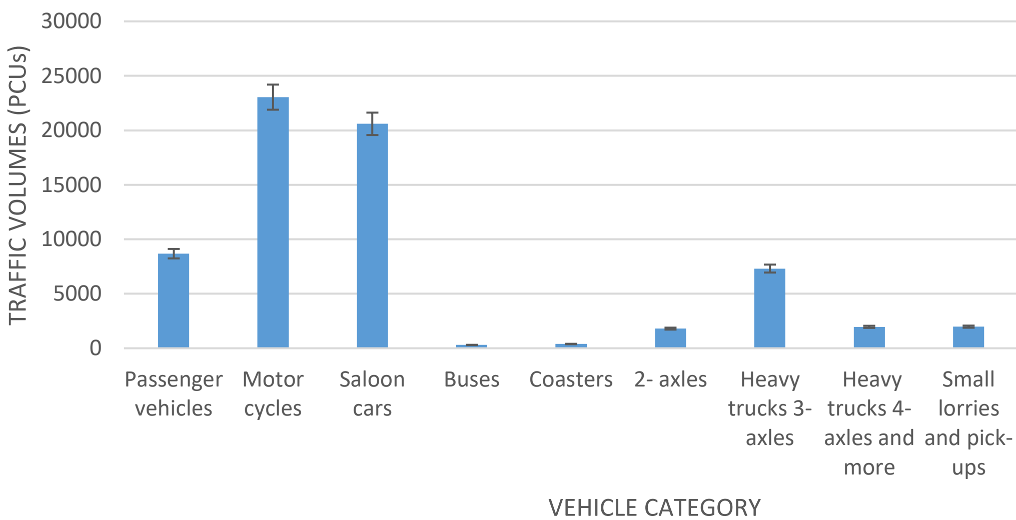

Figure 13: Traffic composition for Namugongo arm

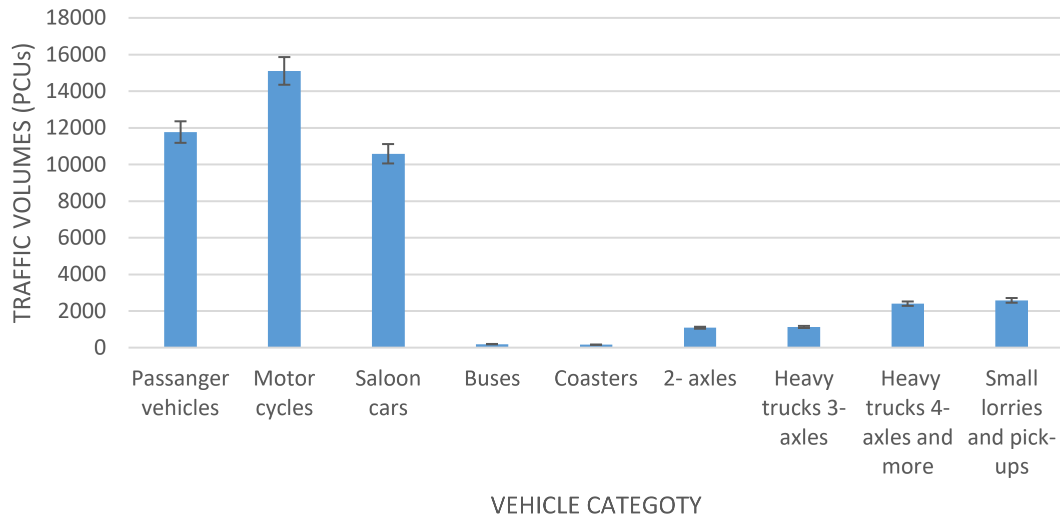

Figure 14: Traffic composition for Kira arm

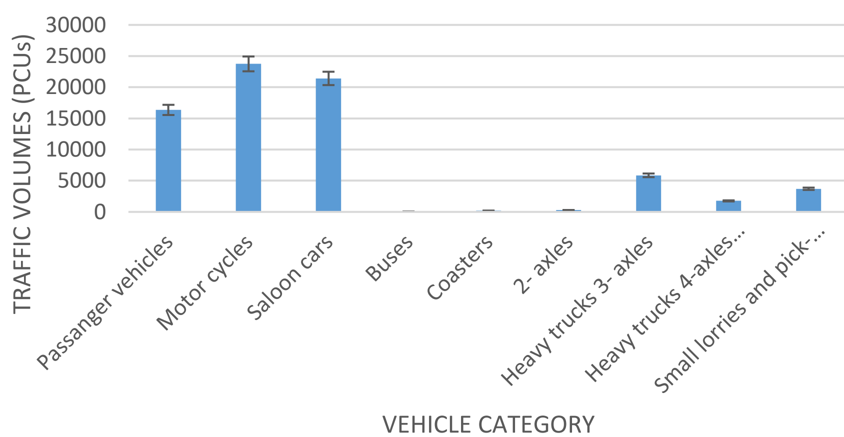

Figure 15: Traffic composition for Kireka Arm

The above graphs indicate that intersection is mostly used by motor cycles, passenger vehicles, and saloon cars. This is believed to be as a result of the increased land use pattern in terms of residential and commercial land use.

