EVALUATING THE EFFECT OF TRAFFIC FLOW ON CONSTRUCTION PROJECT DELAYS IN KAMPALA

BY

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DECLARATION

I, **OKIZA HUMPHREY** hereby declare that this dissertation report titled ***"EVALUATING THE EFFECT OF TRAFFIC FLOW ON CONSTRUCTION PROJECT DELAYS IN KAMPALA"*** is my original work and has never been presented for a degree in any other university.

Signature: ……

Date: ……

APPROVAL

We as University supervisors confirm that the dissertation titled ***"EVALUATING THE EFFECT OF TRAFFIC FLOW ON CONSTRUCTION PROJECT DELAYS IN KAMPALA"*** has been done by the candidate under our supervision.

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DEDICATION

I would like to dedicate this report to my parents Hamu Mbamanya and Schola Busingye who have continually supported me in ensuring that I acquire this milestone. I would like to also dedicate it to my four siblings, Oweka Raymond, Tusasiirwe Layola, Nayebare Graham and Ainembabazi Renick.

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LIST OF ABBREVIATIONS

GDP	Gross Domestic Product
GKMA	Greater Kampala Metropolitan Area
GPS	Global Positioning System
ITS	Intelligent Traffic system
JICA	Japan International Cooperation Agency
KCCA	Kampala Capital City Authority
M.O.M	Moving Observer Method
MoWT	Ministry of Works and Transport
ROU	Republic of Uganda
SPSS	Statistical Package for Social Sciences
UNRA	Uganda National Roads Authority

ABSTRACT

This study assesses traffic congestion and its impact on construction project delays. The research aimed to investigate key traffic variables influencing traffic flow in Kampala's city center and develop a predictive model to guide construction project planning and execution based on traffic patterns. Data on traffic volume, density, speeds, and driver behaviors were collected along major roads, including Entebbe Road, Jinja Road, Sir Apollo Kaggwa Road, Yusuf Lule Road, and the Wandegeya stretch, using the moving observer method. The data were analyzed using regression to determine the relationships between these variables and traffic flow. A predictive model was developed, incorporating both microscopic and macroscopic factors such as traffic density, flow, time of day, day of the week, and road stretch. The study found that traffic flow is primarily influenced by density, time of day, day of the week, and road stretch. The model explains 56% of the variation in traffic flow ($R^2 = 0.56$), with flow decreasing by 28% on weekends compared to weekdays, and a 1% increase in density leading to a 1.5% increase in flow. This model identifies critical periods and roads that experience the highest traffic volumes, enabling project planners to anticipate delays during construction activities. The study recommends utilizing the predictive model to inform construction schedules, optimize resource allocation, and improve traffic management strategies, ultimately reducing the impact of traffic on construction delays in the city center.

Keywords: Traffic density, Traffic flow, Moving observer method, non-motorized transport, microscopic variables, Macroscopic variables

CHAPTER ONE: INTRODUCTION

1.1 Background of the study

A study by the United Nations predicts the world population to grow by 2 billion by 2050, this puts the existing road infrastructure at pressure and necessitating efficient traffic management (Bisio, et al., 2022). Traffic congestion is considered one of the most expensive issues in many countries today. In developing nations, the amount of traffic in cities is rising alarmingly (Arnott, et al., 2005). Many developing countries experience the occurrence of congestion at key hotspots because of poorly planned road networks. Ineffective management of traffic on the roads may lead to prolonged traffic jams (Jain, et al., 2012). Data-driven techniques are gradually becoming more prevalent in construction management initiatives and exploit the potential of digital technologies, Big Data analytics and innovative forecasting approaches (ITF, 2021).

Koźlak and Dagmara (2018), noted that traffic congestion tends to be a result of a road's capacity being exceeded by the volume of vehicles that is using a particular road, which slowed down or completely stops free movement. They also observed that the concentration of movement in both space and time created a strong demand for infrastructure. This resulted into congestion arising from the imbalance between demand and supply for travel. Intelligent traffic management was crucial in our cities to maximize traffic flow while utilizing the archaic infrastructure that was already in place (Langer, et al., 2020). Khan and Gulliver (2018), identified two types of traffic variables that influence its flow, these were macroscopic and

microscopic characteristics. Microscopic traffic variables focused on how individual vehicles interact with one another considering the driver behavior, vehicle locations, and distance and time headways. Macroscopic traffic variables considered the whole traffic flow pattern and included variables like flow, density, and speed.

In Kampala, traffic jams are very common, and they get worse during rush hours causing a slow flow of vehicles. There are no cameras to monitor the behaviors of passengers and no public transport means to regulate traffic flow. Several studies have been carried out with emphasis on the causes and effects of traffic jam in Uganda. JICA (2010) found out that traffic congestion in Kampala has increased to the outskirts including Bombo Road among others.Tukesiga et al. (2021), calculated the unintended cost of traffic congestion in terms of lost time in Kampala. Bayiga (2019), analyzed traffic injuries and accidents. Nansereko (2019), ascertained the causes and consequences of traffic congestion. A study into traffic flow behavior to understand its relationship with delays on the road that consequently affect construction projects scheduling was paramount.

In China and other developed countries, it is difficult to make major adjustment on infrastructure in the city centers. The only option is to rely on technology techniques to support optimization of traffic on existing infrastructure (Zhou, 2021). KCCA plans to construct a Traffic Control Center to leverage on real-time data and predictive analytics (KCCA, 2022). Data-driven technologies enable the automation of processes and the more effective use of resources through evidence-based decision-making such as rerouting deliveries to avoid congested routes and adjusting schedules (Janine & Philippe, 2020).

1.2 Problem Statement

Uganda aspires to have Greater Kampala Metropolitan Area (GKMA) among the most appealing cities in the world by 2040, providing residents and tourists with a secure and effective transportation system built on a network of complementing non-motorized transportation and first-rate public transportation (ROU, 2007).

Roads in Kampala account for 90 percent of the modes of transportation in the city as opposed to rail and water transport (JICA, 2010). However, congestion remains a challenge in the city leading to loss in revenue to the government as well as financial loss to the citizens considering the ever-increasing fuel prices. Baertsch (2020), noted that the Greater Kampala Metropolitan Area (GKMA) incurred daily costs of congestion estimated at USD 1.5 million, or 13.7% of the daily Gross Domestic Product (GDP) of the region.

While prior research has explored traffic congestion in Kampala, there is a critical gap in understanding the specific variables that influence traffic flow, particularly in relation to delays in construction projects. Delays caused by congestion can lead to increased project costs, schedule overruns, and resource misallocation. This study aims to address this gap by analyzing traffic flow variables and developing a predictive model to forecast traffic demands on Kampala's roads. By doing so, it seeks to enhance urban traffic management and provide actionable insights into how traffic congestion impacts construction timelines.

1.3 Objectives of the study

1.3.1 Main Objective

The main objective of this research was to study traffic patterns and quantify delays in construction projects due to traffic in Kampala.

1.3.2 Specific Objectives

The following objectives were adopted for the study.

i) To determine the traffic variables responsible for traffic in Kampala.
ii) To determine the relationship between the traffic variables throughout various times of the day for different days.
iii) To develop a predictive traffic flow model
iv) To compute the delays on construction projects due to traffic congestion

1.4 Research questions

The research questions for the study were.

1. What traffic variables are most responsible for traffic congestion in Kampala?
2. How do traffic variables interact and vary throughout different times of the day and across different days in Kampala?
3. How can a predictive model be developed to accurately forecast traffic flow in Kampala?
4. How does traffic flow impact delays in construction projects?

1.5 Justification of the study

Baertsch (2020), noted that the daily cost of traffic congestion in the Greater Kampala Metropolitan Area was predicted to be USD 1.5 million, and if nothing is done to solve the issue, that cost might rise every day. To solve this, an intelligent traffic management system that can adapt to the varying traffic demands to be developed, up to date information about the current state of traffic was required. When making decisions on investments in Kampala's public transport infrastructure, the KCCA can be directly aided by the expenses associated with traffic congestion. This research was carried out in response to the understudied traffic flow variables and their significance on the traffic flow in Kampala town. The variables included flow rate, density, volume and headways. It is believed that this study will lay the foundation for future research on the causes and effects of traffic in Kampala, including more extensive effects on urban growth and the influence of transport on traffic in the city. If we didn’t do this study, we expected in future the traffic to spring out uncontrollably to other cities neighboring Kampala and further escalate delays in projects.

1.6 Significance of the study

The goal of the study was to examine Kampala's traffic flow, and the results would assist in better planning for construction projects within the city center. This study would also play an important role in helping the traffic police department to understand traffic streams and managing of traffic flows and consequences of changes in design of roadways in Kampala. The findings of this study would directly benefit engineers and engineering students in planning the city's road infrastructure and designing according to the traffic demand. The findings will also be shared with academia, future researchers who would have an overall objective of doing a related study in the same field for improving traffic flow in Kampala.

1.7 Scope of the Study

This section described the extent of the research study and its boundaries.

1.7.1 Geographical scope

The research focused on vehicles passing through five selected road stretches towards Kampala. A preliminary desk study was conducted to identify and select the roads for the study by identifying high traffic volume areas, major intersections and bottlenecks, and areas with frequent traffic incidents. The study relied on literature from previous scholars to identify these objectives. A mix of roads, including busy highways, major arterial roads and local streets were identified providing a comprehensive overview of traffic flow issues within the city. Five stretches were chosen to represent the traffic leading to Kampala. The stretches were

200m long and had no junctions and branch offs for purposes of acquiring accurate results. The selected roads included:

i) Jinja Road
ii) Entebbe Road
iii) Wandegeya Road
iv) Sir Apollo Kaggwa Road
v) Yusuf Lule Road

1.7.2 Financial scope

The study required three field assistants for each selected stretch who collected data simultaneously. All these and other logistics were financed as shown in the in appendix.

1.7.3 Time scope

The research spanned for a period of twelve months (May 2022-June 2023) from proposal writing to final dissertation submission. Data collection was carried out for 20 days of the week (Monday to Sunday) for each of the five stretches which enabled wide coverage of data to be collected for more accurate results and analysis. Final dissertation writing was carried out thereafter.

1.8 Conceptual framework

Jabareen (2009), defined a conceptual framework to represent the relationship a researcher expected to see between variable or the characteristics or properties that

he/she wanted to study. It is developed based on literature review. It shows the variables and how they relate to one another. This study looked at variables influencing traffic flow as the dependent variables. Congestion was due to various factors that influenced the free flow of vehicles in a stretch which were divided into microscopic and macroscopic. Macroscopic factors included density, volume and speed of the traffic. The relationship between the variables is as shown in Figure 1.1.

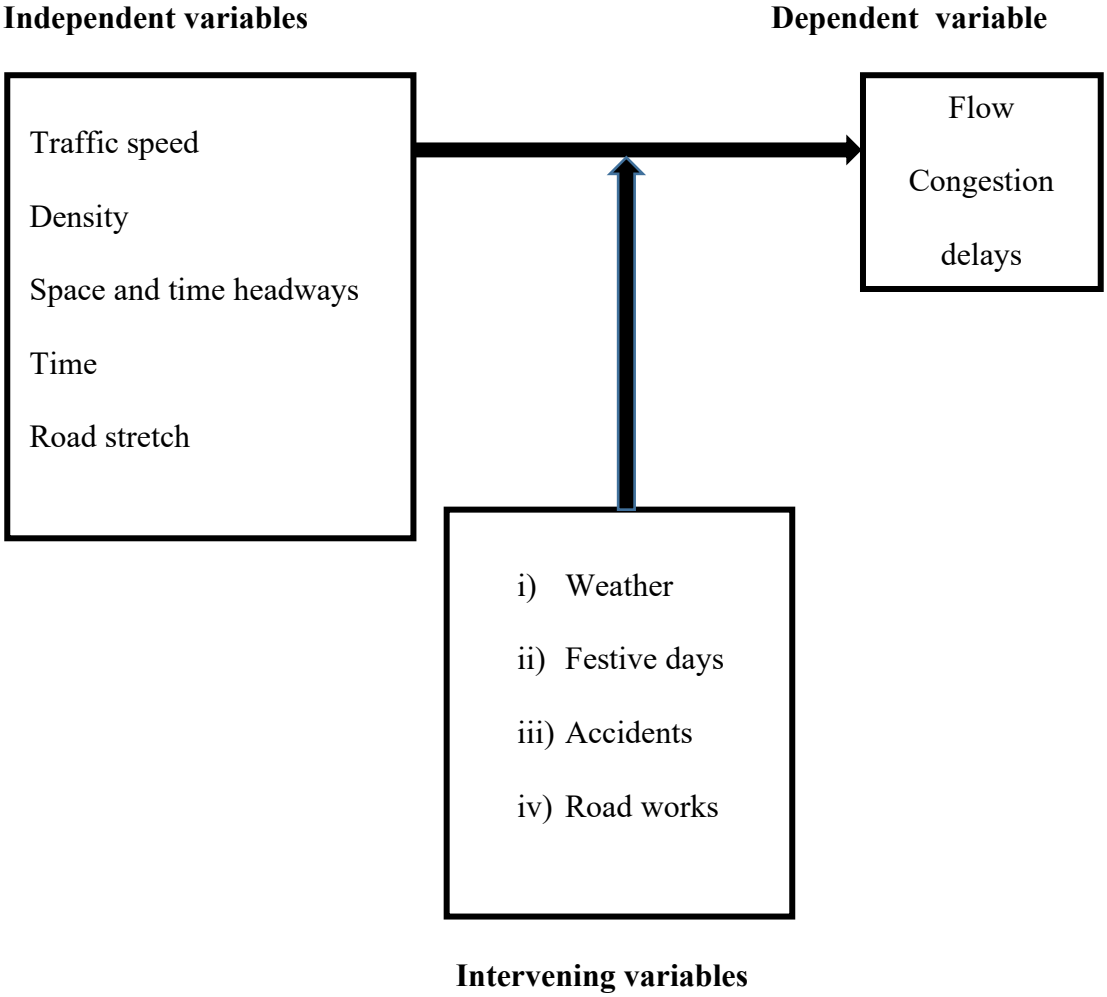


Figure 1. 1: Conceptual framework

1.9 Chapter summary

This chapter introduced the study, background, problem statement, objectives of the study, scope, and the conceptual framework.

CHAPTER TWO: LITERATURE REVIEW

2.1 Introduction

Koźlak and Dagmara (2018), found out that when traffic on a road is delayed due to the presence of other vehicles, congestion takes place. The costs of users grow along with an increase in demand exceeding the capacity of a road facility, and the quality of using the road facility depreciates**.**

2.1.1 Transport congestion

Transport congestion is defined as mutual obstruction of traffic by cars caused by the relationship between the volume of flows and the speed of moving vehicles when the capacity of the infrastructure is exhausted. In other words, traffic jams are caused by a volume of vehicles that is more than the capacity of a road, which slows down free movement. When there are more vehicles using the road at the same time, congestion occurs (Bull, 2003).

According to (Abdulkadir, et al., 2022), there are several reasons why traffic congestion occurs, such as a lack of lanes, careless drivers, VIP travel, particularly for political figures, a rise in the number of automobiles on the road at night, an increase in the population, and inadequate traffic officer management.

2.1.2 Traffic congestion in Africa

According to reports, the biggest issues facing Sub-Saharan Africa include transportation safety, traffic congestion, urban air pollution, road maintenance,

accessibility, and mobility issues. Migration from the countryside to the city has accelerated urbanization, raised poverty rates, and increased the number of slums. These factors have caused the supply and demand for urban mobility to diverge, increasing the number of motor vehicles and causing traffic congestion (Abdulkadir, et al., 2022).

In Uganda, an objective data indication suggests that the behavior of drivers on the road is the cause of 48.2% of reported traffic jam events. This suggests that multi-stakeholder interventions are necessary to address drivers' behavior (Sekalema , et al., 2023).

2.1.3 Interventions to control traffic congestion

Kwikiriza (2014) recommended that instead of relying solely on private vehicles, commuters should be encouraged to adopt non-motorized transportation, telecommuting, carpooling, car sharing, bicycle sharing, and public transportation. All traffic issues will be resolved if all cars are eliminated, additional bike lanes are constructed to promote biking, and mass transit is improved. Then, every city will be intelligent, healthy, and breathing in less pollutants, protecting the environment. If we promoted rail freight and expanded the possibilities for mass transportation, we could reduce the number of vehicles and trucks on the road.

According to Bisio et al. (2022), drone-based traffic control measures were identified as crucial in traffic management, but these relied a lot on real time data and predictions. The cornerstone to a successful smart city is infrastructure that supports vehicular network capacity since this allows for the implementation of

several smart mobility services. Many intelligent transportation systems (ITS) must be created to lessen traffic congestion and increase the effectiveness of public transit on the existing infrastructure (Wei-Hsun & Chi-Yi, 2020). Kwikiriza (2014), wrote that in order to enhance Kampala's transportation system, focus should be placed on improving traffic management and control systems and developing transportation infrastructure. By doing so, Kampala, Uganda, will experience a decline in fatal accidents, government spending, production productivity, and finally clean and smart mobility. The previous studies never dived deep into the role of technology in management of traffic, the use of real time data to manage traffic, modeling the traffic behavior and patterns on roads. This research seeks to cover those areas.

2.1.4 Traffic congestion and delivery of materials

Most of the body of research on the financial implications of urban traffic congestion is extremely general. Nevertheless, there isn't much evidence available above that level to describe how congestion impacts various logistics categories (Glen & Stephen, 2011).

