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A smartphone-based road signs alert system for vehicle drivers' assistance in Tanzania

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NM-AIST

A SMARTPHONE-BASED ROAD SIGNS ALERT SYSTEM FOR VEHICLE DRIVERS' ASSISTANCE IN TANZANIA

Eric Melkiory Masatu

A Dissertation Submitted in Partial Fulfilment of the Requirements for the Degree of Master's in Information Systems and Network Security of the Nelson Mandela African Institution of Science and Technology

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ABSTRACT

Road Traffic Accidents (RTA) are major problems worldwide resulting in significant morbidity and mortality. Advanced driver assistance systems (ADAS) are one of the salient features of intelligent systems in transportation. ADAS improves vehicle safety by providing real-time traffic information on road signs ahead. Road signs play an important role in road safety. To be effective, road signs must be visible at a distance that enables drivers to take the necessary actions. Static road signs, however, are often seen too late for a driver to respond accordingly. In this study, a system for alerting drivers about road signs has been developed and tested using a smart mobile phone. The study was conducted in Tanzania along an 80 km stretch of Arusha to Moshi highway. The haversine method was used precisely for the measure and estimation of the distance between two pairs of coordinates. It uses an existing supported phone-based navigation application, Google Map. The system provides a speech alert to a needed action which enhances attention diversion. According to the experimental results, the proposed methodology has the benefits of high accuracy within a user radius of 10 meters, minimum bandwidth, and low-cost system. Furthermore, the system application package SHA-1 signing certificates fingerprint is secured by limiting access to API key to avoid unauthorized access to sensitive information.

DECLARATION

I, Eric Melkiory Masatu do hereby declare to the Senate of the Nelson Mandela African Institution of Science and Technology that this Project Report is my original work and that it has neither been submitted nor being currently submitted for degree award in any other institution.

Eric Melkiory Masatu

Name and Signature of Candidate   Date

The declaration is confirmed by the following:

Dr. Anael Sam

Name and Signature of Supervisor 1   Date

Dr. Ramadhani Sinde

Name and Signature of Supervisor 2   Date

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CERTIFICATION

The undersigned certify that have read and hereby recommend for acceptance by the Senate of the Nelson Mandela African Institution of Science and Technology, a dissertation titled "*A Smartphone-Based Road Signs Alert System for Vehicle Drivers' Assistance in Tanzania* " in Partial Fulfillment of the Requirements for the Award of the Degree of Master's in Information Systems and Network Security of the Nelson Mandela African Institution of Science and Technology.

Dr. Anael Sam

Name and Signature of Supervisor 1 Date

Dr. Ramadhani Sinde

Name and Signature of Supervisor 2 Date

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DEDICATION

This dissertation is dedicated to my family.

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LIST OF ABBREVIATIONS AND SYMBOLS

ADAS	Advance Driver Assistance System
API	Application Program Interface
APK	Android Package
APP	Application
FGD	Focus Group Discussions
GPS	Global Positioning System
ICT	Information and Communication System
IDE	Integrated Development Environment
IMU	Inertia Measure Unit
JSON	JavaScript Object Notation
LATRA	Land Transport Regulatory Authority
LBS	Location Based Services
NM-AIST	Nelson Mandela African Institution of Science and Technology
OBU	On-Board Unit
OECD	Organization for Economic Co-operation and Development
OS	Operating System
PEOU	Perceived Ease of Use
PU	Perceive Usefulness
RAD	Rapid Application Development
RFID	Radio Frequency Identification
RSU	Road Side Unit
RTA	Road Traffic Accidents
SDK	Software Development Kit
SPSS	Statistical Package for Social Sciences
SUMATRA	Surface and Marine Transport Regulatory Authority
TAM	Technology Acceptance Model
V2I	Vehicle-to-Infrastructure
V2V	Vehicle-to-Vehicle
VAN	Vehicle Area Network
VTS	Vehicle Tracking System
WHO	World Health Organization
Wi-Fi	Wireless Fidelity
WLAN	Wireless Local Area Network

CHAPTER ONE

INTRODUCTION

1.1 Background of the Problem

Road traffic accidents (RTA) are defined as accidents that occurred or originated on a way or street open to public traffic. These collisions result in an injury or death between automobiles or human beings (Organization for Economic Co-operation and Development [OECD], 2020).