From the daily traffic volumes, the following parameters were determined;

The current Average daily traffic volume, ADT of the junction was determined from:

ADT = $\frac{2218042}{7}$

= $31149\ veh/day$

Using conversion factors, the Annual average Daily Traffic of the junction was also determined.

4.4 Design

4.4.1 Design year

Basing on the low level of reliability of the collected data, and high level of importance of the road, a design year of 15 years was selected,('Traffic count and traffic surveys.pdf', no date).

4.4.2 Selection of intersection control type

Following the procedure in the URDM, section 8.4, an intersection upgrade was selected using figure 15:

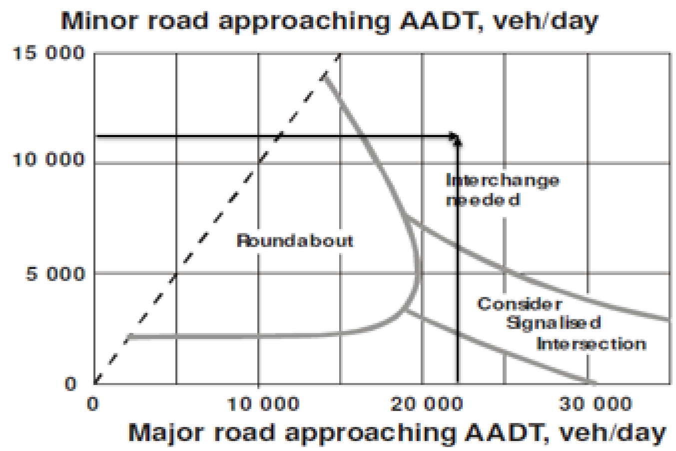

Figure 16: Selection of intersection control type

The intersection was found to have an AADT of 23505 veh/day along the major arm and 11078 veh/day along the minor arm implying that it needed to be improved to an interchange

Basing on the traffic volumes of the major road and the minor road, it was found that the intersection needs to be upgraded to an interchange.

This will reduce delays and congestion experienced by the vehicles at the intersection since despite the channelization that was done at Kyaliwajjala intersection, there is no effect in reduce the severity of the conflict points which basically causes continuous congestion leading to delays.

From the traffic surveys done, the problem lying at Kyaliwajjala-Namugongo intersection can be reduced by upgrading the existing design to an interchange.

4.4.3 Geometric design

From the different types of interchanges, the following options were selected;

1. Diamond interchange
2. Grade separated round about (roundabout with an overpass)

An evaluation used to select the final alternative followed these criteria so as to choose the best alternative, (Alzaubaidi M., and Molan,, 2021)

Table 10: Evaluation of the alternatives

Criteria	**Alternative one**	**Alternative two**
Safety	**+++**	**++**
Space requirement	**-**	**---**
Aesthetics	**+**	**++**
Economic	Saves 50-30%	Saves 20-30%
Total	**4**	**2**

From the above evaluation, the grade separated round about was found to have more benefits compared to the diamond interchange.

Therefore, a grade separated roundabout was chosen. This will have a roundabout to facilitate the turning movements and the through traffic of the minor road. It will also have an overpass to facilitate smooth flow of the through traffic of the major road only.

This geometry will have the following design parameters:

Table 11: Proposed design parameters for the upper level (overpass)

Parameter	**Dimension**	**Value**	**Standard reference**
Number of lanes	lanes	2	Circulating traffic = 413 and entering traffic = 580 veh/h
Entry radius	m	18	Between 15-0
Turning radius	m	14	Design vehicle
Lane width	m	3.65	3.65 for dual carriage ways
Circulatory carriage way width	m	21.6	Not > 1.2 x entry width
Approach speed	Km/h	30	<40
Design vehicle	-	-	Semitrailer combination large
Entry width	m	6	Design vehicle
LOS	-	C	A for multi-lane roads
Delay	s	Around 36	<45 according to the RGDM
Design volume	Veh/day	70037	-
Design hourly volume	Veh/hr.	8405	-
Central island radius	m	21	GRDM graphs for 2-lane carriage ways
Shoulders / cycle lanes	m	2	2 – 2.5
Design year	yr.	15	GRDM
Exit width	m	5.5	Design vehicle

Parameter	unit	Value	Standard
Ramp design speed	Km/h	45	40-50
Number of lanes	Lanes	1	1 secondary roads
Lane width	m	3.5	3 -3.65
Height from ground level	m	4.4	Design vehicle of height 4.1m
LOS	-	C	A or B
Average delay	s	Around 25	<30