Boye (2018), noted that congestion delay and uncertainty increases demand for material or product inventory hence costs. The study concluded that supply chain performance and traffic congestion are inversely related. This suggested that supply chain performance is impacted as traffic congestion rises. Consequently, the study suggested that the government and other interested parties view congestion as a shared responsibility in order to enhance traffic flow, which would greatly enhance supply chain efficiency.

The practical implications of the study by Dorasamy and Peprah (2023) , emphasized how crucial knowledge-based decision-making, safety precautions, and community involvement are to attaining the best possible logistics chain responsiveness.

The average speed of vehicles in Kampala city was documented by Lee (2024), as 11km/hr and the average commuter spends 2.5 hours in traffic daily. Commuters lose an estimated 240 hours per year due to traffic jams. The lost time translates to about 52 working days lost annually. Traffic jam is at its highest during peak hours to (between 6am and 10am) and from (between 5pm and 8pm) work (Net_Africa_Press, 2022)

2.2 Traffic variables

The main types of traffic characteristics are macroscopic and microscopic. Khan and Gulliver (2018). These variables are believed to be the main cause of traffic congestion on the road. They are further explained below.

2.2.1 Microscopic traffic flow variables

Khan and Gulliver (2018), identified that microscopic variables concentrate on how individual vehicles interact with one another. These characteristics consider variables like vehicle locations, driver behavior, distance and time headways, and individual vehicle velocities and accelerations.

According to Maerivoet and Bart (2005), drivers operating various cars, each with unique features, make up the flow of traffic on the road. Microscopic characteristics

are determined by the behavior of each driver, as well as the physical characteristics of the vehicles. These characteristics included length, space, and time headway.

Khan, Gulliver, & Khattak (2021), defined time headway as distance between the lead vehicle to the one following it. Distance headway is small during congestion and large during free traffic flow. An aggressive driver responds quickly to traffic flow leading to smaller distance headway and greater changes in traffic flow while a slow one does not, leading to a bigger distance headway and thus lower changes in traffic. Recognizing that traffic composition, particularly the proportion of heavy trucks, has a significant impact on traffic dynamics or merely wanting to reflect the various vehicle classes in the simulation, each of which behaves differently from the others (Schultz&Rilett, 2005).

2.2.2 Macroscopic traffic flow variables

Khan and Gulliver (2018), noted that macroscopic variables examine the entire traffic flow pattern. These traffic variables are frequently used because of their simplicity. There are four important macroscopic traffic flow variables: density, flow, travel time, and mean speed (Abdulrahman, et al., 2017).

i) Density

Density is a very difficult traffic parameter to quantify. The stationary observer method and the moving observer method can be used to measure flow and speed. Once traffic flow and speed of a stream are calculated, the density can be easily calculated using the flow-density-speed relationship (Barua, et al., 2015).

A free-flowing road segment is known to have a critical jam density point K jam, as shown in figure 2.1, beyond which any traffic input can cause the density to spiral out of control. This results in the road segment running at low capacity. Many congested areas in developing countries have poor traffic management strategies which if they experience a congestion collapse can cause the road network to become severely congested for extended periods of time (Jain, et al., 2012).

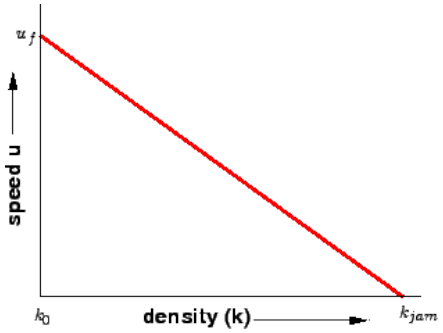


Figure 2. 1: Relationship between speed and density showing jam
Source: (Wu, 2021)

According to Kalman (1960), the maximum traffic flow divides the density flow parabolic curve into uncongested and congested regions. This means when congestion occurs, the critical speed at capacity is about half of the free flow speed.

ii) Traffic flow

Dzhuruk and Zedgenizov (2018), defined the flow as the quantity of cars that pass a certain location on a road in a certain amount of time. The term "flow" can relate to a road's entire cross-section or only a portion of it, such as a single lane or a roadway that runs in one direction. Understanding traffic volume is necessary for developing methods to enhance road traffic management. The most important factor

in traffic flow is flow, which influences the importance of the road, its dimensions, the amount of traffic control required, and the cost of road maintenance services.

Traffic volume

Volume in general is measured using different ways like manual counting, detector counting, and moving observer method (Assouli, 2019). There have been numerous attempts to create sampling methods that would allow for simultaneous estimation of traffic flows and speeds using a small sample of the overall traffic stream. One such development was the moving observer method, in which observers in a moving vehicle in the traffic stream gather data on speeds, flows, and travel times (O'flaherty & Simons, 1970).

2.3 Moving observer method and measuring the variables.

Using data acquired from moving cars, the moving observer method is a method that is widely used to estimate the average journey time and traffic flow. This technique involves a test vehicle performing a series of runs both "with" and "against" traffic. The test vehicle's observers record the number of oncoming and passing vehicles, the number of vehicles that pass it while it is driving, the average speed, and the observer's travel time for each run (Solanki, et al., 2016). The key benefit of using this method is that it can be used to identify features over a wider area, such as a network's links. Furthermore, the approach only yields significant results provided the flow does not alter significantly. The traffic flow rate is calculated from the gathered information using the appropriate equations. The major advantage of the moving observer method is that flow and speed data may be

gathered simultaneously. Additionally, it is cost-effective because measuring requires fewer participants and takes less time (Barua, et al., 2015).

The observer in the Moving Observer Method (M.O.M) goes along a segment of road whose flow is indicated by the letter q. A test vehicle (observation vehicle) must do several runs both with and against a one-way traffic flow (q). Human observers who are riding inside the test vehicle simultaneously gather the fundamental traffic data (Guerrieri, et al., 2019).

All methods of data collecting that are done from a distance, like from an aircraft, a helicopter, or a satellite, are generally considered to fall under the category of remote sensing. From the video, the automobiles are recognized and located using specialized software. Thus, the vehicles' trajectories and their speeds can be ascertained. Given that it is expensive and time-consuming; it is evident that this method should only be used for specialized studies. The system can be mounted on top a tall building as an alternative (Ossen, 2008).

2.4 Theory of moving observer method

The moving observer technique requires a number of runs in a test vehicle driven both "with" and "against" a one-way traffic flow. For each run, the test vehicle observers record the following data (Guerrieri, et al., 2019).

i) Cars the test vehicle passed.

ii) The number of vehicles passing the test vehicle while it is moving.

iii) The test vehicle's average speed.

iv) The length of the run and the test vehicles travel times on each run.

Moving observer methods are often considered to be cheaper than traditional data collecting methods and are compatible with more sophisticated data collection methods that can cover larger study areas (Abdulrahman, et al., 2017).

2.5 Moving observer calculation.

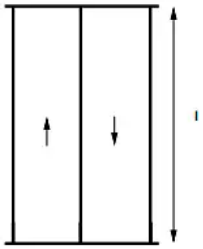


Figure 2. 2: Moving observer method illustration.
Source: (Abdulrahman, et al., 2017)

Consider a person who is watching a stream of cars moving in one way while they are stationary. If there are n_o vehicles passing past the observer in total time, t,

then traffic flow q is $\frac{n_o}{t}$, or

$$\boldsymbol{n_o = q \times t} \quad \textbf{(Equation 2. 1)}$$

when the observer is travelling at speed v_o, while the stream is not moving, if n_p represents how many vehicles the observer passed over a length l, then, density k is $\frac{n_p}{l}$, or

$$\boldsymbol{n_p = k \times l = k \times v_o \times t} \text{..... (Equation 2. 2)}$$

In the case where the observer is moving together with the stream, *mp* vehicles will be passed by the observer in the test vehicle, while *mo* vehicles will overtake the observer. Let (*m0 - mp)* represent the difference *m*

$$\boldsymbol{m = m_o - m_p = qt - kv_o t} \text{..... (Equation 2. 3)}$$

Equation 2.3 is the fundamental equation of moving observer method, which relates *q, k* to the counts *m*, *t* and v_o that can be derived from the test. However, there is only one equation and two unknowns, *q* and *k*. The test vehicle is then run twice, once with the traffic stream and once against it, to obtain another equation, i.e.

$$m_\omega = qt_\omega - kv_\omega t_\omega$$

$$\boldsymbol{m_\omega = qt_\omega - kl} \text{ ..... (Equation 2. 4)}$$

$$m_a = qt_a - k(-v_a t_a$$

$$\boldsymbol{m_a = qt_a + kl} \text{..... (Equation 2. 5)}$$

Where, *a* and *w* stand for movement against and with traffic flow, respectively. It may be noted that the sign of equation 2.5 is negative, because test vehicle moving in the opposite direction can be considered as a case when the test vehicle is moving

in the stream with negative velocity. Combining the two equations 2.4 and 2.5, we will get the first variable of the traffic stream, known as the flow (q) as:

$$\boldsymbol{q = \frac{m_\omega + m_a}{t_\omega + t_a}} \quad \textbf{..... (Equation 2. 6)}$$

Using equation 2.6, the space mean speed is calculated;

$$\frac{m_\omega}{t_\omega} = q - kv_\omega = q - \frac{q}{v}v_\omega = q - \frac{q}{v}(\frac{l}{t_\omega}) = q(1 - \frac{l}{v} \times \frac{1}{t_\omega}) = q(1 - \frac{t_{avg}}{t_\omega})$$

If v_s is the mean stream speed, then average travel time is given by $t_{avg} = \frac{l}{v_s}$.

Therefore,

$$\boldsymbol{\frac{m_\omega}{q} = t_\omega(1 - \frac{t_{avg}}{t_\omega}) = t_\omega - t_{avg}} \textbf{..... (Equation 2. 7)}$$

and

$$\boldsymbol{t_{avg} = t_\omega - \frac{m_\omega}{q} = \frac{l}{v}} \textbf{..... (Equation 2. 8)}$$

By rewriting the equation 2.8, one can obtain the mean speed *vs*, the second parameter of the traffic flow,

$$\boldsymbol{v_s = \frac{l}{t_\omega - \frac{m_\omega}{q}}} \quad \textbf{..... (Equation 2. 9)}$$

*V*s- Speed

tw- time taken while moving with along with traffic.

mw- number of vehicles while moving with traffic.

q-flow

l- length of stretch

As a result, two stream variables can be found. When the first two variables are known, the third traffic flow density parameter (k) can be determined using equation 2.10.

$$\boldsymbol{k = \frac{q}{v_s}} \quad \textbf{..... (Equation 2. 10)}$$

The relationship between traffic flows and traffic densities can therefore be determined by using the equation: $q = ku$ (flow=density * speed). This equation is used to relate the traffic density to the traffic flow (Popping, 2013).

The linear speed-density relationship assumed by Greenshields theory is typically expressed as

$$\boldsymbol{v = vf - \left(\frac{vf}{kj}\right)k} \textbf{..... (Equation 2. 11)}$$

This gave rise to the linear relationship between speed and density as shown in figure 2.3.

Substituting v in the fundamental traffic equation of, $Q = kv$,

$Q = kj(u - \frac{u^2}{uf})$ where vf is free speed and kj jam density. This gave rise to a parabolic curve denoting the relationship between density and flow.

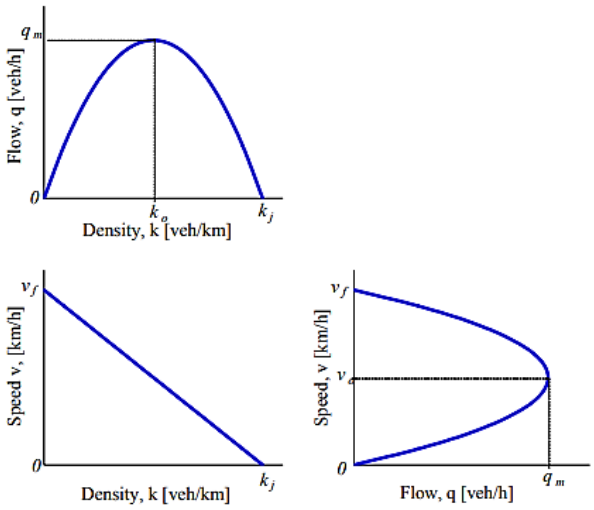


Figure 2. 3: Fundamental traffic flow diagrams
Source: Google images

2.6 Chapter summary

This chapter studied the previous literature from the scholars who looked at the same subject matter. It pointed out the factors that influenced the traffic flow and the various methods used in measuring these variables.

CHAPTER THREE: METHODS AND MATERIALS

3.1 Introduction

This chapter described the methods used to collect data. It included research design, data collection methods, sample size, area of study and data analysis techniques.

3.2 Research design

A descriptive research design was adopted since the researcher observed, recorded, and measured the variables affecting traffic flow. The main reason for considering this was that the descriptive research designs helped provide answers to the questions of who, what, when, where, and how associated with a particular research problem, compared to other designs like cross sectional, casual, case study, experimental and exploratory among others. Causal research designs, such as experimental designs, aim to establish cause-and-effect relationships while Case studies offer rich, in-depth descriptions of specific cases, often focusing on unique or unusual situations and Exploratory research is conducted when the topic or problem is relatively unexplored or not well understood. Descriptive research was used to obtain information concerning the current status of the traffic situation in Kampala and to describe "what exists" with respect to variables or conditions on the roads. It illustrated the characteristics and frequency of the traffic. The design paid attention to, described, and recorded specifics of traffic on the road as it actually happened (Dulock, 1993). This research did not adopt either experimental or exploratory design since the former involves manipulating the variables which was not the case, and it involves using the researcher's ideas to explore the theories.

3.3 Research Approach

This research utilized a quantitative approach to determine the microscopic and macroscopic traffic variables. The data were collected from the field on the selected roads leading to the Kampala city, therefore, the research was field based.

3.4 Population and sample size

3.4.1 Population

The researcher considered five selected sections of roads in Kampala city; these roads were selected based on previous statistics about traffic flows. This study considered private vehicles, passenger cars, light commercial vehicles, and heavy trucks. Motorcycles were excluded from the analysis due to their differing traffic dynamics. Focus was on all vehicles passing through the chosen stretches leading to Kampala city. An attempt was made to include a variety of road types having different traffic volumes for more accurate results. The road stretches were:

i) Jinja Road

ii) Entebbe Road

iii) Wandegeya Road

iv) Sir Apollo Kagwa Road

v) Yusuf Lule Road

3.4.2 Sample size and sampling strategies

Turner (2020), defined sampling as the selection of a subset of the population of interest in a research study since practically the whole population participation is not possible and a smaller group is relied upon to represent the whole. Non-probability sampling technique was used. Specifically, researcher relied on traffic statistics to choose the sample population. An attempt was made to include a variety of road types having different traffic volumes for more accurate results. Seven major routes brought in traffic from out of the city. The study based on these major routes shown in Figure 3.1 to choose the appropriate stretches where the study was carried out.



Figure 3. 1: Map showing roads entering Kampala

A preliminary desk study was conducted to identify and select the roads for the study by identifying high traffic volume areas, major intersections and bottlenecks, and areas with frequent traffic incidents. The study relied on literature from previous scholars to identify these objectives. Hamza et al (2022), found the routes that experienced highest levels of traffic congestion and delays during peak hours included: the Bombo Road-Kampala Road route, Kampala Road-Jinja Road route, as well as the Kampala Road-Entebbe Road route. They are some of the main entrances and exits to Kampala's Central Business District. The study also identified a mix of roads, including busy highways (e.g., Jinja Road, Nothern bypass), major arterial roads (e.g., Sir Apollo Kaggwa Road), and local streets e.g. Wandegeya road. This involved reviewing JICA reports, KCCA urban planning documents to identify high traffic roads and strategic importance for the city's transportation. These roads represent a variety of traffic conditions and urban planning challenges,

providing a comprehensive overview of traffic flow issues within the city. Also, the desk study considered roads safe to conduct the field work. The study also identified that there are 7 major routes as shown in Figure 3.1 leading into the city as identified by JICA report 2010. From these, five stretches were chosen to represent the traffic leading to Kampala.

i) Along Jinja road, a 200m stretch from the last branch-off to first street up to the roundabout at centenary park,
ii) Along Entebbe Road, 200m of stretch along towards Kibuye round about.
iii) Along Yusuf Lule Road from Kafu road to lifecare wellness SPA 200m long stretch,
iv) Along sir Apollo Kaggwa road carrying traffic from Bombo Road,
v) A 200m stretch along Wandegeya- Kampala carrying traffic to Kampala.

3.5 Data collection methods

The data collection tools used to carry out this research were observation, counting and recording the vehicles moving along the selected road stretches using moving observer technique. To achieve the main objective, the following methods were employed to achieve the specific objectives.

3.5.1 To find out the macroscopic traffic variables that influence the traffic flow in Kampala.

In order to ascertain the many characteristics of the traffic variables and the typical daily traffic on several routes in Kampala city, the researcher used the moving

observer method technique. This method was preferred since it measures all the variables at once. Permission to carry out the study was sought from the traffic department of Uganda Police at the headquarters in Naguru. One-month period was granted for this study. Data collection started daily from 6.30 am through to 6:30 pm for a period of twenty days (for the dates stated in section 3.6.1) as it was identified by (KCCA, 2015) that peak hours in Kampala were (in the morning, 5:30AM –9:00AM and in the evening 4:00PM – 9:00 PM) also Hamza et al (2022), suggested the peak hours to be both the early morning (i.e. 6:30 AM-8:30 AM) and late afternoon (i.e. from 5:30 PM-7:30 PM) in the Central Business District.. The collection was done in sessions of intervals of 15minutes.