The RTA is a major problem worldwide resulting in significant morbidity and mortality. According to the World Health Organization road safety report of 2018, the number of road traffic deaths increased to 1.35 million in 2016 (World Health Organization, 2018). According to the report, 93% of global road accidents occurred in low- and middle-income countries, which account for 60% of the world's vehicles.

The burden of road accidents and loss of life is generally high in Africa (Adeloye *et al*., 2016). For instance, data obtained from the 2016 Ethiopia demographic and health survey indicated that RTA accounted for 22.8% of all injuries (Abegaz & Gebremedhin, 2019). Another study in Ethiopia reported a magnitude of 23.17% for road traffic accidents (Woldu *et al.,* 2020). The RTA rate in Kenya during the year 2009 was 59.96 per 100 000 people (Bachani *et al*., 2012). The WHO report of 2018 on road safety indicated that the magnitude of deaths due to RTA in Africa is the highest in the world at 26.6 per 100 000 people (World Health Organization, 2018).

In the study in Ethiopia by Abegaz and Gebremedhin (2019), RTA-related deaths per 100 000 motor vehicles were estimated at 4922. Sadly, the most affected people represent the young male in the productive age group. In Ethiopia, approximately 47% of the accident’s victims were between 15 and 29 years of age and 65% were males (Abegaz & Gebremedhin, 2019). A study in Tanzania found that 70.2% of road traffic injury patients were the age of group 18 - 45 years and 76.6% were men (Boniface *et al*., 2016).

Apart from injuries and deaths, road traffic accidents have economic, social, and emotional consequences for the nation and individuals (Bun, 2012; Machumu, 2018). These include costs for medical expenses, insurance payments, funerals, productivity loss, and loss of property.

Several factors contribute to road traffic accidents. These factors broadly can be divided into driver, vehicle, and roadway (Bun, 2012). Driver factors are related to drivers and other road users. This may include driver behaviour like a violation of traffic rules and signs, incapacitation, decision-making ability, and reaction speed. In Saudi Arabia, over 65% of the accidents were due to excessive speed and violation of signals at intersections (Ansari *et al*., 2000). Violation of traffic rules and failure to notice traffic signs by drivers have been reported as causes of accidents (Rajale *et al.,* 2014; Wold *et al.,* 2020).

Vehicle factors include vehicle design and vehicle maintenance. A well-designed and maintained vehicle is less likely to be involved in accidents (Bun, 2012). A study in Ethiopia found one of the major causes of accidents was the lack of vehicle service (Woldu *et al.*, 2020).

Roadway factors include road design, maintenance, and availability of signs. A well-designed and properly maintained road and availability of signs reduce the chances of accidents. The absence of road signs has been reported to be the cause of road accidents (Haulle & Kisiri, 2016; Machumu, 2018). More over factors such as inadequate road signs, inadequate carriageway width, lack of pedestrian facilities and lack of law enforcement are considered to be critical shortcomings (Nyakyi, 2018).

Several approaches are being used in various countries to reduce road accidents. These include the setting of safer vehicle standards, better road construction, enforcement of traffic laws, speed control, road safety education to road users, and road signs alert to drivers (Afukaar, 2003; Rajale *et al.,* 2014; SUMATRA, 2017; World Health Organization, 2018).