4.4.4 Determination of the design volume for the intersection

Using a growth rate 6% as required provided by KCCA,

Future design daily traffic = $ADT(1 + r)^n$

Where n = 15years

ADT= 31149veh/day

Therefore;

Design daily traffic volume = $31149(1 + 0.06)^{15}$

=74650 veh/day

Design hourly volume, DHV was also determined from:

DHV = ADT $\times K$

Where K = 0.12 for heavily trafficked roads under congested conditions

DHV = 74650×0.12

$= 8958$ Veh/h

CHPAPTER FIVE: CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

From the analysis made in the previous sections, Kyaliwajjala was found to lie in a rolling country characterized with gentle and steep slopes and this not only affect the speeds of the traffic but also contributes to the congestion. Kyaliwajjala is one the areas in the metropolitan with the fastest growth and development rate. It is a busy sub-urban area with many business units situated with in the road reserve which limits the space available for road activities hence leading to more congestion yet the law requires any road users to position their land uses 15m from the road centerline. From the analysis, some structures were even situated as little as 5.6m from the road centerline and such people should not only be displaced but also penalized.

The intersection was found to be operating in its failed state, since despite the channelization that was done at Kyaliwajjala intersection, there is no effect in reduce the severity of the conflict points which basically causes continuous congestion leading to delays.

From the analysis of the results, and evaluation of the available alternatives, a grade separated round about was selected. Depending on the terrain of the intersection and the traffic volumes, it was suitable to provide the overpass to the through traffic along Namugongo – Naalya road. This will greatly reduce the delays, travel time, queues and also improve the performance of the intersection.

5.2 Recommendations

Recommend according to conclusions

In order to improve the LOS of the Kyaliwajjala- Namugongo junction from E to C the adoption of this geometry is recommended as it will reduce the delay to 35s, and also reduce the ques experienced at the intersection hence reducing traffic congestion. From the analysis and the field surveys made, this design will not be very expensive to implement since it will not require acquisition of large areas of land as compared to other types of interchanges. This is because there is large space available in the road reserve and this can be used, but not all as analyzed, for all the necessary expansions. Despite the fact that this land is occupied by encroachers, this is being done illegally, and therefore, they should be displaced with no or minimal compensation, depending on the will of the client.

From the information obtained from the different engineers, the consultancy company that plans to upgrade this intersection has various alternatives of geometric designs that it intends to implement, however, it was planning to implement a half-diamond interchange at the intersection. The project progress is still under planning stage and therefore, since implementation of this design has not yet been implemented, adoption of this design is recommended to the consultancy company instead of using the diamond interchange as planned, because of the discussed advantages and comparisons made in the previous sections.

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APPENDIX A

Figure 17: Traffic data collection

Figure 18: Collection of topographic data

Appendix B: Topographic survey data

Table 12; Shows the survey data that was collected

points	elevations and coordinates			reflector points
1	2000	5000	1200	pkt1
2	2026.545	4995.311	1201.393	pkt2
3	2022.523	5001.254	1201.415	Rd
4	2025.531	5007.283	1201.533	Tr
5	2022.192	5007.311	1201.501	Rd
6	2021.956	5020.601	1201.623	Rd
7	2024.582	5022.508	1201.861	Tr
8	2009.255	4997.704	1200.588	Rd
9	2004.456	5000.697	1200.353	Tr
10	1987.905	5003.313	1199.077	Tr
11	1987.383	5002.291	1199.088	Rd
12	1977.793	5006.369	1198.429	Tr
13	1977.653	5005.529	1198.421	Rd
14	1972.43	5008.322	1198.201	Tr
15	1961.999	5011.767	1197.553	Tr
16	1961.535	5010.824	1197.527	Rd
17	1944.852	5017.398	1196.541	Tr
18	1944.492	5016.597	1196.524	Rd

19	1935.944	5020.458	1196.013	Tr
20	1935.713	5019.759	1196.014	Rd
21	1920.924	5025.063	1195.339	Rd
22	1907.491	5029.479	1194.522	Rd
23	1893.175	5033.539	1193.589	Rd
24	1925.44	5022.299	1195.512	Rd
25	1875.729	5029.913	1192.561	Tr
26	1875.883	5029.914	1192.564	Rd
27	1876.485	5032.084	1192.532	Rd
28	1895.197	5024.111	1193.546	Rd
29	1896.276	5025.064	1193.69	Rd
30	1897.021	5023.601	1193.785	Rd
31	1912.202	5017.301	1194.571	Tr
32	1912.197	5018.2	1194.574	Rd
33	1929.972	5011.979	1195.663	Rd
34	1929.619	5009.942	1195.657	Tr
35	1944.545	5005.022	1196.567	Tr
36	1945.091	5006.042	1196.549	Rd
37	1957.178	5001.317	1197.305	Rd
38	1986.349	4995.467	1197.745	Tr
39	1970.293	4997.324	1198.183	Rd
40	1978.487	4994.494	1198.734	Rd