Three field data collection assistants manned each section of the selected road stretches. One assistant moved at a constant speed which was recorded by the observer. While moving in the same direction as the vehicles on the road, the observer recorded the number of vehicles overtaking and those overtaken by the observer moving on the pavement side of the road.

The observer then turned and moved in the same direction opposite to the flow of the traffic as the he recorded the number of vehicles moving against the observer vehicle.

3.5.2 To determine the microscopic traffic variables responsible for the amount of traffic in Kampala.

Microscopic traffic variables were recorded by ascertaining the number of vehicles in a given stretch at a given time. Time and space headway were then obtained from

the recorded data by calculating them as inverse of density and flow. A stopwatch timer and a record sheet were used to capture the information. Two arbitrary marks were set on the road sections at a distance sufficient for the moving observer to capture various vehicles within the selected stretch. The time headway was obtained by determining the time the vehicle took to cross the two reference points while space headway was determined using the number of vehicles within the specified length shown in Figure 3.2.

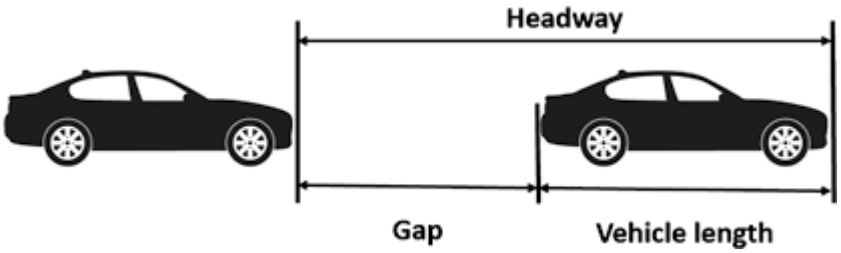


Figure 3. 2: Space Headway
Source: https://www.google.com/url?sa=i&url=https%3A%2F%2Fascelibrary.org% (Accessed 18 July2022)

The distance considered for the study was demarcated by two reference points. Point A and point B as shown in Figure 3.3.

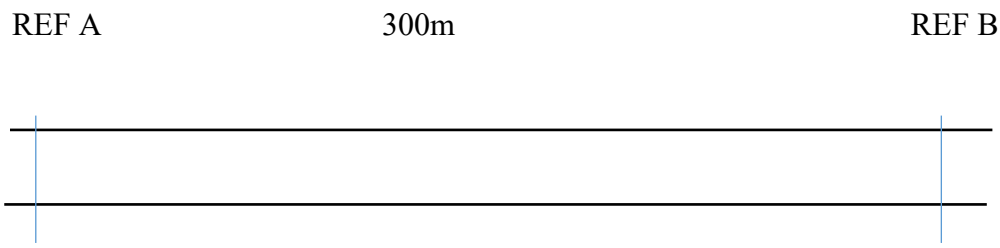


Figure 3. 3: Distance between stretches

Point A was the point where the vehicle entered the stretch and B was the point it left the stretch. Two observers one at point A and another at the extreme point B, a reference vehicle was identified by observer at point A and alerted observer B to

start counting the number of vehicles that passed point B until the reference vehicle passed, and recorded the time it took. This gave us the number of vehicles in the stretch at a given time. The researcher used naturalistic observation of the traffic as it flowed on the roads.

3.5.3 To develop a traffic flow model and determine the relationship between the variables.

The data collected were divided into two phases; phase one for Three road stretches (Jinja Road, Entebbe Road, Yusuf Lule Road) and phase two for the other two roads (Sir Apollo Kagwa Road, and Wandegeya road), data from the first phase was used to develop the model and data from phase two was used to test the model. The observed data from the field and predicted data using the model were compared and their relationship determined using the Chi-square goodness of fit method.

3.5.4 To compute the construction project delays.

The results of the model were then studied to determine the traffic on the various road stretches which identified the roads that would face more traffic than the others and therefore be prone to delaying construction logistic chain. The delays were then computed into hours lost per month during the project.

3.6 Sources of data

3.6.1 Primary data

The research was field based. The data were collected and recorded by observers using moving observer method and stationary counts. Several runs were carried out using a moving observer and the counts with and against the observer were recorded. The researcher carried out the study for twenty days which included all days of the week. The data were recorded on sheets 1 and 2 provided in appendix iii for both macroscopic and microscopic traffic variables. The data were collected starting from the 14th December 2022 to 20th December 2022 and 23rd January 2023 to 2nd February2023 from 6.30 o'clock in the morning till 6.30 o'clock in the evening. All the field assistants were at the selected locations recording the counts as they went on. To identify the characteristics of traffic, the headways flow, density and speed were calculated and tabulated for all the 20 days of the study. This study was meant to quantify the density, flow speed and driver behavior of the vehicles on the roads. Further to note, these characteristics affected each other to cause traffic jam. Average density and flow rate for different days of the week was plotted to show how it varied and which days had more traffic.

Density and hourly flow fluctuations were also plotted to show how the traffic changed by the hour for specific selected days for each road and peak hours. The relationship between flow and density was aggregated by plotting the data points for 20 days which showed the study how the traffic behaved and helped the study to predict the future trends of the traffic.

3.6.2 Secondary data

The secondary data were obtained from publications by relevant authorities of KCCA, UNRA, JICA and Ministry of Works and Transport who had made surveys around the same subject matter. The reliability and validity of data was ensured through the vehicle counts and were carried out for over many time intervals to reduce the error.

3.7 Data analysis

Once the data were collected and tabulated, it was grouped in terms of time of observation. The formula for the moving observer method was used to get the flow rate, Speed was calculated using the Moving Observer Method formula as well, density was obtained from the speed of the vehicle and traffic flow. The average daily and hourly traffic flow data were analyzed, tabled and represented in graphs and the relationships between different days of the week determined using percentages and mean. The collected data were checked and analyzed as percentages and mean for quantitative analysis. The relationship between the variables of speed, density, flow, and headways was determined using multiple linear regression and descriptive statistics. As well, a model that predicts traffic magnitude was developed. Traffic density (k) was calculated as:

$k = \frac{q}{v_s}$ where q is the flow(flow), k being density and vs being speed.

The unknowns were calculated as density q using equation 2.6.

Speed, Vs, unknown was also calculated using equation 2.9.

The researcher thereafter used multiple linear regression to forecast future trends of the traffic along each of the roads. The traffic data and flow projections were analyzed and used to understand the traffic flow on the various road stretches that further informed how much delays to expect on the roads within Kampala.

3.8 Reliability and Validity

3.8.1 Reliability

The vehicle counts were carried out for over many time intervals to increase the confidence to 95%. Every 15-minute interval, a count would be carried out to give more accuracy to the counts. 48 data points were collected on each road daily.

3.8.2 Validity

The observed data from the field and predicted data using the model were compared and their relationship determined using the Chi-square goodness of fit method to confirm its reliability and validity. Scatter plots were used to compare data to see the patterns and if there are relationships with the data collected. Relationships were identified by plotting graphs and comparing the field data with the model's projected flow.

3.9 Limitations

Not all the roads in Kampala were surveyed although the data were taken to be representative of the city traffic.

3.10 Chapter summary

The methods and materials utilized for data gathering and analysis were covered in this chapter.

CHAPTER FOUR: RESULTS AND DISCUSSION

4.1 Introduction

The researcher provided results from the field data collection in this chapter. It covered data collected for twenty days, presentation, analysis, and discussion of results of average daily flow on Sir Apollo Kaggwa Road, Jinja road, Entebbe Road, Wandegeya road, Yusuf Lule Road, the density and flow fluctuation through the day for the different road sections, relationship between density and flow over twenty days recorded for each hour, traffic variables relationships and modeling of traffic flow and delays..

4.2 Research results

The results for this research were aimed at studying the traffic variables influencing traffic flow in Kampala.

4.2.1 Average daily flow and density at Sir Apollo Kagwa Road

Figure 4.1 shows results from Sir Apollo Kaggwa Road, the highest traffic flow was experienced on Monday while the lowest flow was exhibited on Sunday, Sunday as well had the lowest traffic density while Wednesday exhibited the highest traffic density with 55 vehicles per Km.

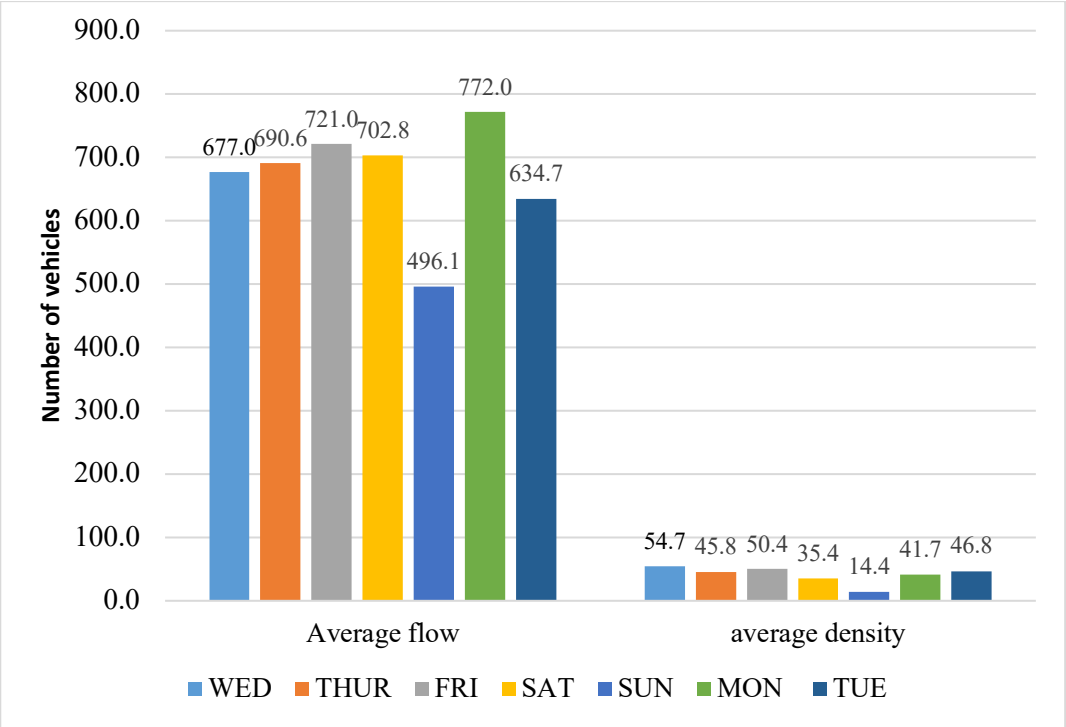


Figure 4. 1: Average daily flow for whole week at Sir Apollo Kaggwa Road

4.2.2 Average daily flow and density on Jinja road

Figure 4.2, showed that Jinja road experienced the highest average daily flow on Monday, while it recorded the lowest density on Sunday and highest density on Wednesday with 122 vehicles per km. This implied that during the course of the week on Monday many people were moving to town and Sunday a few vehicles.

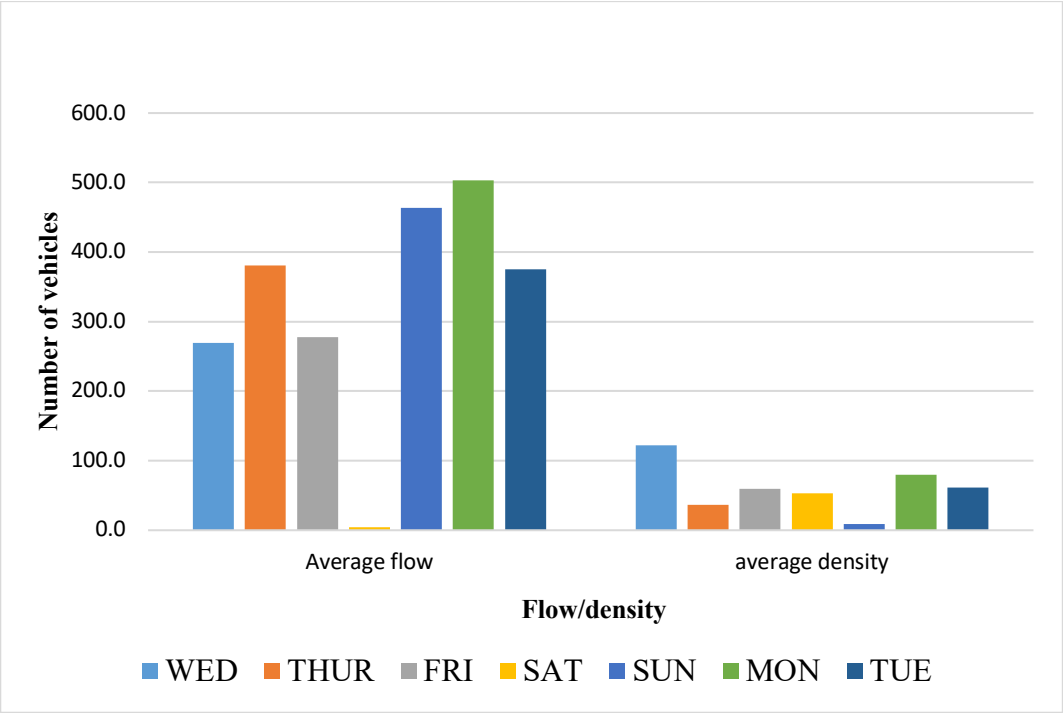


Figure 4. 2: Average daily flow and density at Jinja Road

4.2.3 Average daily flow and density on Entebbe Road

Figure 4.3, showed that along Entebbe Road, Sunday had the lowest average density and Tuesday recorded the highest average density of 178 vehicles per km. These results suggested that Sunday experienced low traffic and vehicles were moving freely.

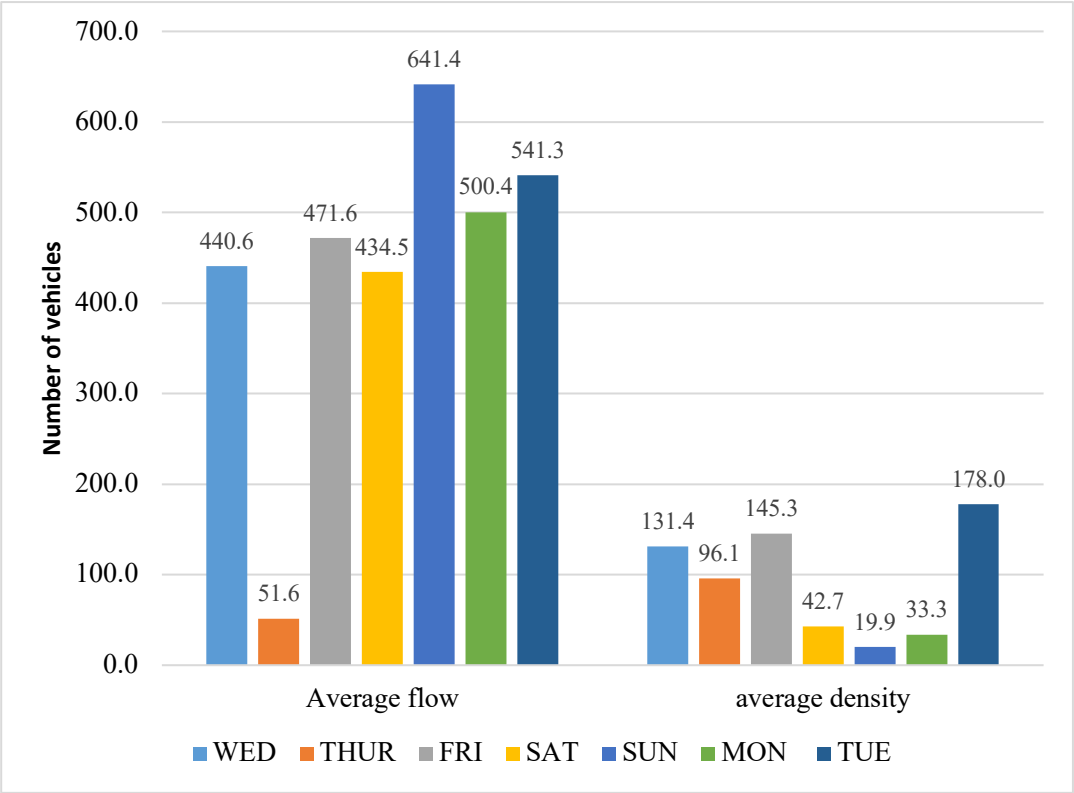


Figure 4. 3: Average daily flow and density at Entebbe Road

4.2.4 Average daily flow and density at Wandegeya road

Figure 4.4 shows that, along Wandegeya road, Monday recorded the highest flow of vehicles at 621 vehicles per hour, Wednesday recorded the lowest average flow, while Tuesday recorded the lowest density and Wednesday recorded the highest at 49 vehicles per kilometer.