The advancement of information communication technology (ICT) like geographical information, allows people to quickly adapt to current technology. Currently, navigation products used in the motor vehicle mainly include in-vehicle navigation systems such as FlyAudio and CASKA. Portable navigation devices like Garmin and TomTom, and mobile navigation applications like Google Maps, Gaode Maps, and Baidu Maps (Yang *et al*., 2021). Due to its attraction for mobile users, ease of updating, and high precision, the mobile application navigation is growing in popularity. Mobile navigation apps make life easier for users. According to a survey conducted in the United States by Hu *et al*. (2015), as many as 91% of 500 drivers would like to have mobile navigation applications with an energy-saving mode. The observation that smartphones have become widely used for navigation served as inspiration for this research. Because of the intelligent features, cost-free of download and ease of use, the use of Google Maps has grown in popularity.

Several studies have been conducted for road safety on signs detection and recognition using a device onboard a vehicle. Examples are the use of traffic signs recognition, devices on a vehicle and communication infrastructure, Wireless Local Area Network (WLAN) mobile device technology, and Vehicle to Vehicle communication (V2V).

However, on-board systems are an expensive option compared to the use of smartphone applications, these devices need a constant power supply and regular maintenance.

The purpose of this study was to develop a system that can be tested on a smartphone to notify drivers about the road traffic signs ahead. The development of the system was motivated by the fact that smartphones are currently serving as a primary computing device as they are lightweight, have multi-active windows, and more powerful. Smartphones contains an inbuilt sensors like Global Positioning System (GPS), accelerometer and gyro-sensor, and Inertia Measure Unit (IMU). These distinctive features of smartphones can be utilized by the developed system. To provide information to the drivers. This valuable information can be about the speed of the vehicle, specific location of road signs, driver's distance, and time required to reach the road signs. As a result, smartphones provide a golden opportunity for enhancing vehicle safety.

Moreover, compared to onboard hardware, the performance of smartphones is better than on-board equipment. Smartphones are easy to calibrate for enhancing GPS accuracy performance by gently waving the mobile phone in the Fig. 8-pattern. Also, the updating of road information to the system can be done easily and upgrading can be done quickly and securely.

1.2 Statement of the Problem

Road transport is the most common mode of transportation in Tanzania. However, this mode is characterized by a low level of road safety. According to available data in the country, RTA is the country's most serious problem. The majority of victims in Tanzania are between the ages of 18 and 45 years, who are economically active (Boniface *et al*., 2016). In 2018, Tanzania ranked sixth in the world in terms of RTA with an age-adjusted death rate of 46.17 per 100 000 population (World Life Expectancy, 2018). The findings from Nyakyi (2018) indicated the considerable proportions of accident in Moshi-Arusha Highway and its outcomes of death and injuries at various black spots such as Kikavu River (60%), Kikatiti (20%), Nduruma bridge (10%), Kilala slope (5%), and Sadec (5%). In Tanzania, inappropriate road use behaviours, such as speeding, have been identified as the leading cause of road accidents (Eliakunda *et al.,* 2018). Other factors include a lack of critical road signs (Haulle & Kisiri, 2016; Machumu, 2018; Nyakyi, 2018). Interventions aimed at improving road safety in Tanzania include improvements in road infrastructure, traffic law enforcement, speed control and road safety education. The use of speed governor devices and Vehicle Tracking System (VTS) in passenger buses, as well as the use of speed radars, are among the speed control measures used (Surface and Marine Transport Regulatory Authority [SUMATRA], 2017). Passenger buses are limited to 80 km/h by speed governors. A bus traveling at more than 80 km/h will trigger an alarm from the VTS, indicating over speeding. This will be noted in the SUMATRA control room, and the speeding driver will be penalized. However, the VTS monitors only specified speed limit set by the authority at 80 km/h. They are incapable to track over-speeding in areas where there are road signs limiting speed in various locations, like 50 or 30 km/h. Speed radars are deployed by road traffic Police officers in several places along major highways. Drivers violating speed limits receive penalties. This system is resource-intensive as it requires having plenty of radars and Police officers on the road. Furthermore, the fact that traffic Police officers do not work at night limits the use of speed radars. Furthermore, the use of speed radars may be undermined by drivers who notify each other about places where such radars are in use. This situation makes drivers reduce speed only in the areas where speed radars are deployed.