41	1980.456	4992.638	1198.762	Rd
42	1980.481	4990.596	1198.611	Tr
43	1986.034	4988.644	1199.019	Tr
44	1986.473	4989.783	1199.148	Rd
45	1996.942	4984.945	1199.684	Tr
46	1997.229	4985.796	1199.686	Rd
47	2006.378	4983.769	1199.943	Rd
48	1999.857	4983.013	1200.038	Tr
49	2005.405	4977.234	1200.291	Tr
50	2006.213	4977.723	1200.318	Rd
51	2007.975	4970.508	1200.585	Tr
52	2009.221	4970.743	1200.579	Rd
53	2021.612	4957.184	1201.129	Rd
54	2022.453	4966.045	1201.274	Rd
55	2023.632	4968.468	1201.372	Tr
56	2024.562	4971.066	1201.358	Rd
57	2033.543	4968.489	1201.637	Tr
58	2033.821	4969.522	1201.642	Rd
59	2044.05	4968.007	1202.108	Rd
60	2044.615	4966.795	1202.031	Tr
61	2086.947	4952.508	1204.352	Rd
62	2086.41	4951.619	1204.352	Tr

63	2105.184	4943.791	1205.452	Rd
64	2106.214	4942.141	1205.712	Tr
65	2127.461	4933.793	1206.678	Rd
66	2126.641	4932.732	1206.711	Tr
67	2139.451	4927.753	1207.297	Rd
68	2140.887	4926.081	1207.434	Rd
69	2146.148	4935.102	1207.814	Rd
70	2145.725	4936.345	1207.982	Tr
71	2170.651	4922.983	1209.214	Tr
72	2180.644	4917.099	1209.647	Rd
73	2195.393	4905.714	1210.517	Rd
74	2179.626	4915.895	1209.684	Rd
75	2175.162	4907.895	1209.454	Rd
76	2159.383	4916.589	1208.547	Rd
77	2144.713	4924.162	1207.715	Tr
78	2133.982	4941.464	1206.933	Rd
79	2113.687	4950.677	1205.958	Rd
80	2113.736	4951.239	1205.988	Tr
81	2098.388	4958.211	1205.171	Tr
82	2097.934	4957.572	1205.026	Rd
83	2083.648	4964.888	1203.949	Rd
84	2083.888	4966.113	1204.177	Tr

85	2065.081	4974.046	1203.3	Tr
86	2064.671	4972.985	1203.017	Rd
87	2051.978	4978.781	1202.458	Rd
88	2051.137	4979.544	1202.477	Tr
89	2040.441	4987.301	1201.755	Tr
90	2039.419	4985.764	1201.942	Rd
91	2026.291	4995.065	1201.482	Rd
92	2007.795	4953.773	1200.912	Rd
93	2001.159	4914.579	1200.641	Rd
94	1999.164	4898.549	1200734	Rd
95	1995.339	4873.393	1200.751	Rd
96	1997.046	4872.822	1200.842	Rd
97	1993.132	4842.949	1200.744	Rd
98	1991.043	4842.81	1200.685	SP
99	1988.082	4819.997	1200.533	Rd
100	2020.391	4948.465	1200.939	Rd

Where;