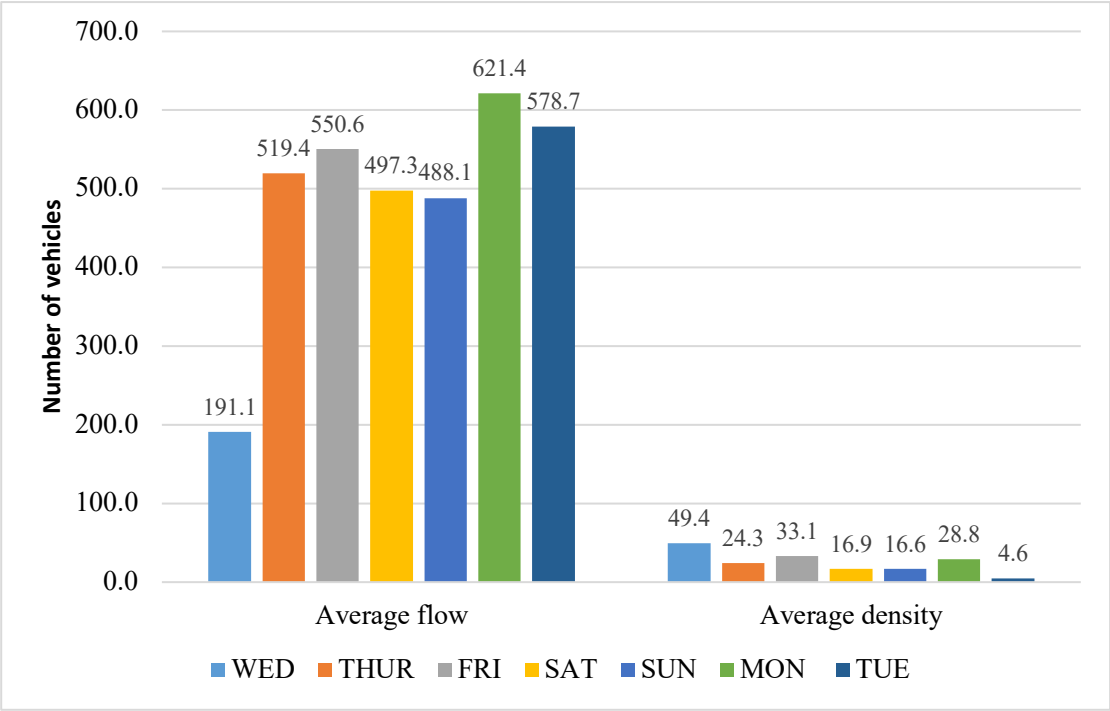


Figure 4. 4: Average daily flow and density at Wandegeya

4.2.5 Average daily flow and density at Yusuf Lule Road

Along Yusuf Lule Road, Tuesday recorded the highest average traffic flow and Sunday had the lowest traffic flow, Sunday as well exhibited the lowest traffic density and Wednesday had the highest traffic density. This suggested that Sunday had less moving traffic along Yusuf Lule Road probably due to it not being a working day, and Tuesday and Wednesday were busy days because of work in town, which explained the trend as shown in Figure 4.5.

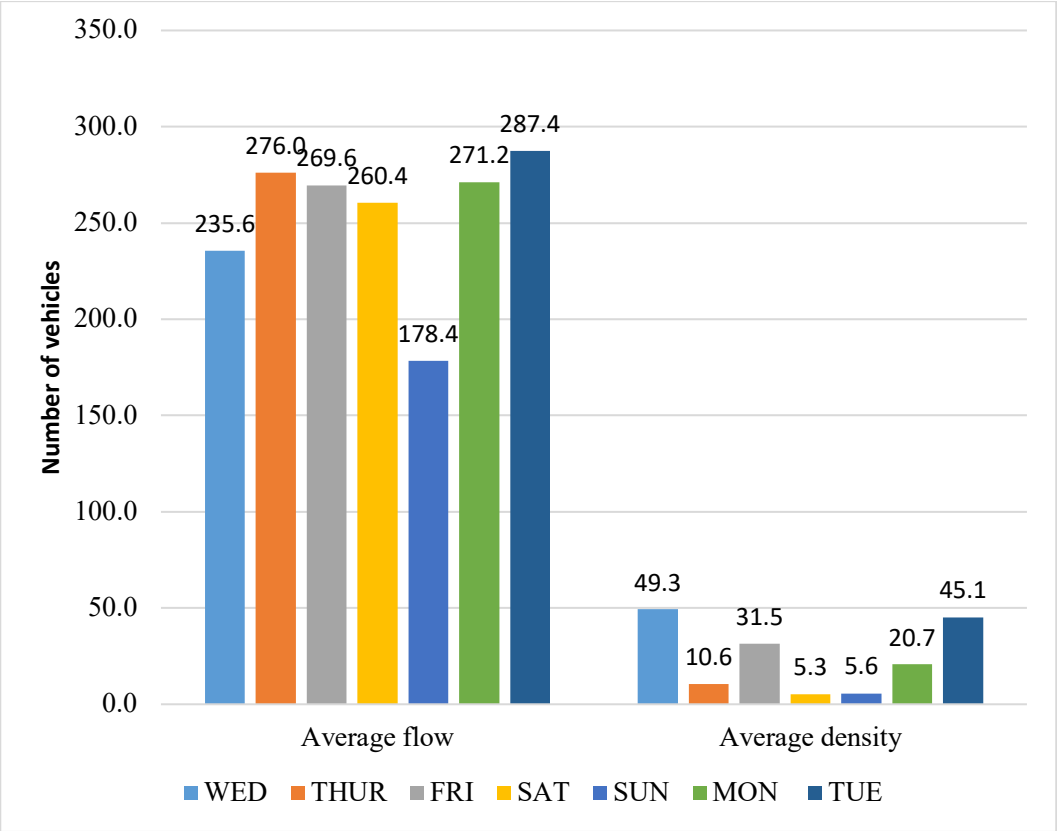


Figure 4. 5: Average daily flow and density at Yusuf Lule Road

4.3 Relationship between density and flow over twenty days

The relationship between density and flow was established by plotting the average data points against each other to identify how the two trended along each other for the whole period of the study along each road. The outcome graphs were then presented according to each road.

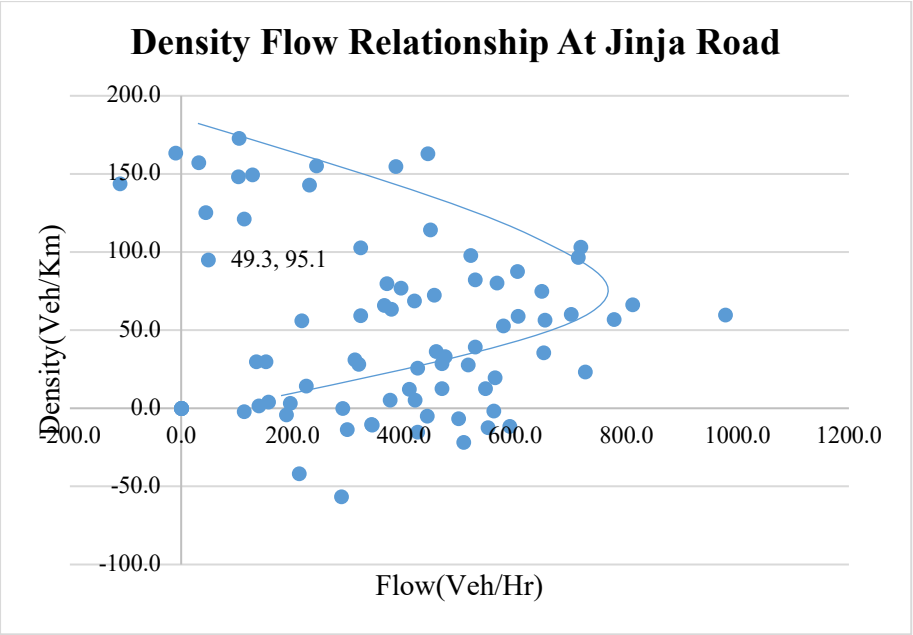


Figure 4. 6: Density -flow relationship along Jinja road

Results from Figure 4.6 above showed the relationship between density and flow over twenty days recorded for each hour along Jinja road. It was found out that at a low density, the flow was high, as density increased, flow increased as well. This indicated that during periods of lower traffic density, vehicles were able to move more freely, resulting in a higher flow rate. The flow rose along with the density. This showed that originally, the flow of vehicles grew as more cars entered the route and the amount of traffic rose. According to this, a rise in density did not, up until a certain point, slow down traffic instead it correlated with an increase in flow.

But eventually, further increase in density started to negatively affect flow. Beyond this point, the traffic flow began to reduce as density continued to increase. This suggested that a point of saturation was achieved, where the capacity of the road to accommodate traffic was exceeded, resulting in decreased flow despite increased density. The results from Figure 4.6 suggest an initial positive relationship between

density and flow, where low density corresponds to high flow. However, beyond a certain threshold, further increases in density led to a decrease in flow, indicating the presence of congestion or reduced traffic efficiency.

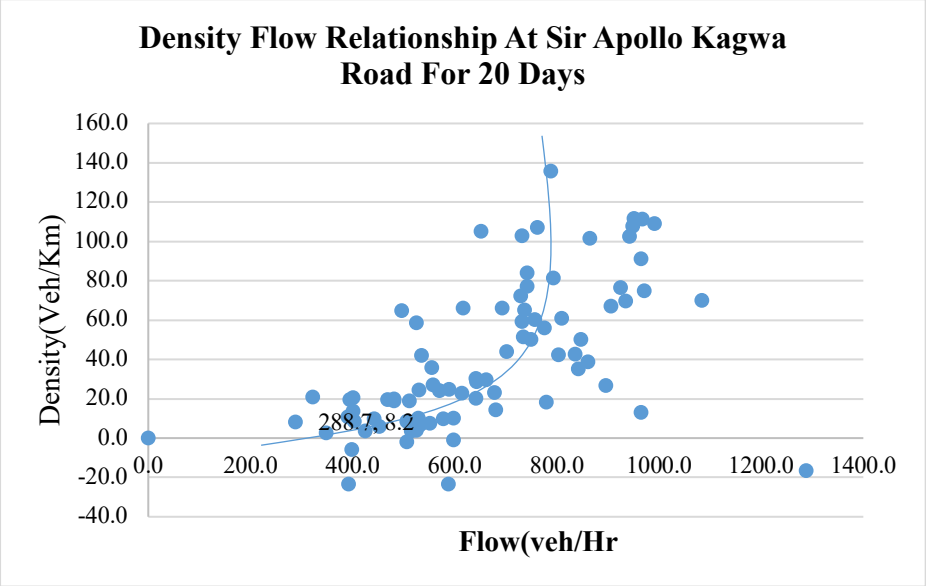


Figure 4. 7: Aggregate Density-flow relationship along Sir Apollo Kaggwa Road

More so from Figure 4.7, for Entebbe Road, the aggregate data points recorded for 20 days on the roads were plotted on a scatter and they showed the relationship between density and flow, Aggregate data points from Sir Apollo Road showed the same behavior with flow slowing as density increased on the road as previously explained by figure 4.6.

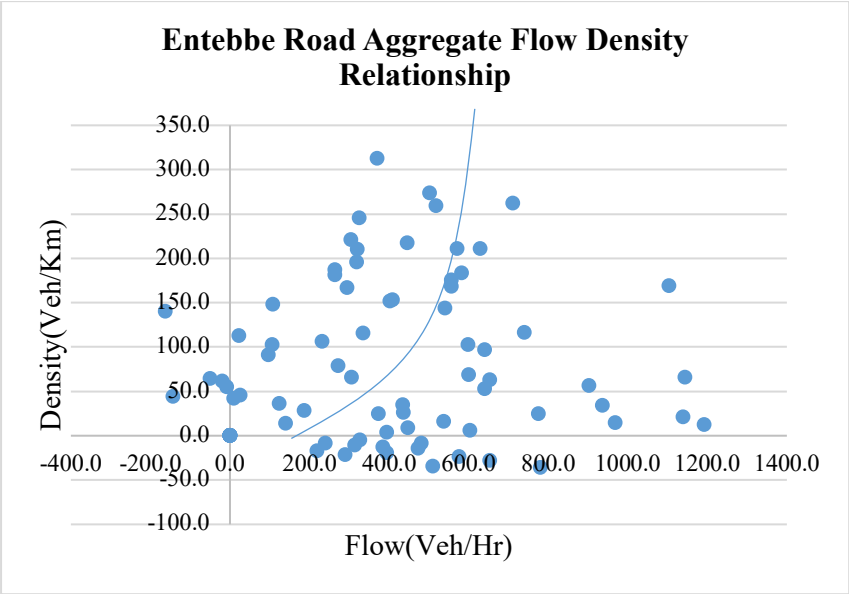


Figure 4. 8: Density flow relationship for Entebbe Road

Results from Figure 4.8 above show aggregate data points along Entebbe Road. That is, the aggregate data points recorded for 20 days on the roads were plotted on a scatter and they showed the relationship between density and flow on Entebbe Road. The same behaviour between density and flow was exhibited as previously described in figure 4.6.

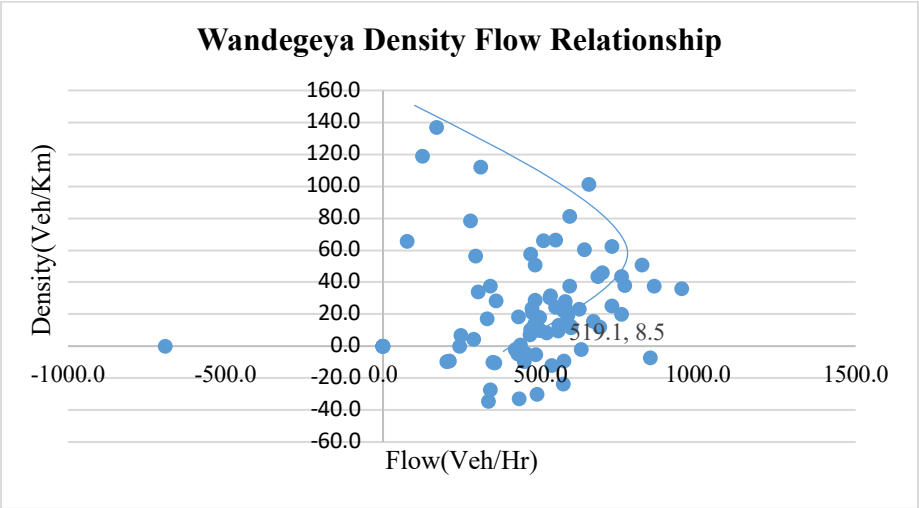


Figure 4. 9: Density -flow relationship along Wandegeya Road

Results from Figure 4.9 above shows the data points obtained from Wandegeya road and the results showed the same relationship with other roads like Sir Apollo Kaggwa Road and Entebbe Road for 20 days on the roads were plotted on a scatter which is somehow related. This indicated that during periods of lower traffic density, vehicles were able to move more freely, resulting in a higher flow rate. The flow rose along with the density. This showed that originally, the flow of vehicles grew as more cars entered the route and the amount of traffic rose. According to this, a rise in density did not, up until a certain point, slow down traffic instead it correlated with an increase in flow.

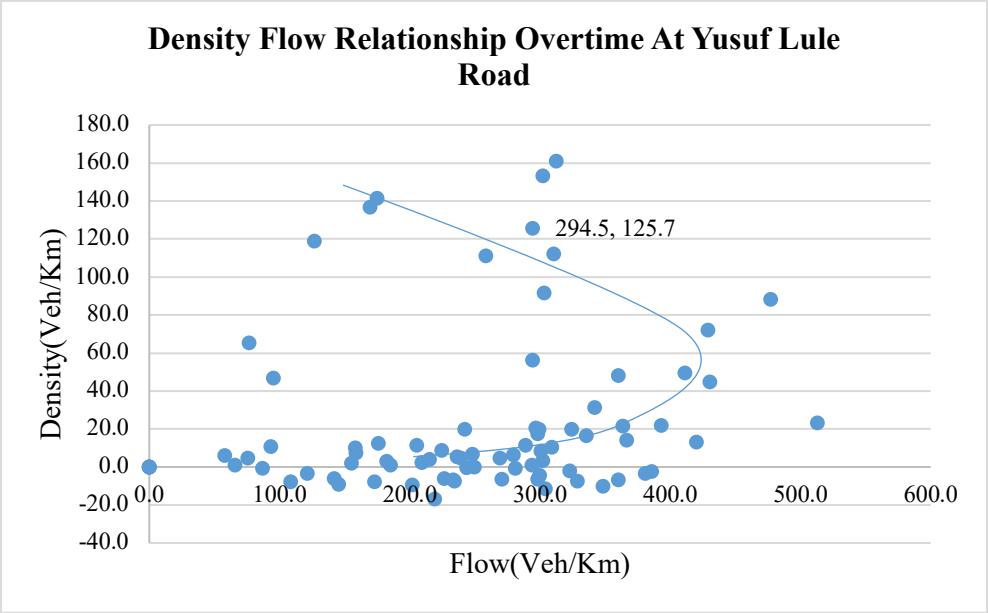


Figure 4. 10: Yusuf Lule Road density -flow relationship

Yusuf Lule road also exhibited the same relationship as the density increased, the flow increased as well as shown in Figure 4.10. The specific pattern observed on Yusuf Lule Road, where flow initially increased with density and then decreased, suggested that the road could have been operating near or at its capacity. Once the

density surpassed a certain threshold, it became congested, and the flow diminished due to the limited capacity to accommodate more vehicles.

It should be noted that all the five roads of Jinja road, Entebbe road, Sir Apollo Kagwa road, Yusuf Lule road, Wandegeya stretch, all showed same trend in how the flow and density related. This behavior also related to existing findings by Greenshield in 1934.Where he came up with traffic density flow diagrams that exhibited closely the same relationship as exhibited by the graphs in this study.

4.4 The density speed relationship overtime

The data points from the density and speed recorded over a period of twenty days on various roads were plotted as shown in the graphs.

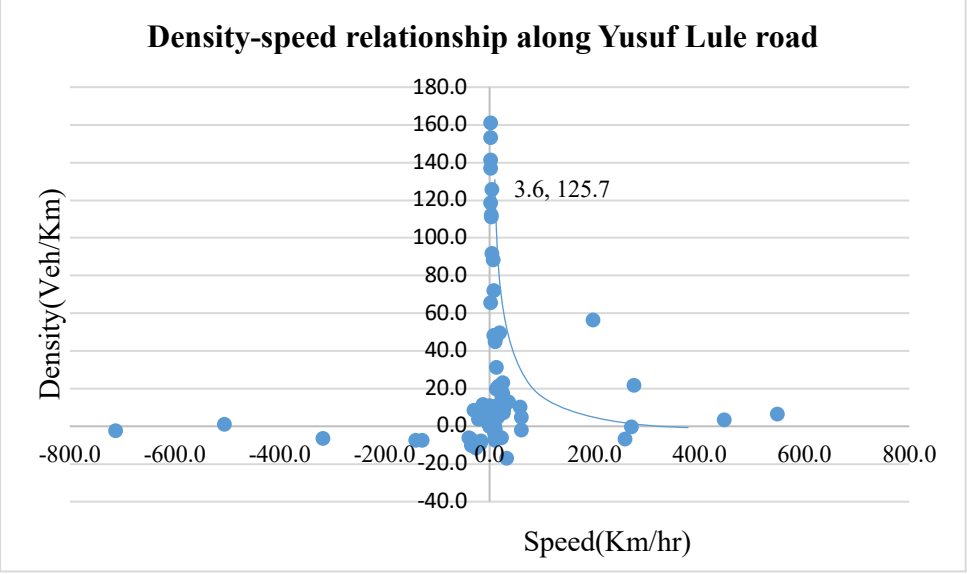


Figure 4. 11: Aggregate density speed relationship along Yusuf Lula Road

Figure 4.11 shows a scatter plotted graph, which displayed the density speed relationship for Yusuf Lule Road. According to the results, any increase in density

on Lule road led to a reduction in the speed of travel. This meant that as the number of vehicles of traffic increased, the average speed at which vehicles were able to travel decreased.

This relationship suggested that higher traffic density-imposed congestion that hindered the smooth flow of vehicles, resulting in slower speeds. The increase in density led to a higher number of vehicles sharing the same road space, which resulted in reduced gaps between vehicles, frequent braking, and overall slower movement.

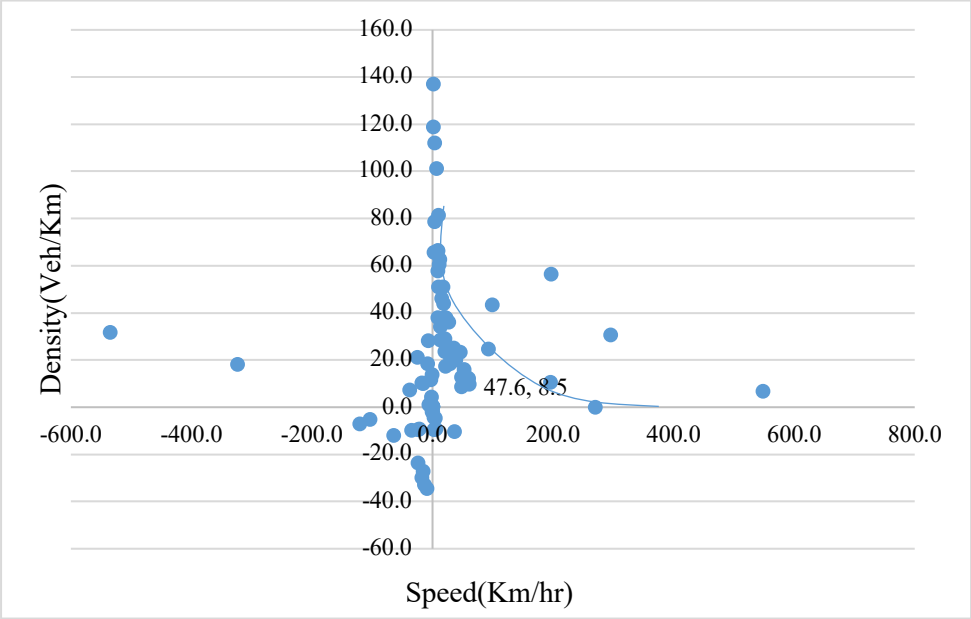


Figure 4. 12: Density speed relationship along Wandegeya road

Results from Figure 4.12 shows that along Wandegeya road, there was an increase in density which reduced the travel speed. This implies that as the density increased along Wandegeya road, there were many vehicles thus travel speed had to reduce. Larger concentrations of vehicles cause congestion and slower traffic flow in a

particular location. Due to the greater number of vehicles using the available road space, the travel speed consequently decreased. This result agrees with established traffic patterns and the idea of traffic congestion. When there are lots of cars on the road, they can slow down other cars' progress, which could result in longer travel times.

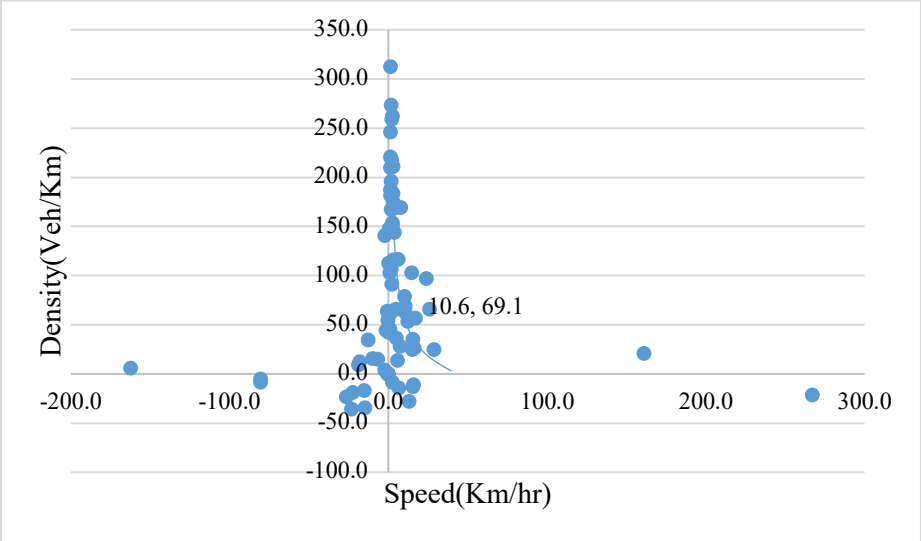


Figure 4. 13: Density speed relationship along Entebbe roads

More so results from Figure 4.13 of a plotted scatter graph showed a relationship between density and speed on Entebbe Road, it was found out that an increase in density reduced travel speed towards zero value at along Entebbe Road. This finding suggested that as more vehicles accumulated on Entebbe Road, the traffic congestion became severe, causing the travel speed to progressively slow down. Eventually, when the density reached a certain threshold, the travel speed came to a standstill, resulting in a speed of zero.

The relationship between density and travel speed in this case is consistent with the principles of traffic flow theory. As the number of vehicles increases, the available road space becomes more crowded, leading to reduced travel speeds. At a certain point, when the density reaches its maximum capacity, the traffic can come to a complete halt.

4.5 Microscopic variables and their influence on traffic flow

The microscopic variables measured were space and time headways.

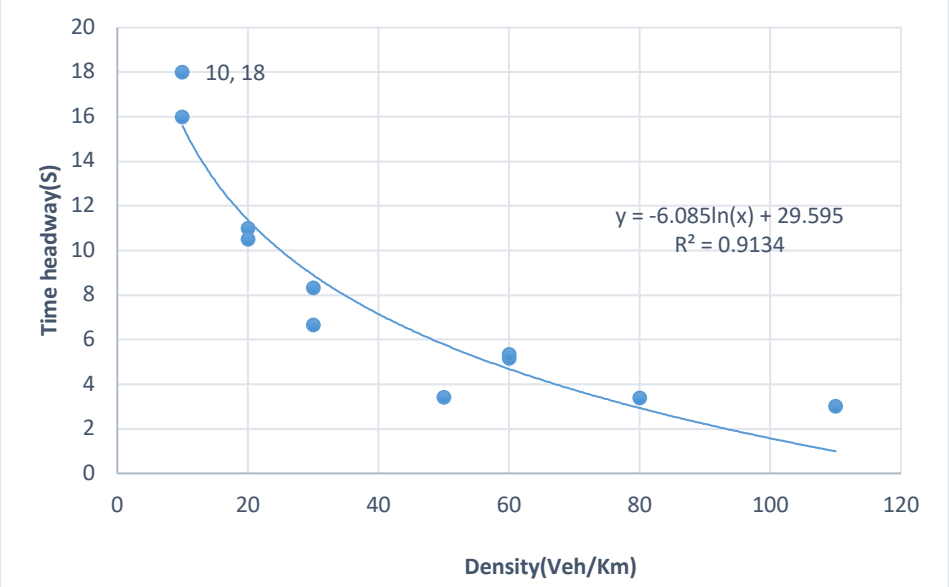


Figure 4. 14: Headways and density relationship along Wandegeya

According Figure 4.14 shown, the time headway reduced with increase in the density. The driver behavior in terms of distance and space headways determined the flow and amount of traffic jam on the road since they gave a linear relationship. As the headways increased, the density on the road also increased. A shrewd driver had less headways which led to lesser jam density. A linear relationship is exhibited.

The R-Squared value of 0.9134 showed a strong relationship between the variables of density and time headway along Wandegeya road. In this case, it implied that as the density of vehicles changed along Wandegeya Road, there was a substantial influence on the time headway between vehicles.

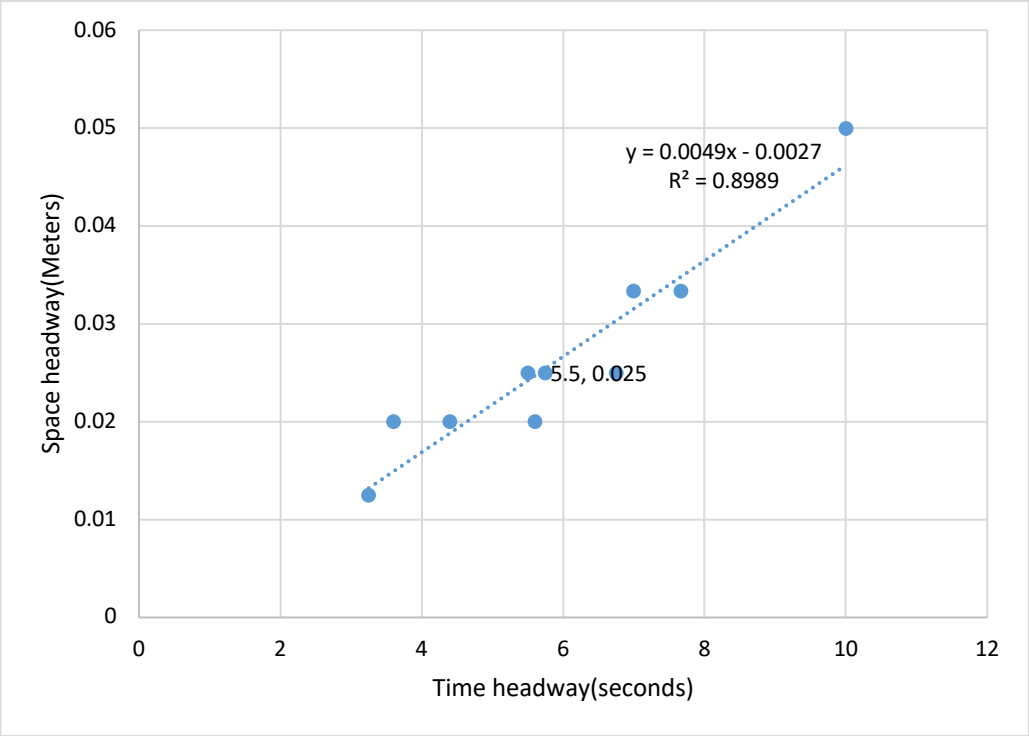


Figure 4. 15: Time headways vs Space headways along Wandegeya

Results from Figure 4.15 above showed that the time and space headway exhibited a directly proportional relationship, as the space headway increased, the time headway increased as well. Using the displayed equation, one can determine the time and space headway respectively the R-square value mentioned indicates the strength of the relationship between time headways and space headways. A high R-square value of 0.8989 indicated a strong relationship, suggesting that changes in space headway can explain a significant portion of the variation in time headway.

4.6 Relationship between the traffic variables

Using the moving observer method, Data from the field were recorded for several hours of the day and represented in tables. The tables showing every 30-minute record of the traffic data recorded for 20 days across various roads were combined and analyzed. The data included traffic flow, time of the day, traffic density, road stretch and day of the week. This data was then analyzed using linear regression to come up with models that aided in prediction of the traffic magnitude on the road in Kampala city. The time and days were encoded using ordinal encoding while the different road sections were label encoded as shown in Table 4.1.

Table 4. 1: Coding for categorical data

Road name	Code	Day of the week	Code
Yusuf Lule	1	Monday	1
Wandegeya	2	Tuesday	2
Sir.Apolo Kagwa	3	Wednesday	3
Jinja	4	Thursday	4
Entebbe	5	Friday	5
		Saturday	6
		Sunday	7

The researcher found the coefficients of the independent variables in the equation by employing multiple linear regression. The intensity and direction of the relationship between each independent variable and the dependent variable were represented by these coefficients. A positive coefficient indicated a positive association, indicating that traffic flow tends to rise along with the independent variable's value. A negative relationship was indicated with a negative coefficient.

Table 4. 2: Sample data from the field for flow, time, density

Time	Flow (Veh/Hr)	Time Code	Density(veh/Km)	Day of the week	Road stretch
8.00	408	4	101	3	1
8.30	263	5	52	3	1
9.00	284	6	93	3	1
9.30	213	7	92	3	1
10.00	211	8	120	3	1
10.30	277	9	150	3	1
11.00	169	10	34	3	1
11.30	235	11	62	3	1
12.00	337	12	70	3	1
12.30	360	13	77	3	1
1.00	48	14	33	3	1
1.30	106	15	73	3	1
2.00	419	16	70	3	1
2.30	169	17	92	3	1
3.00	72	18	46	3	1
3.30	267	19	133	3	1
4.00	533	20	95	3	1
4.30	88	21	127	3	1
5.00	190	22	42	3	1
5.30	172	23	83	3	1

Data for all the 20 days, for all the roads were put together. Table 4.2 shows the sample arrangement of the data which were thereafter subjected to multiple linear regression. The researcher was then able to come up with an equation that can predict the traffic flow on a given road, at a particular time and on a given day of the week. The regression results were as indicated in Tables 4.3 and 4.4.

Table 4. 3: Regression statistics for the 20 days data set

Regression Statistics	
Multiple R	0.752065
R Squared	0.565602
Adjusted R Squared	0.56429
Standard Error	98.02963
Observations	1329

The R-squared value was 0.565. This showed that 56.5% of the variability in traffic flow is explained by the chosen independent variables of time, day, density and stretch of the road. It further showed that there was a significant amount of unexplained variation of 43% which was probably due to other causes of traffic like road infrastructure, weather, festive days among others.

Table 4. 4: Calculated coefficients

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%
Intercept	251.4797	13.81024	18.20966	2.7E-66	224.3874	278.5721
X Variable 1	-0.08773	0.412786	-0.21253	0.831725	-0.89752	0.722056
X Variable 2	1.516567	0.075786	20.01114	4.84E-78	1.367893	1.665241
X Variable 3	-28.4285	1.640896	-17.325	9.13E-61	-31.6475	-25.2095
X Variable 4	1.132072	3.289569	0.34414	0.730796	-5.32126	7.585409

An equation was therefore derived from the regression results shown in table 4.4 as

$$\boldsymbol{y = 251.478 - 0.088x_1 + 1.517x_2 - 28.429x_3 - 1.132x_4 + 0.420} \quad \textbf{...}$$

(Equation 4. 1)

Using equation 4.1, the researcher could predict the traffic flow at a given road stretch, on a given day at a given time.

y – flow, x_1 -Time, x_2- Density, x_3- Day, x_4- Road stretch, c-intercept

Table 4. 5: Sample predictions using equation (4.1)

Observed Y	Predicted Y	Residual
293	344.609173	-52
291	346.887893	-56
377	268.38701	109
233	233.566407	-1
320	386.952945	-67
391	299.448425	92
182	207.901362	-26
348	235.589808	112
442	370.19647	71
402	285.629473	116
327	256.291828	71
186	323.286235	-137
410	206.295761	204
391	269.911001	121
360	380.826255	-21
408	296.97351	111

The predictions were compared with actual data from the field and the residuals represented the differences. From the predictions of traffic flow, the early morning hours would exhibit more traffic than later afternoon hours. Using the illustrated Table 4.11, the user would just input the data and the flow is calculated. The days are according to coding provided in Table 4.5. Further predictions would show Sundays and Saturdays having the lowest traffic flow while Mondays Tuesdays, Wednesdays and Fridays would exhibit high traffic flow and density.