SP spot height

Rd Road

Tr trench

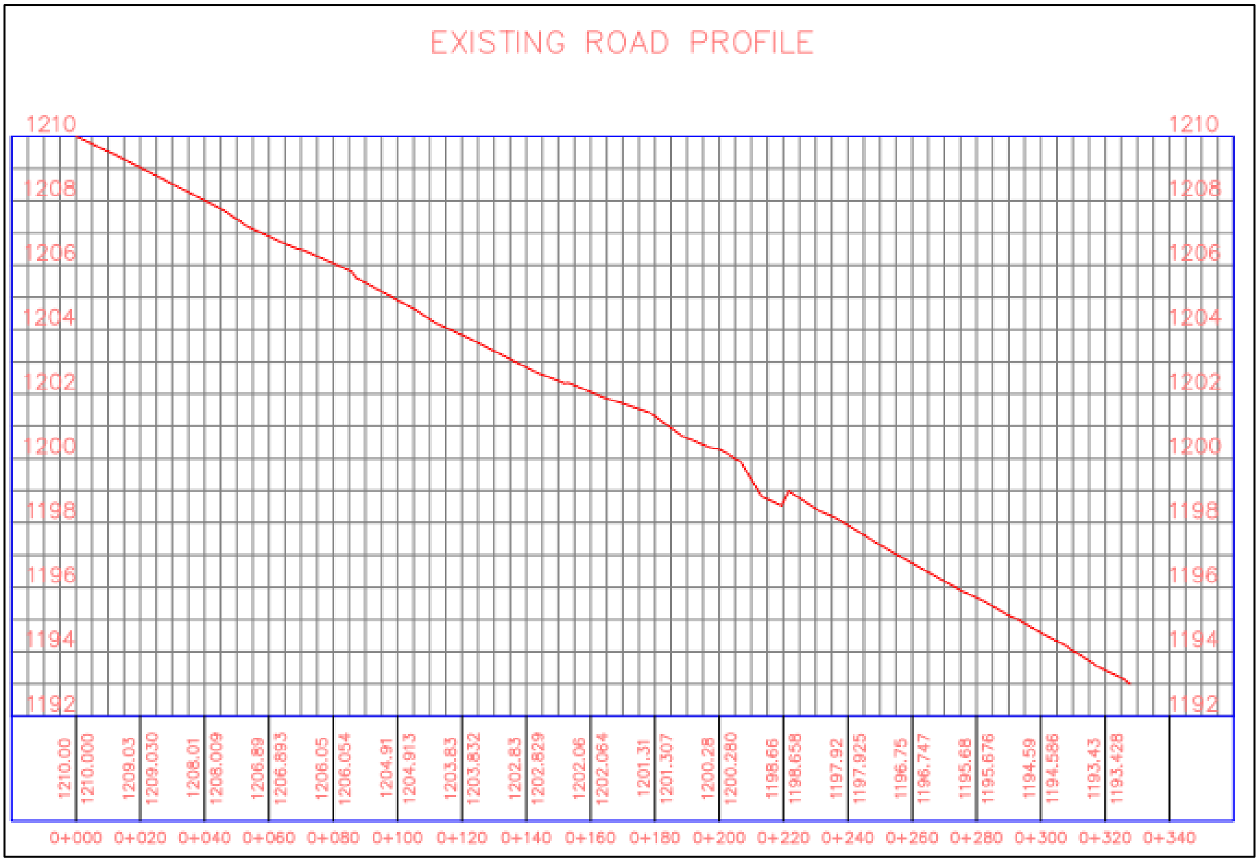


Figure 19: Existing Road profile for the major arm

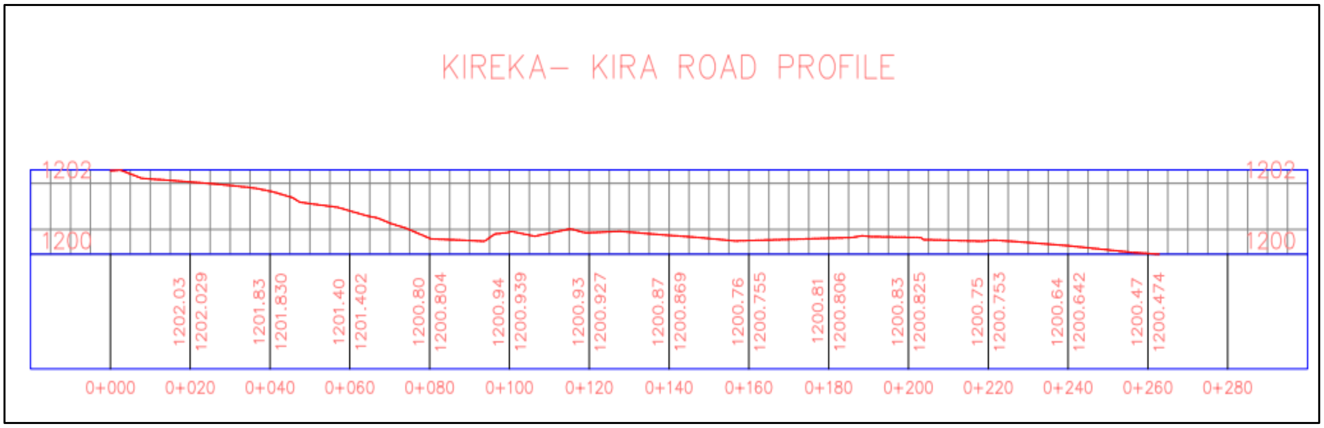


Figure 20: Existing profile of the minor arm

Slopes Table

Number	Minimum Slope	Maximum Slope	Area	Color
1	0.77%	2.84%	441.80	
2	2.84%	3.69%	532.53	
3	3.69%	4.51%	233.65	
4	4.51%	4.80%	637.34	
5	4.80%	5.30%	1921.27	
6	5.30%	5.47%	557.36	
7	5.47%	5.75%	1681.87	
8	5.75%	5.84%	691.22	
9	5.84%	6.04%	876.94	
10	6.04%	6.24%	535.13	
11	6.24%	6.65%	470.41	
12	6.65%	6.93%	915.40	
13	6.93%	7.28%	442.50	
14	7.28%	7.75%	1407.22	
15	7.75%	9.48%	339.63	
16	9.48%	11.32%	67.39	
17	11.32%	12.84%	174.42	
18	12.84%	18.94%	145.18	
19	18.94%	25.39%	141.18	