Table 4. 6: Traffic flow predictor

Flow (Veh/Hr)	**Time**	**Density (Veh/km)**	**Day**	**Road stretch**
Y	X1	X2	X3	X4
79.24	1	20	7	3
259.27	8	20	1	2
199.82	8	20	3	4
140.39	8	20	5	5
109.84	17	20	6	1

Equation (4.1) could therefore help travelers foretell the traffic that is going to be at a specific road, at a given time on a given day, therefore drivers can make appropriate decisions on which roads to take that have lighter traffic.

Using the Chi-square method of determining the goodness of fits, the expected outcomes were hypothesized as shown;

Null Hypothesis: (Ho), $P1=P2$, the predictions are the same as observed values

Alternative hypothesis: (Ha), $P1\neq P2$, the predictions are not the same as observed values

P1 being the observed and *P2* being the predicted values.

Table 4. 7: Sample calculation of the chi-square

OBSERVED	PREDICTED	(P2-P1)	(P2-P1)2	(P2-P1)2/P1
263	248	14.973	224.205	0.851
217	231	-14.140	199.927	0.923
228	214	13.870	192.368	0.845
216	202	13.284	176.475	0.819
193	178	15.117	228.510	1.182
198	215	-16.415	269.450	1.359
262	240	22.449	503.945	1.923
232	226	5.950	35.406	0.153
234	248	-13.993	195.798	0.838
294	284	9.640	92.926	0.316
114	119	-5.060	25.603	0.225
121	129	-8.262	68.257	0.566
131	133	-2.598	6.749	0.052
100	114	-13.990	195.723	1.962
147	135	11.979	143.501	0.978
130	115	14.772	218.202	1.679
60	61	-0.786	0.618	0.010
87	74	12.383	153.335	1.772
68	59	8.195	67.152	0.995
58	69	-11.340	128.605	2.231

Table 4.7 shows sample predicted and observed values of the traffic flow and how the chi-square was obtained. Using Excel formula, =CHISQ.INV.RT(0.05,427), the researcher got the critical value of 476 which was compared with the Chi-square value obtained in the Excel table as 347.Since the Chi-square value of 347 was less than the critical value of 476, then the Null hypothesis was not rejected, therefore the predicted values of traffic flow relate closely with the observed values of traffic flow.

Table 4. 8: Calculation of the Mean Absolute Percentage Error

Expected (E)	**Predicted (P)**	***Residuals (P-E)***	***(P-E)²***	***(P-E)²/E***		**Absolute P-E**	**(Absolute P-E)/E**	**Absolute percentage error**
263	248	14.973	224.205	0.851	0.057	15	0.057	5.684
217	231	-14.140	199.927	0.923	-0.065	14	0.065	6.529
228	214	13.870	192.368	0.845	0.061	14	0.061	6.096
216	202	13.284	176.475	0.819	0.062	13	0.062	6.162
193	178	15.117	228.510	1.182	0.078	15	0.078	7.822
198	215	-16.415	269.450	1.359	-0.083	16	0.083	8.277
262	240	22.449	503.945	1.923	0.086	22	0.086	8.567
232	226	5.950	35.406	0.153	0.026	6	0.026	2.567
234	248	-13.993	195.798	0.838	-0.060	14	0.060	5.988
294	284	9.640	92.926	0.316	0.033	10	0.033	3.282
114	119	-5.060	25.603	0.225	-0.044	5	0.044	4.441
121	129	-8.262	68.257	0.566	-0.069	8	0.069	6.851
131	133	-2.598	6.749	0.052	-0.020	3	0.020	1.989
100	114	-13.990	195.723	1.962	-0.140	14	0.140	14.023
147	135	11.979	143.501	0.978	0.082	12	0.082	8.168
130	115	14.772	218.202	1.679	0.114	15	0.114	11.364
60	61	-0.786	0.618	0.010	-0.013	1	0.013	1.305
87	74	12.383	153.335	1.772	0.143	12	0.143	14.309
68	59	8.195	67.152	0.995	0.121	8	0.121	12.139

The acceptable percentage error was calculated in excel as shown in Table 4.8 above using Mean Absolute Percentage Error. It was obtained as 6.4% deviation from the expected traffic flow. This meant that the model could predict up to a 6.4%. This margin of error indicated that, on average, the predicted traffic flow values may deviate from the actual observed values by approximately 6.4%. This level of accuracy is considered good since it is less than 10%, between 10% and 20%, it is considered a reasonable forecast (Walker, 2021).

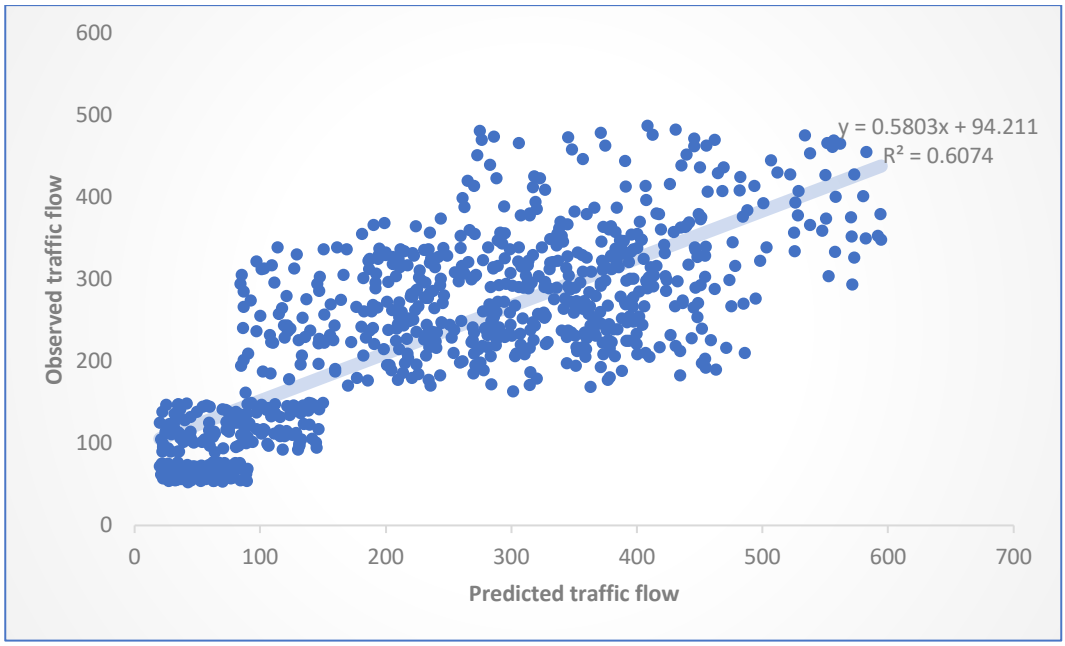


Figure 4. 16: Observed traffic flow against predicted traffic flow

Plotting the observed values against predicted traffic flow values showed a linear relationship between the two, confirming the goodness of fit for the developed model. The high R-squared value of 0.61 showed a great connection between the two and therefore predicted traffic flow could easily tell the traffic situation on the road at a given point in time.

Therefore, the findings above demonstrated that the developed model is capable of precisely forecasting the flow of traffic on the route at any given time to a small margin of error estimated at 6.4% as shown in Table 4.8. This meant that model's predictions are reliable and can be used effectively to assess the traffic conditions on roads in Kampala.

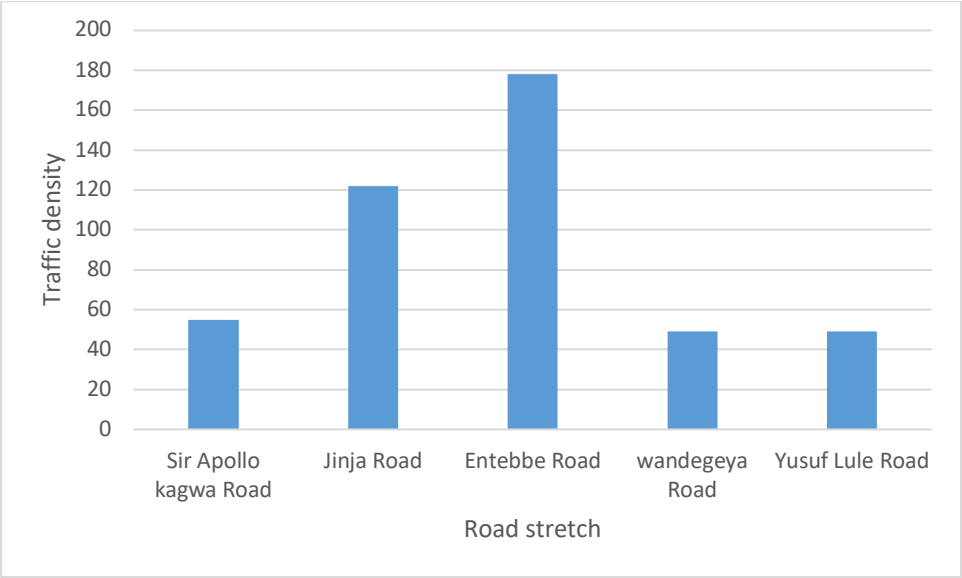


Figure 4. 17: Traffic load on the various road stretches

Figure 4.17 shows the comparison of roads by traffic load. Entebbe road recorded the highest number of vehicles per Km (178) due to high volume of traffic moving from the outskirts of Entebbe, while Yusuf Lule Road recorded lower average daily density below 50 vehicles per Km since it was not usually used as a highway.

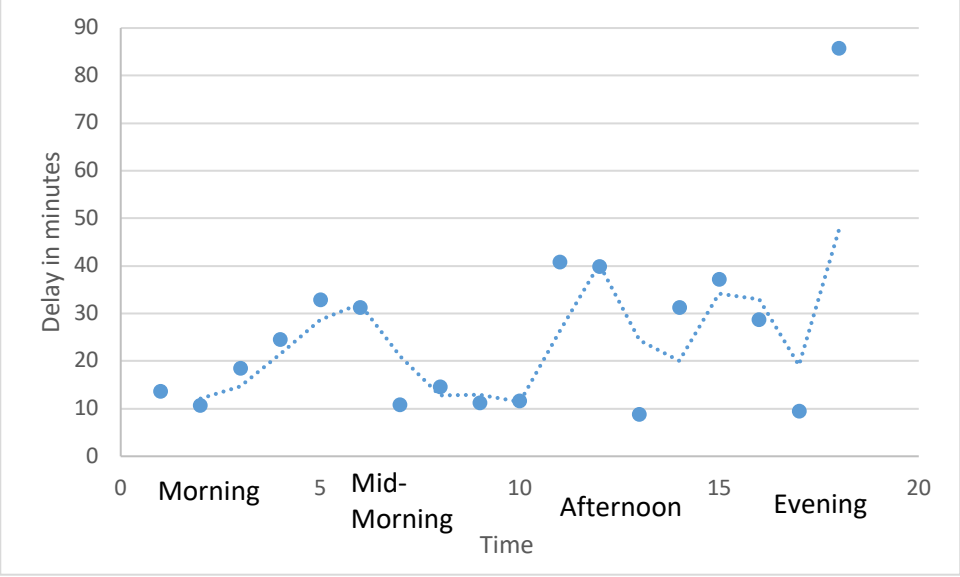


Figure 4. 18: Average daily delays

Figure 4.18 shows average daily delays in traffic flow clustered in morning, mid-morning, afternoon, and evening. The morning hours show less but increasing delay at 20 minutes to cover a 10km stretch, which drops in the midmorning to 12 minutes and increases again in the afternoon to 31 minutes and 32 in the evening hours of the day. This encourages planning material, equipment and logistic for construction during the mid-morning towards afternoon hours and avoiding peak hours.

Table 4. 9: Calculation of lost time

	AVERAGE DELAY(Mins)	DELAY FOR 5 TRIPS DAILY	MONTHY DELAYS	NO. OF HOURS LOST
Morning	20.07	100.33	3009.92	50.17
Mid-morning	12.09	60.44	1813.24	30.22
Afternoon	31.60	157.98	4739.52	78.99
Evening	32.79	163.93	4917.95	81.97

Table 4.9 shows up to 80 hours a month lost in traffic if the construction deliveries are scheduled for evening hours, with mid-morning hours potentially dropping the delay by 60%.

4.7 Discussion

4.7.1 Traffic variables

Results from the five different road sections on the roads leading to the city showed on average, all the five roads exhibited less traffic on Sundays with average density of 10 vehicles, most traffic was recorded during the weekdays of Monday, Tuesday, Wednesday due to the enormous number of people going to work in town during

these days with average peak density of over 170 vehicles. Entebbe road recorded the highest number of vehicles per Km (178) due to high volume of traffic moving from the outskirts of Entebbe, while Yusuf Lule Road recorded lower average daily density below 10 vehicles per Km since it was not usually used as a highway.

The tendency of increased traffic on weekdays, especially early in the week, is consistent with research conducted by KCCA (2015) , which found that weekday traffic volumes are often highest because of travel related to work. The study's findings confirm the idea that, for traffic management systems to be successful, they must take periodic variation in traffic patterns into account.

4.7.2 Relationship in variables

There is an inverse linear relationship between the time headways and the amount of gridlock on the road. The R-Squared value of 0.9134 indicates a strong correlation between time headway and traffic density. This indicates that variations in time headway account for about 91.34% of the difference in traffic density. Drivers who maintain shorter headways tend to contribute less to overall traffic density, leading to fewer traffic jams.

An inverse relationship between density and speed was also evident, with speeds dropping to as low as 25 km/h during peak congestion periods on Wandegeya road, Entebbe Road and Yusuf Lule Road. These statistics align with KCCA (2023), which documented that traffic speeds in Kampala can fall below 25.9 km/h during peak hours, reflecting severe congestion suggesting that construction projects

scheduled during these times are likely to face increased delays due to traffic congestion.

All road stretches exhibited the same trend in the relationship between traffic density and flow. This behavior also related to existing findings by Green shield in 1934, Where he came up with traffic density flow diagrams that exhibited closely the same relationship as exhibited by the graphs in this study showing that traffic density increases as the flow of vehicles also increases until a certain point which is also recounted by Zhang, Yuan, Yang, & Liu, (2020).

4.7.3 Regression model

The regression model explains 56% of the variance in traffic flow ($R^2 = 0.56$). The model shows that changing from weekdays to weekend, the flow decreases by about 28%. As density increases by 1%, the flow also increases by 1.5% over time. This aligns with traffic flow diagrams highlighted Zhang, Yuan, Yang, & Liu., (2020) which proposed that as traffic density increases, the flow of vehicles also increases until a certain point, known as the maximum flow. Beyond the capacity, further increases in density leads to reduced flow and eventually traffic congestion. This drop in flow during weekends presents an opportunity for construction activities that require moving in traffic to be scheduled more effectively on weekends, potentially reducing delays by 28%. Furthermore, the finding that a 1% increase in traffic density correlates with a 1.5% increase in flow reinforces the notion that high traffic density, often seen during weekdays, is a critical factor contributing to construction delays.

4.7.4 construction delays

The analysis shows that Entebbe Road, with an average of 178 vehicles per kilometer, faces considerable congestion that can adversely affect construction logistics movement. The high traffic load on this route highlights the need for careful planning of construction delivery activities to avoid peak traffic times. while, Yusuf Lule Road, which recorded lower average daily densities below 50 vehicles per kilometer, presents fewer challenges for construction projects, potentially allowing for smoother progress and construction project planners can re-route material deliveries through that route during weekdays. With generally 60% less delays, as shown in table 4.9, the midmorning hours can be prioritized for scheduling of construction materials movement.

CHAPTER FIVE: CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

This chapter summarized the final remarks and recommended future research areas.

5.2 Conclusions

1. The research confirms that traffic volume in Kampala significantly varies between weekdays and weekends, with peak densities occurring during the early part of the week. This finding is consistent with previous studies, highlighting the need for traffic management systems to consider periodic variations in traffic patterns for effective planning.
2. The study identified a strong inverse relationship between time headways and traffic density, suggesting that shorter headways may reduce overall traffic density but can increase the risk of accidents. Furthermore, the inverse relationship between traffic density and speed underscores the critical impact of congestion on travel times, especially on major routes like Entebbe Road.
3. The regression model indicates that the shift from weekdays to weekends can reduce traffic flow by approximately 28%. Additionally, the relationship between density and flow suggests that careful monitoring of traffic conditions is essential to mitigate congestion, especially for construction deliveries.
4. Entebbe Road's high traffic load presents significant challenges for construction activities, emphasizing the need for strategic planning to avoid peak congestion periods. In contrast, Yusuf Lule Road offers a viable

alternative for construction-related activities, allowing for smoother logistics movement.

5.3 Recommendations

The following recommendations were made by the researcher after carrying out the study.

5.3.1 Policy recommendations

1. Construction regulatory authorities should encourage construction project planners to prioritize scheduling major delivery activities during weekends or off-peak hours to minimize the impact of traffic congestion. This approach could reduce delays and enhance overall project efficiency.
2. Traffic department should implement adaptive traffic management systems that respond to real-time traffic conditions, particularly during peak hours. This could include dynamic signage, variable speed limits, and optimized traffic signal timings.
3. KCCA should enforce public transportation to reduce reliance on personal vehicles which increases vehicle density within the city center.
4. KCCA should promote non-motorized transport by developing safe infrastructure for walking and cycling.
5. KCCA should consider decentralizing business hubs to distribute traffic more evenly across the city.
6. Traffic department should Initiate public awareness campaigns to inform commuters about peak traffic times and encourage alternative routes or modes

of transportation. This could help distribute traffic more evenly throughout the city. This model can help inform that.

5.3.2 Future research recommendations

1. longitudinal studies to monitor how traffic patterns evolve with ongoing urban development and infrastructure improvements should be carried out. This can provide valuable data for future traffic flow models and construction project planning.
2. Additional studies incorporating more variables such as weather conditions and road incidents to refine the predictive model should be conducted.
3. Further studies into the use of traffic flow data towards computing the carbon footprint should also be carried out.

References

1. Abdulkadir, J. O., Ambiga, k., Sani , A. & Muhaise, H., 2022. Causes of Traffic Congestion- A Case Study of Jinja Road on Central Division Kampala City Uganda. *International Journal of Innovative Research in Science Engineering and Technology,* 11(11), p. 12.
2. Abdulrahman, H. S., Ali, A. A. & Mahmud, A., 2017. Comparative Assessment of Macroscopic Traffic Flow Properties Estimation Methods: A Case for Moving Car Observer Method. *Engineering Science and Technology International Research Journal,* 1(2), pp. 11-15.
3. Arnott, R., Rave, T. & Schöb, R., 2005. *Alleviating urban traffic congestion.* 1 ed. Massachusetts: MIT Press Books.
4. Assouli, A., 2019. Fundamental parameters of traffic flow. *Student Research Rournal,* 11(7), pp. 25-47.
5. Baertsch, L., 2020. *Quantifying the economic benefits of public transportation in kampala,* Uganda: Internatioal Growth Center.
6. Barua, S., Das, A. & Hossain, J. M., 2015. Estimation of traffic density to compare speed-density models with moving observer data. *International Journal of Research in Engineering and Technology,* 4(8), pp. 471-474..
7. Bayiga, Z. E. et al., 2019. Road traffic injuries in Uganda: pre-hospital care time intervals from crash scene to hospital and related factors by the Uganda police. *International journal of injury control and safety promotion ,* 26(2), pp. 170-175.

8. Bisio, I. et al., 2022. A Systematic Review of Drone Based Road Traffic Monitoring System. *IEEEAccess,* Volume 10, p. 19.
9. Boye, A. B., 2018. The effect of road traffic delay on supply chain performance of manufacturing firms in Lagos state, Nigeria. *International Journal of Management Technology,* 5(3), pp. 9-22.
10. Bull, A., 2003. *Traffic Congestion The Problem and How to Deal with it,* Santiago: United Nations Publication.
11. Dorasamy, N. & Peprah, A. . J., 2023. The influence of road transport infrastructure on supply chain responsiveness: the moderating role of traffic management. *Russian Journal of Agricultural and Socio-Economic Sciences,* 143(11), pp. 105-120.
12. Dulock, H. L., 1993. Research design: Descriptive research. *Journal of Pediatric Oncology Nursing,* 10(4), pp. 154-157.
13. Dzhuruk, D. & Zedgenizov, A., 2018. Forecasting of traffic intensity on suburban routes. *Transportation research procedia,* 1(36), pp. 135-140.
14. F, N., Causes and Consequences of Traffic Flow in Kampala Capital City. *2019.* Kampala: Diss, Uganda Management Institute.
15. Glen, W. & Stephen, F., 2011. Traffic Congestion Effects on Supply Chains: Accounting for Behavioral Elements in Planning and Economic Impact Models. *Supply Chain Management - New Perspectives.*
16. Guerrieri, M., Parla, G. & Mauro, R., 2019. Traffic Flow Variables Estimation: An Automated Procedure Based on Moving Observer Method. Potential Application for Autonomous Vehicles. *Transport and Telecommunication,* 20(3), pp. 205-214.

17. Hamza, . S. et al., 2022. Characterizing Peak-Time Traffic Jam Incidents in Kampala Using Exploratory Data Analysis. *Journal of Transportation Technologies,* 13(1), pp. 61-86.

18. ITF, 2021. Data-driven Transport Infrastructure Maintenance. *International Transport forum Policy Papers.*

19. Jabareen, Y., 2009. Building a conceptual framework;philosophy,definitions and procedure. *International Journal of Qualitative Methods,* 8(4), pp. 49-62.

20. Jain, V., Sharma, A. & Subramanian, L., 2012. Road traffic congestion in the developing world. *Proceedings of the 2nd ACM Symposium on Computing for Development.,* pp. 1-10.

21. Jain, V., Sharma, A. & Subramanian, L., 2012. Road traffic congestion in the developing world. *Proceedings of the 2nd ACM Symposium on Computing for Development,* 11(1), pp. 1-10.

22. Janine, R. & Philippe, B., 2020. *Leveraging Artificial Intelligence and Machine Learning to improve the Process of Road Maintenance at the City of Copenhagen,* Copenhagen: Copenhagen Business School, Department of Digitalization.

23. JICA, 2010. *The Study on Greater Kampala Road Network and Transport Improvement in the Republic of Uganda.* 1 ed. Kampala: Japan International Cooperation Agency.

24. Kalman, 1960. A new approach to linear filtering and prediction problems. *Journal of Basic Engineering,* 82(1), p. 35–45.

25. KCCA, 2015. Kampala Capital City Authority. The Kampala Mobility News Bite. Entambula YO. *Aston Digital Transiton for Sustainable and Inclusive Cities,* 2(1), pp. 1-3.
26. KCCA, 2022. *KCCA launches construction of a traffic control center.* [Online]
Available at: https://www.kcca.go.ug/news/634/kcca-launches-construction-of-a-traffic-control-center
[Accessed 20 August 2024].
27. KCCA, 2023. *State of Kampala Roads,* Kampala: KCCA.
28. Khan, Z. H. & Gulliver, A. T., 2018. A macroscopic traffic model for traffic flow harmonization. *European Transport Research Review,* 10(2), pp. 1-12.
29. Khan, Z. H., Gulliver, A. T. & Khattak, K. S., 2021. A Novel Macroscopic Traffic Model based on Distance Headway. *Civil Engineering Journal,* 7(2), pp. 32-40.
30. Koźlak, A. & Dagmara, W., 2018. Causes of traffic congestion in urban areas. Case of Poland. *SHS Web of Conferences EDP Sciences.,* 57(1), pp. 1-9.
31. Kwikiriza, B. C., 2014. *Causes and Effects of traffic congestion in kampala city.* [Online]
Available at: https://rb.gy/0ztcn
[Accessed 17 October 2020].
32. Langer, M., Schien, T., Kates, R. & Bogenberger, K., 2020. An Improved Moving Observer Method for Traffic Flow Estimation at Signalized Intersections. *IEEE Intelligent Vehicles Symposium (IV),* pp. 1498-1503.

33. Lee, D. O., 2024. *The real cost of traffic jam, potholes in Kampala.* [Online] Available at: https://www.monitor.co.ug/uganda/oped/commentary/the-real-cost-of-traffic-jam-potholes-in-kampala-4487964 [Accessed 11 November 2024].

34. Maerivoet,, S. & Bart , D. M., 2005. *Traffic Flow Theory.* Belgium: ArXiv preprint physics/0507126.

35. Marcel Langer, T. S. M. H. R. K. a. K. B., 2020. An improved moving observer method for traffic flow estimation at signalized intersections. *Intelligent vehicles symposium.*

36. Nansereko, 2019. *Causes and Consequences of Traffic Flow in Kampala Capital City.* Kampala: Uganda Management Institute.

37. Nansereko, F., 2019. *Causes and Consequences of Traffic Flow in Kampala Capital City,* s.l.: s.n.

38. Nansereko, F., 2019. *Causes and consequences of Traffic jam in Kampala Capital City.* 1 ed. Kampala: Uganda Management Institute.

39. Net_Africa_Press, 2022. *Africa Press Net.* [Online] Available at: https://www.africa-press.net/uganda/all-news/kampalans-lose-52-days-to-traffic-jam-every-year [Accessed 3 November 2024].

40. O'flaherty, C. A. & Simons, F., 1970. An evaluation of the moving observer method of measuring traffic speeds and flows. *Australian Road Research Board (ARRB) Conference,* 7(3), pp. 293-311.

41. Ogenyi, O. H., 2014. *Analysis of Road Asset Management Systems in Uganda: The Case of Mount Elgon Region,* Kampala: Makerere University.

42. Ossen, S. J. L., 2008. *Longitudinal Driving Behavior: Theory and Empirics.* 109 ed. Delft-Netherlands: Delft University of Technology.

43. Popping, J., 2013. *An overview of microscopic and macroscopic traffic models..* s.l.:s.n.

44. Rilett, S., 2005. Calibration of Distributions of Commercial Motor Vehicles in CORSIM. In, Transportation Research Record. *Journal of the Transportation Research Board National Research Council, Washington, D.C.,* pp. 246-255.

45. ROU, 2007. *Uganda Vision 2040,* Kampala: National Planning Authority.

46. Schultz&Rilett, 2005. Calibration of Distributions of Commercial Motor Vehicles in CORSIM. In, Transportation Research Record. *Journal of the Transportation Research Board National Research Council, Washington, D.C,* 1934(1), pp. 254-265.

47. Sekalema , H. et al., 2023. Characterizing Peak-Time Traffic Jam Incidents in Kampala Using Exploratory Data Analysis. *Journal of Transportation technologies,* 13(1), pp. 61-86.

48. Solanki, M. J., Umrigar, F. S., Zala, L. B. & & Amin, A., 2016. Application of Moving Car Observer Method for Measuring Travel Time, Delay & Vehicle Flow under Heterogeneous Traffic Condition of C.B.D. Area: Case Study of Surat-Rajmarg (Chowk to Delhi Gate). *International Journal of Current Engineering and Technology,* 6(3), pp. 799-803.

49. Tukesiga, G., Bakaki, I., Kiniagi, C. H. & Wagima, C., 2021. The Control and Analysis of hidden Performance costs as a result of traffic jam in

kampala capital city. *Journal of Economics, Finance And Management Studies,* 4(7), pp. 887-895.

50. Turner, D. P., 2020. Sampling methods in research design. *American headache society,* 60(1), pp. 8-12.
51. Umar.Y, S. H. &., 2023. *Characterizing Peak-Time Traffic Jam Incidents in Kampala Using Exploratory Data Analysis.* Kampala: s.n.
52. Walker, S., 2021. *Sustainable energy transition scenario analysis for buildings and neighborhoods: Data-driven optimization,* Eindhoven: Technische Universiteit Eindhoven.
53. Wei-Hsun, L. & Chi-Yi, C., 2020. Design and Implementation of a Smart Traffic Signal Control Sstem for Smart Cit Applications. *MDPI,* 20(508), p. 18.
54. Wright, C., 1973. A theoretical analysis of the moving observer method.. *Transportation Research, ,* pp. 293-311.
55. Wu, C., 2021. Traffic flow theory-Macroscopic perspective on traffic flow fundamentals. *Transportation: foundations and methods,* 1(4), pp. 12-15.
56. Zanule, P. G., 2015. *Road management system and road safety in Uganda.* 368 ed. Kampala: Walden Dissertations and Doctoral Studies.
57. Zhang, L., Yuan, Z., Yang, L. & Liu, Z., 2020. Recent developments in traffic flow modelling using macroscopic fundamental diagram. *Transport Reviews,* Volume 40, pp. 1-22.
58. Zhou, X., 2021. Construction and Application of Urban Intelligent Traffic Control System Based on Cloud Computing. *Journal of Physics:conference series,* Volume 4, p. 6.

Appendices

Appendix I: Data Collection Sheets

Date: ……

Time: ……

Name of recorder: ……

Location: ……

Direction of flow	**Time**	**No. of Overtaking vehicles (*Mo*)**	**No. of Overtaken vehicles (*Mp*)**	**Time taken to cover stretch *(Tw)***	**No. of vehicles Moving against (*Ma*)**	**time taken moving against *(Ta)***

Data Collection Sheet 2

Date: ……

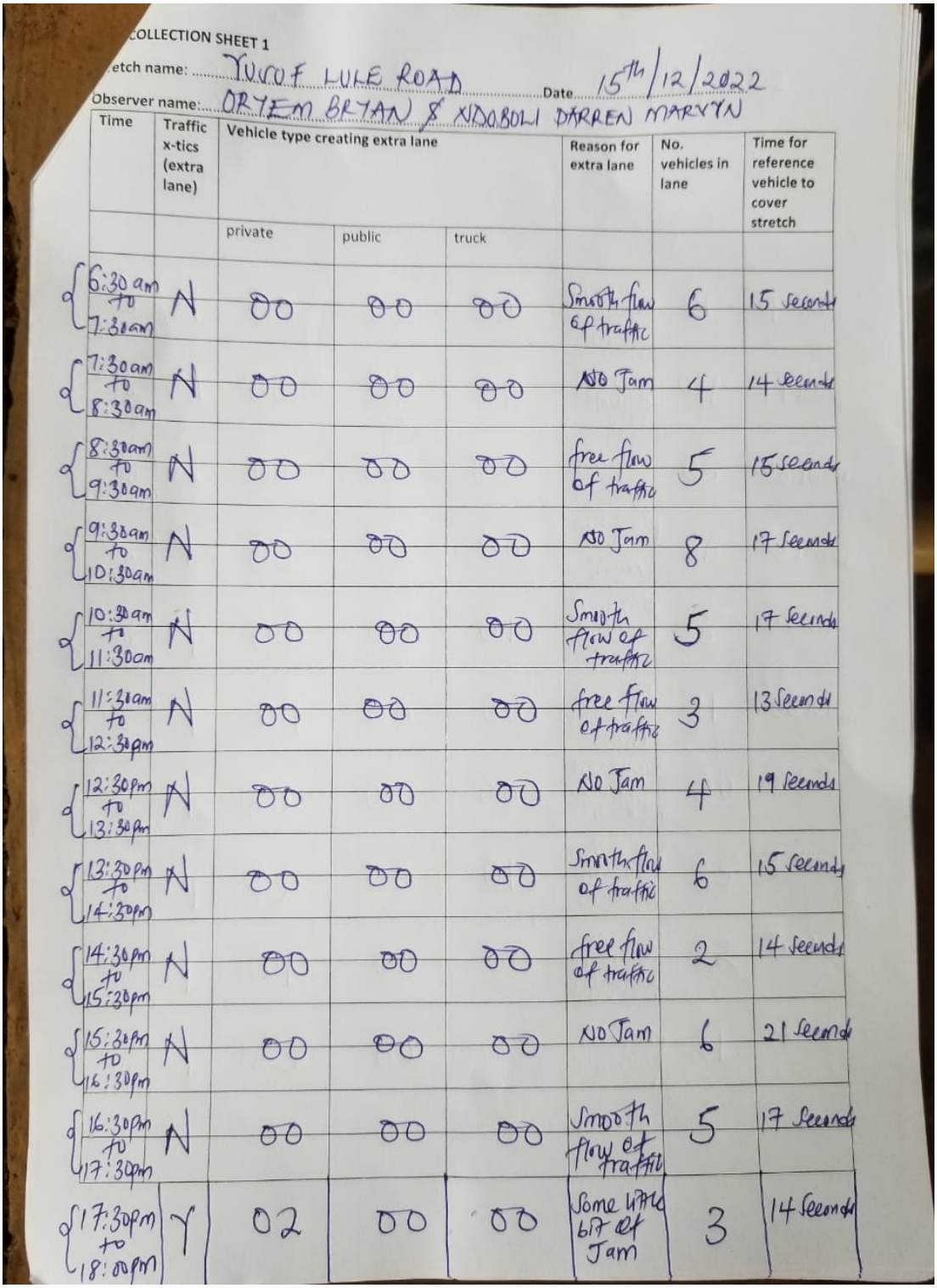
Time: ……

Name of recorder: ……

Location: ……

Stretch name /length	Vehicle identification	Time vehicle crosses reference point	No. of vehicles in stretch