Elevations Table

Number	Minimum Elevation	Maximum Elevation	Area	Color
1	1192.53	1193.59	105.36	
2	1193.59	1194.57	155.36	
3	1194.57	1196.01	394.78	
4	1196.01	1196.57	278.42	
5	1196.57	1198.18	1367.90	
6	1198.18	1198.73	736.52	
7	1198.73	1199.15	546.30	
8	1199.15	1200.04	1205.52	
9	1200.04	1200.58	883.37	
10	1200.58	1200.74	374.22	
11	1200.74	1201.13	1038.87	
12	1201.13	1201.42	544.79	
13	1201.42	1201.64	563.37	
14	1201.64	1202.03	739.75	
15	1202.03	1203.30	1542.35	
16	1203.30	1205.03	680.64	
17	1205.03	1205.99	189.75	
18	1205.99	1207.43	336.26	
19	1207.43	1209.21	381.59	

Figure 21: Slopes and elevations

Figure 22: Layout of the existing intersection and some of the existing features

Appendix 2: Traffic count data

1. Traffic volumes for Naalya arm

Vehicle type	Monday	Wednesday	Thursday	Friday	Sunday	Saturday	Tuesday	TOTAL	TOTAL (PCUs)
Passenger vehicles	2101	1981	1729	1393	1067	1192	2090	11553	11553
Motor cycles	4451	4251	4111	4212	2981	3990	3321	27317	27317
Saloon cars	2964	2818	2702	2902	1922	1712	2897	17917	26876

Buses	8	5	4	6	9	4	7	43	172
Coasters	20	24	32	22	10	8	19	135	270
2- axles	882	843	885	881	690	762	855	5798	5798
Heavy trucks 3-axles	242	238	234	228	237	200	227	1606	8030
Heavy trucks 4-axles and more	35	38	31	37	23	30	29	223	1784
Small lorry and pick-ups	494	488	384	388	357	438	401	2950	4425
TOTAL									86224

2. **Traffic volumes for Namugongo arm**

VEHICLE TYPE	Monday	Wednesday	Thursday	Friday	Sunday	Saturday	Tuesday	TOTAL	TOTAL (PCUs)
Passenger	1312	1271	1291	1297	1116	1101	1293	8681	8681

vehicles									
Motor cycles	3852	3651	2418	3002	3998	2912	3212	23045	23045
Saloon cars	2220	2020	2087	2172	1167	1983	2082	13731	20597
Buses	10	13	11	8	9	9	16	76	304
Coasters	38	22	27	23	18	19	49	196	392
2- axles	293	279	228	248	233	233	291	1805	1805
Heavy trucks 3- axles	248	239	237	131	130	219	259	1463	7315
Heavy trucks 4-axles and more	37	34	38	33	39	31	34	246	1968
Small lorries and pick-ups	223	211	192	207	109	169	211	1322	1983

TOTAL									6609 0

3. **Traffic volumes for Kira arm**

VEHICLE TYPE	Monday	Wednesday	Thursday	Friday	Sunday	Saturday	Tuesday	TOTAL	TOTAL (PCUs)
Passenger vehicles	1992	1995	1888	1911	1058	1104	1820	11768	11768
Motor cycles	2421	2322	2001	2108	1941	2112	2201	15106	15106
Saloon cars	1055	1007	1017	1002	933	998	1044	7056	10584
Buses	8	5	9	6	4	8	8	48	192
Coasters	9	10	6	11	12	14	18	80	160
2- axles	129	130	124	127	123	220	233	1086	1086
Heavy trucks 3- axles	48	38	27	28	19	33	33	226	1130
Heavy trucks 4-axles and more	59	48	49	47	36	26	35	300	2400
Small lorries and	245	241	231	233	25	325	420	1720	2580

pick-ups									
TOTAL									45006

4. **Traffic composition for Kireka Arm**

KIREKA ARM									
VEHICLE TYPE	**Monday**	**Wednesday**	**Thursday**	**Friday**	**Sunday**	**Saturday**	**Tuesday**	**TOTAL**	**TOTAL (PCUs)**
Passenger vehicles	2348	2241	2280	2325	1966	2291	2910	16361	16361
Motor cycles	3987	3891	2621	3963	2058	3234	3990	23744	23744
Saloon cars	2551	2226	2110		1872	2989	2529	14277	2141
Buses	3	4	2	1	0	1	1	12	48
Coasters	15	17	14	10	8	10	16	90	180
2- axles	47	32	38	35	28	62	40	282	282
Heavy trucks 3- axles	132	128	134	120	193	229	237	1173	5865
Heavy trucks 4-axles and more	31	27	29	26	27	35	46	221	1768