Appendix II: Sample filled data collection sheets

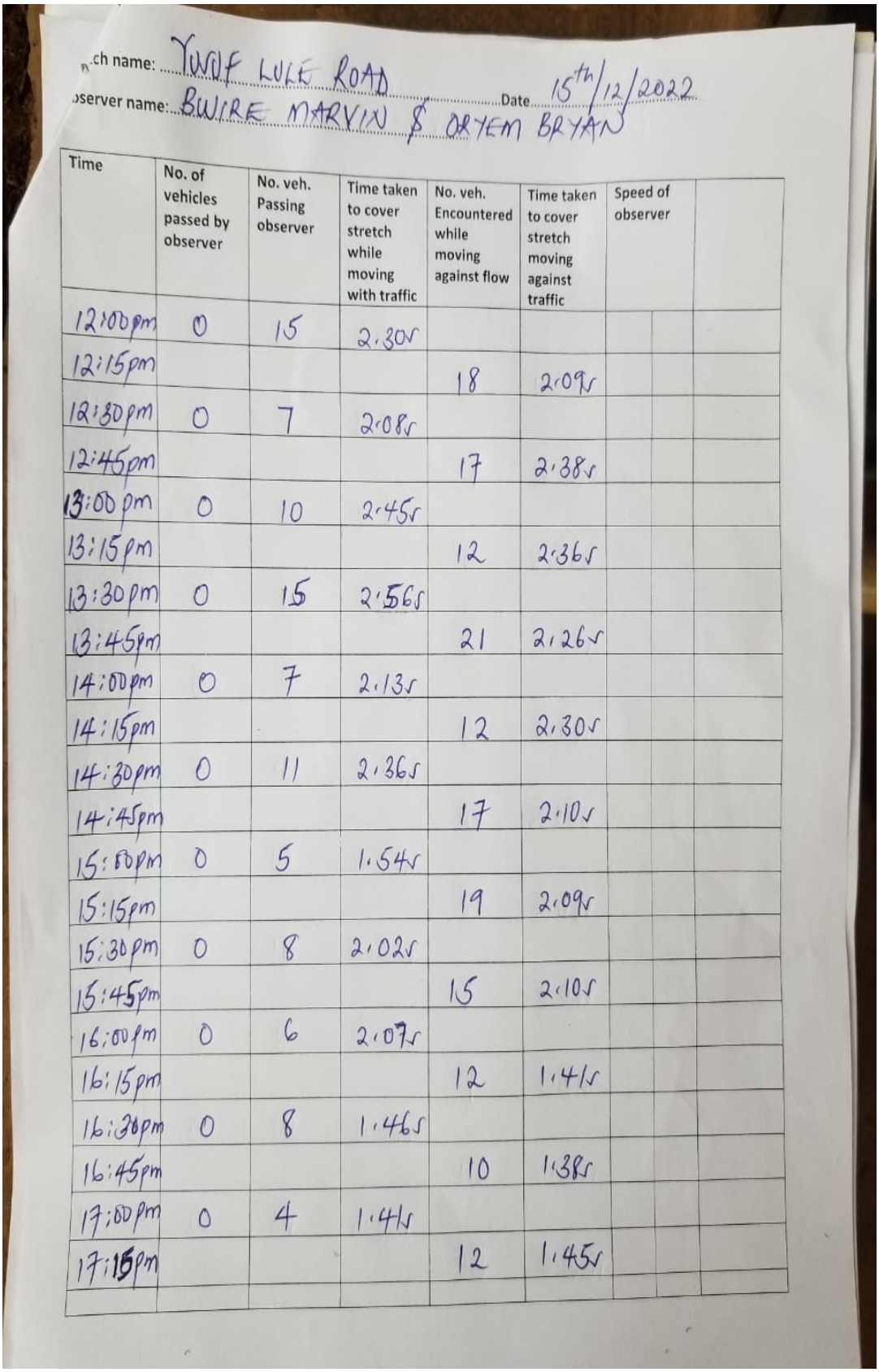


COLLECTION SHEET 1

Sketch name: YUSUF LULE ROAD Date: 15th/12/2022

Observer name: ORYEM BRYAN & NDOBOLI DARREN MARVYN

Time	Traffic x-tics (extra lane)	Vehicle type creating extra lane			Reason for extra lane	No. vehicles in lane	Time for reference vehicle to cover stretch
		private	public	truck			
6:30 am to 7:30am	N	00	00	00	Smooth flow of traffic	6	15 seconds
7:30 am to 8:30am	N	00	00	00	NO Jam	4	14 seconds
8:30am to 9:30am	N	00	00	00	free flow of traffic	5	15 seconds
9:30am to 10:30am	N	00	00	00	NO Jam	8	17 seconds
10:30 am to 11:30am	N	00	00	00	Smooth flow of traffic	5	17 seconds
11:30am to 12:30pm	N	00	00	00	free flow of traffic	3	13 seconds
12:30pm to 13:30pm	N	00	00	00	NO Jam	4	19 seconds
13:30pm to 14:30pm	N	00	00	00	Smooth flow of traffic	6	15 seconds
14:30pm to 15:30pm	N	00	00	00	free flow of traffic	2	14 seconds
15:30pm to 16:30pm	N	00	00	00	NO Jam	6	21 seconds
16:30pm to 17:30pm	N	00	00	00	Smooth flow of traffic	5	17 seconds
17:30pm to 18:00pm	Y	02	00	00	Some what bit of Jam	3	14 seconds



...ch name: YUSUF LULE ROAD Date 15th/12/2022

...bserver name: BWIRE MARVIN & ORYEM BRYAN

Time	No. of vehicles passed by observer	No. veh. Passing observer	Time taken to cover stretch while moving with traffic	No. veh. Encountered while moving against flow	Time taken to cover stretch moving against traffic	Speed of observer		
12:00pm	0	15	2.30s					
12:15pm				18	2.09s			
12:30pm	0	7	2.08s					
12:45pm				17	2.38s			
13:00pm	0	10	2.45s					
13:15pm				12	2.36s			
13:30pm	0	15	2.56s					
13:45pm				21	2.26s			
14:00pm	0	7	2.13s					
14:15pm				12	2.30s			
14:30pm	0	11	2.36s					
14:45pm				17	2.10s			
15:00pm	0	5	1.54s					
15:15pm				19	2.09s			
15:30pm	0	8	2.02s					
15:45pm				15	2.10s			
16:00pm	0	6	2.07s					
16:15pm				12	1.41s			
16:30pm	0	8	1.46s					
16:45pm				10	1.38s			
17:00pm	0	4	1.41s					
17:15pm				12	1.45s			

Appendix III: Exell attachments

Residuals(P-E)	*(P-E)²*	*(P-E)²/E*		Absolute P-E	(Absolute P-E)/E	Asolute percentage error	Mean Absolute Percentage Error
14.973	224.205	0.851	0.057	15	0.057	5.684	6.386
-14.140	199.927	0.923	-0.065	14	0.065	6.529	
13.870	192.368	0.845	0.061	14	0.061	6.096	
13.284	176.475	0.819	0.062	13	0.062	6.162	
15.117	228.510	1.182	0.078	15	0.078	7.822	
-16.415	269.450	1.359	-0.083	16	0.083	8.277	
22.449	503.945	1.923	0.086	22	0.086	8.567	
5.950	35.406	0.153	0.026	6	0.026	2.567	
-13.993	195.798	0.838	-0.060	14	0.060	5.988	
9.640	92.926	0.316	0.033	10	0.033	3.282	
-5.060	25.603	0.225	-0.044	5	0.044	4.441	
-8.262	68.257	0.566	-0.069	8	0.069	6.851	
-2.598	6.749	0.052	-0.020	3	0.020	1.989	
-13.990	195.723	1.962	-0.140	14	0.140	14.023	
11.979	143.501	0.978	0.082	12	0.082	8.168	
14.772	218.202	1.679	0.114	15	0.114	11.364	
-0.786	0.618	0.010	-0.013	1	0.013	1.305	
12.383	153.335	1.772	0.143	12	0.143	14.309	
8.195	67.152	0.995	0.121	8	0.121	12.139	
-11.340	128.605	2.231	-0.197	11	0.197	19.669	
10.557	111.441	1.418	0.134	11	0.134	13.436	
11.014	121.308	1.424	0.129	11	0.129	12.933	
-9.608	92.323	1.816	-0.189	10	0.189	18.902	
-5.745	33.003	0.571	-0.099	6	0.099	9.944	
3.601	12.965	0.032	0.009	4	0.009	0.894	
6.761	45.707	0.130	0.019	7	0.019	1.920	
-25.975	674.718	2.150	-0.083	26	0.083	8.276	
-9.552	91.235	0.284	-0.030	10	0.030	2.969	
17.273	298.368	0.918	0.053	17	0.053	5.317	
6.269	39.297	0.128	0.020	6	0.020	2.040	
-9.114	83.061	0.176	-0.019	9	0.019	1.928	
5.386	29.006	0.072	0.013	5	0.013	1.337	
2.160	4.666	0.015	0.007	2	0.007	0.673	
6.694	44.807	0.142	0.021	7	0.021	2.115	
18.308	335.172	0.919	0.050	18	0.050	5.018	
26.956	726.636	1.722	0.064	27	0.064	6.390	
0.954	0.910	0.004	0.004	1	0.004	0.373	
21.068	443.855	1.677	0.080	21	0.080	7.960	
-18.896	357.076	1.543	-0.082	19	0.082	8.166	
4.039	16.310	0.062	0.015	4	0.015	1.536	
16.525	273.074	0.932	0.056	17	0.056	5.642	

Appendix IV: Images of data collection on going along the stretches










YUSUF LULE ROAD
14/12/2022 11:26:51 AM

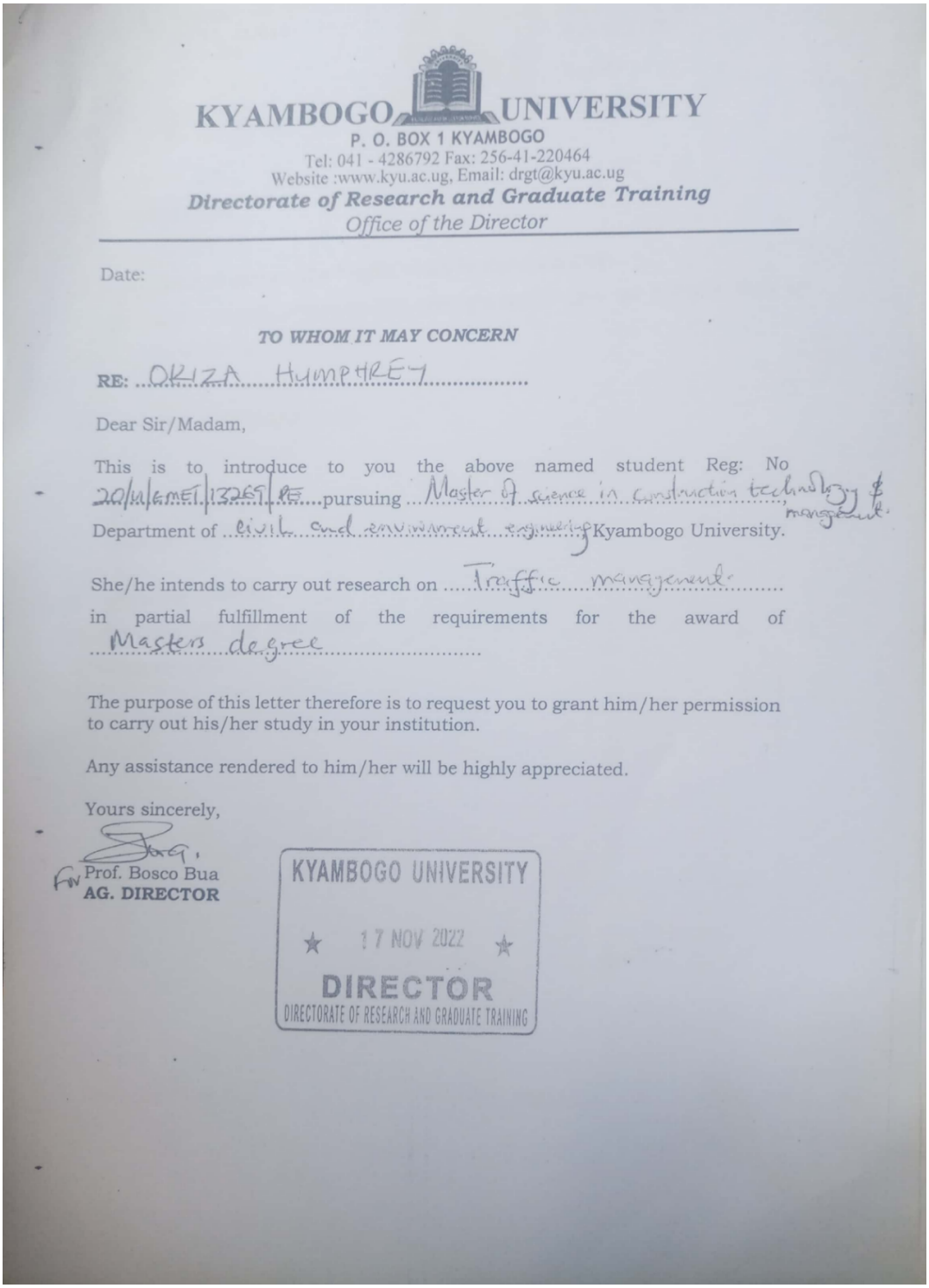

YUSUF LULE ROAD
14/12/2022 11:26:59 AM


wandegeya
0°19'38", 32°34'27", 1193.9m
12/14/2022 01:34:02 PM


wandegeya
0°19'38", 32°34'27", 1193.9m
12/14/2022 01:33:56 PM


Believing
is
Magic
entebe

Appendix V: Permission letters



KYAMBOGO UNIVERSITY
P. O. BOX 1 KYAMBOGO
Tel: 041 - 4286792 Fax: 256-41-220464
Website :www.kyu.ac.ug, Email: drgt@kyu.ac.ug
Directorate of Research and Graduate Training
Office of the Director

Date:

TO WHOM IT MAY CONCERN

RE: OKIZA HUMPHREY

Dear Sir/Madam,

This is to introduce to you the above named student Reg: No 20/U/GME1/13269/PE pursuing Master of Science in construction technology & management.
Department of civil and environment engineering Kyambogo University.

She/he intends to carry out research on Traffic management.
in partial fulfillment of the requirements for the award of Masters degree

The purpose of this letter therefore is to request you to grant him/her permission to carry out his/her study in your institution.

Any assistance rendered to him/her will be highly appreciated.

Yours sincerely,

Prof. Bosco Bua
AG. DIRECTOR

KYAMBOGO UNIVERSITY
17 NOV 2022
DIRECTOR
DIRECTORATE OF RESEARCH AND GRADUATE TRAINING

22

KYAMBOGO UNIVERSITY

P.O. BOX 1 KYAMBOGO

FACULTY OF SCIENCE

DEPARTMENT OF MATHEMATICS AND STATISTICS

HEADQUARTERS OPEN REGISTRY
28 NOV 2022
RECEIVED
P. O. BOX 7055, KAMPALA

28th November 2022

The Inspector General of Police Uganda Police Force.
Uganda Police Force P.O Box, Naguru
Kampala, Uganda.

II D/R,P+D
Handle in liaison with Ag D/TRS.
29/11/22

Dear Sir,

RE: REQUEST FOR PERMISSION TO CARRY OUT A TRAFFIC STUDY ON SELECTED ROAD STRETCHES IN KAMPALA CITY

I hereby request for permission to allow a group of researchers from Kyambogo University (as attached) to carry out traffic counts from 30/11/2022 to 29/12/2022 on the roads mentioned below:

i) Along Entebbe Road, 300m of stretch along Queensway towards Kibuye Roundabout.

ii) Along Yusuf Lule Road from Kafu Road to Lifecare wellness SPA about 200m long stretch

iii) Along Kampala-Masaka Road, A 300m stretch is chosen from the Busega Roundabout towards Total Kyengera Highway.

iv) Along Sir Apollo Kagwa Road besides Makerere University Small Gate to Nakulabye junction, A 250M stretch.

v) Along Jinja Road, a 200m stretch from the last branch-off to 1st Street up to the Roundabout at Centenary Park

The purpose of this study is to determine the current traffic status and volume of vehicles on the roads so that we can finally model the traffic flow and help advice on traffic

OKIZA HUMPHREY
0759104014
0791054821
okizahum1@gmail.com

1

TELEGRAMS. "GENPOL"
TELEPHONE: 231761, 233814
FAX NO: (041) 255630)

IN ANY CORRESPONDENCE ON.
THIS SUBJECT QUOTE NO. UPF 00/000/00

UGANDA POLICE FORCE
POLICE HEADQUARTERS
P.O. BOX 7055

Uganda

12/12/2022.

C/O Okiza Humphrey

Re: Permission to carry out a Traffic study in Kampala City.

In regard to the subject, permission has been granted to carry out a Traffic study on selected road stretches in Kampala City.

Liaise with KMP Traffic Commander.

SCP Niwabiine Lawrence
Ag. Director Traffic and Road Safety
12th December,2022.

TELEGRAMS: "GENPOL"
TELEPHONE: 0414-233814, 0414-250613
FAX NO. (0414)255630

UGANDA POLICE FORCE
POLICE HEADQUARTERS
P.O.BOX 7055
Kampala
Uganda

DIRECTORATE OF RESEARCH, PLANNING AND DEVELOPMENT

Our Ref: .....

Research Form

1. **Particulars of Researcher**
   a) Name: OKIZA HUMPHREY Sex: MALE
   b) Address: KYAMBOGO UNIVERSITY Tel: 0751104014/0780848121
   c) Age: 27 email: okizahum1@gmail.com
   d) Designation: STUDENT
   e) Nationality: UGANDAN
2. **Subject Particulars**
   a) Name of Organization carrying out the research: KYAMBOGO UNIVERSITY
   b) Subject of the study: TRAFFIC MANAGEMENT
   c) Introductory Authority: DIRECTORATE OF RESEARCH AND GRADUATE TRAINING - KYAMBOGO
   d) Name and Address/Contact of Supervisor: DR. RICHARD AWICHI, 0772862362
3. **Details of Information/Data required/Location of Research Centre e.g. Police Station and/or Dept**
   Daily traffic counts, traffic volume and density
4. **Benefits of the Research to Uganda Police Force**
   The research findings will help us understand the current traffic status in the city so that we can advise the traffic and city authorities on how to better solve the traffic congestion problems on the road.
5. **Undertaking**
   I promise to provide a copy of my research report to the resource centre of the Uganda Police by (Date).....
   Failure to do so, the Uganda Police Force should liaise with my supervisor and render my paper null and void.
   Name and Signature: OKIZA HUMPHREY Date: 6/12/2022
6. **For Official Use**
   Remarks: The researchers should report to the Director of Traffic & Road Safety for the necessary support. A copy of the research document to be availed to the A/R PSD

Authorizing Officer: OCAYA JAMES AIGP - RPSD

Signature: [signature] Date: 07/12/2022

Note: Information obtained for the research should be used exclusively for the intended purpose.

Developing, coordination, Monitoring & Reviewing of Strategic Plans and Policies for effective protection of life and property

Received: Nawasa SEED TRS 12/12/2022