Small lorries and pick-ups	464	402	388	482	8	312	417	2473	3710
TOTAL									73373

Table 13: Pces used for the different vehicle categories

Passenger vehicles	**pce**
Motor cycles	1
saloon cars	1.5
buses	4
coaster	2
2-axles	1
3-axles	5
4+more	8
Small lorry	1.5

Table 14: Conflicting volumes at the intersection

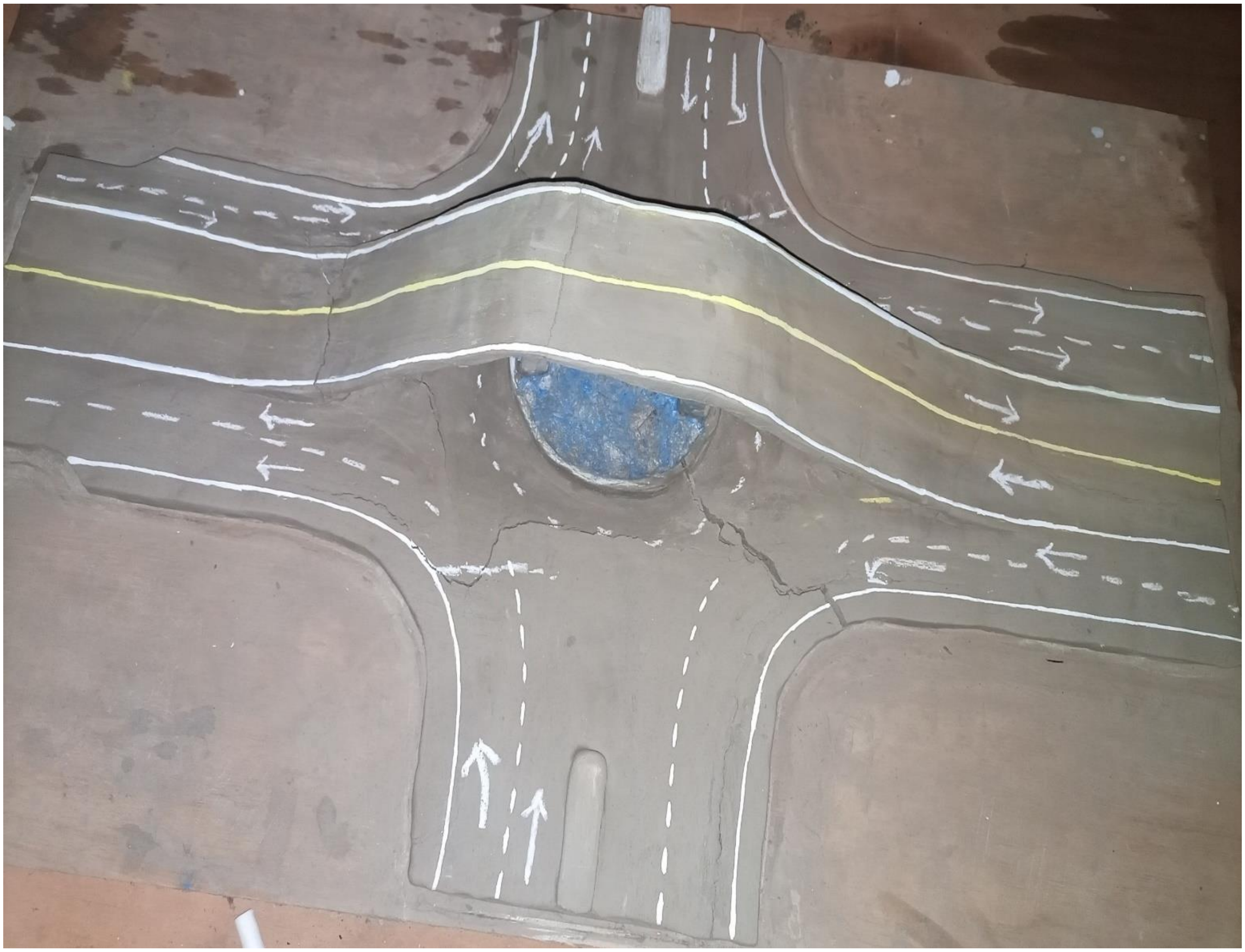
ARM	**Conflicting volumes**		**Capacity**	
Major LT	Namugongo-Kireka	Naalya-Kira	Namugongo-Kireka	Naalya-Kira
	869	552	769	552

Minor RT	Kira-Naalya	Kireka-Namugongo	Kira-Naalya	Kireka-Namugongo
	1445	1400	464	483
Minor TH	Kira	Kireka	Kira	Kireka
	1394	1328	649	516
Minor LT	Kira-Namugongo	Kireka-Naalya	Kira-Namugongo	Kireka-Naalya
	1394	1328	642	516

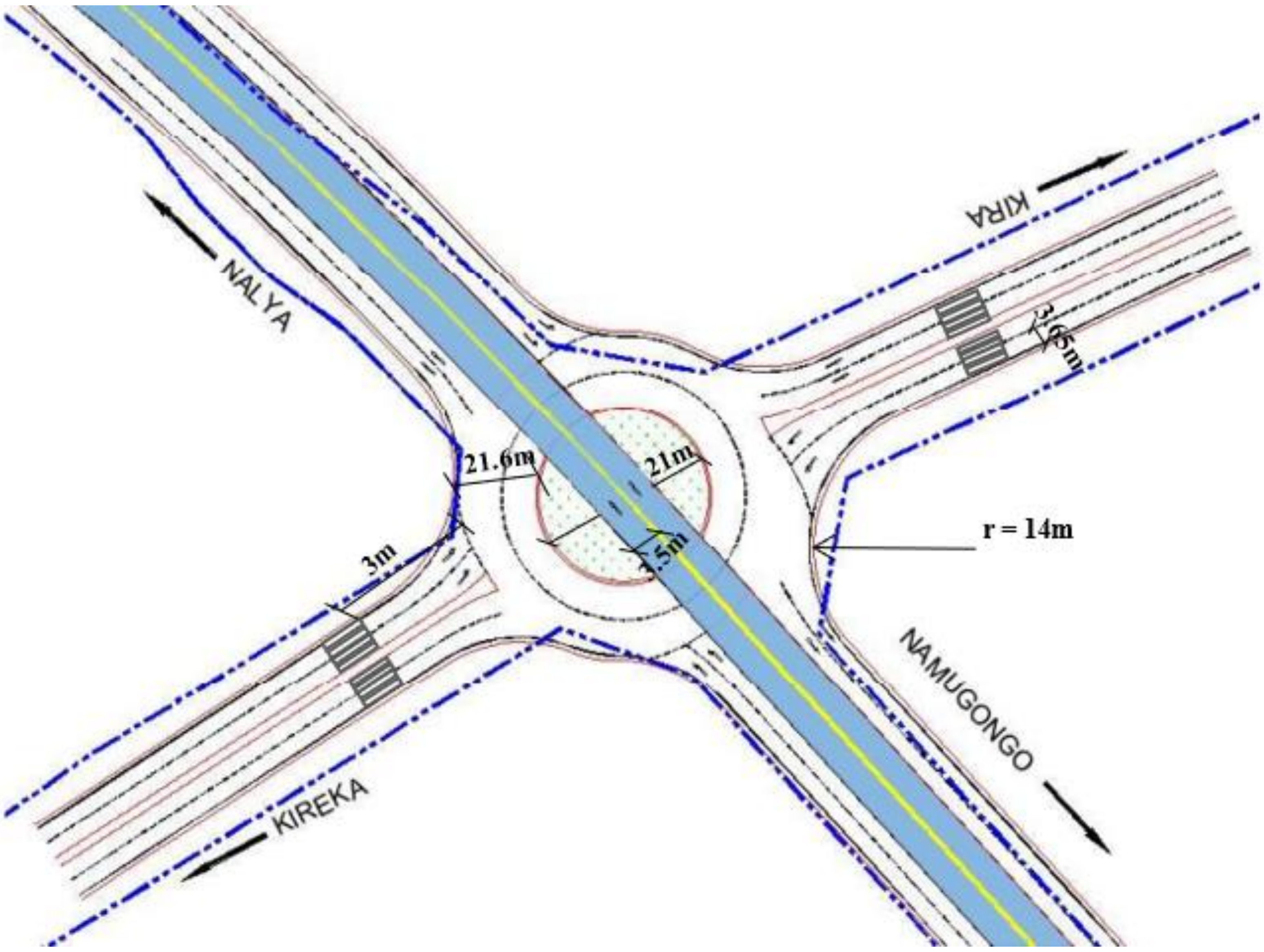
Figure 23: Interpretation of the evaluation symbols

+	Small positive significance
++	Fairly large positive significance
+++	Large positive significance
-	Small negative significance
---	Large negative significance

Figure 24: Prototype of the prosed model



PROPSOED LAYOUT



LEGEND

Road edge

Lane

Island

Shoulder / cycle lane

Central island

Drainage system

Pedestrian crossing

Traffic flow direction

Over pass

Road centre

PLAN VIEW OF THE PROPOSED LAYOUT

SIDE VIEW FROM NAMUGONGO