1.3 Rationale of the Study

Despite the presence of road signs on most Tanzanian highways, currently there is no ICT-based system in place to alert drivers in advance and in real time about the location of those road signs. As a result, drivers encounter road signs at a short distance, making them unable to take the necessary precautions in time, leading them to apply brakes abruptly, which can cause an accident. Advanced Driver Assistance Systems (ADAS) can improve road safety by informing drivers about upcoming road conditions such as curves, bumps, speed humps, pedestrian crossings and speed limits. Smartphones have features such as a Global Positioning System (GPS), a database, microelectronic systems, and an inertial measurement unit (IMU). These features can be used to provide information about the location of road signs, the vehicle's speed, and the time required to reach the road signs ahead. As a result, smartphones provide a golden opportunity for enhancing vehicle safety. It is for these reasons that this study was conducted.

1.4 Research Objectives

1.4.1 Main Objective

The main objective of this research was to develop a road signs alert system using a smart mobile phone.

1.4.2 Specific Objectives

The following specific objectives were addressed:

(i) To identify the requirements of the system.

(ii) To design and develop a smartphone-based system for road signs alert.

(iii) To implement and validate the developed system.

1.5 Research Questions

The following research questions were answered:

(i) What are the requirements for the smartphone-based system for road signs alerts?

(ii) Which are the best methodologies to develop the proposed system?

(iii) Will the developed system meet the specified requirements?

1.6 Significance of the Study

The study will make use of the Information and Communication Technology (ICT) based system for digital storing of road traffic signs for an in-vehicle highway driver. The information will alert drivers about upcoming traffic signs at an ideal distance before encountering the signs. Hence, drivers will be able to take appropriate action for the forthcoming road sign, such as stopping, reducing speed, etc. In so doing, driving safety will significantly be enhanced, thereby minimizing road traffic accidents and reducing the violation of traffic rules.

1.7 Delineation of the Study

The study aimed at developing driver's assistance system that aimed to improve the quality and security of road transportation service in Tanzania. Road signs carry out a significant role in road safety through driver guidance. They provide significant information that assists drivers to operate their vehicles in a manner that enhances road safety. To be effective, road signs must be visible, legible, and comprehensible. The study provides an ICT-based system for signalling drivers in advance. The drivers are signalled at the farthest possible distance so that they have enough time to decide in time. The development of this system provides an opportunity for further development and integration with the developed system.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This Chapter presents a theoretical and empirical literature reviews. The theoretical literature review state the theory and asses the acceptance to use the developed system. The empirical literature review reports the studies done previously on the topic and identify research gap. The empirical review focus on three major themes.

2.2 Theoretical Literature Review

2.2.1 Technology Acceptance Model

The Technological Acceptance Model (TAM) founded by Davis (1989) as depicted in Fig. 1, is the most extensively used model to assess how people come to accept and employ a given technology. The model is made up of four constructs that influence consumers' decisions to use information technology. Perceived usefulness (PU), perceived ease of use (PEOU), attitude toward use (ATU), and actual system use are examples of these. The degree to which an individual accepts that using a given system would increase their work performance is described as perceived usefulness. It denotes whether or not someone regards the innovation as useful for what they need to perform. The degree to which people feel utilizing a certain system will be devoid of problems is characterized as perceived ease of use. When using a system or technology, attitude is described as the overall impression. The point at which the user employs the technology is referred to as actual use.

Previous researches have used the TAM model. The studies investigate the service's acceptance and attitude toward the user. Park *et al*. (2012) and Park & Ohm (2014) studied user approval of navigation systems and mobile map services, including speed and location accuracy. Furthermore, the findings of Wang and Ju (2015) demonstrate that the actual system uses a mobile phone app as its primary navigation method. The TAM model was used in this study to assess the developed system and investigate the reasons for its potential use.

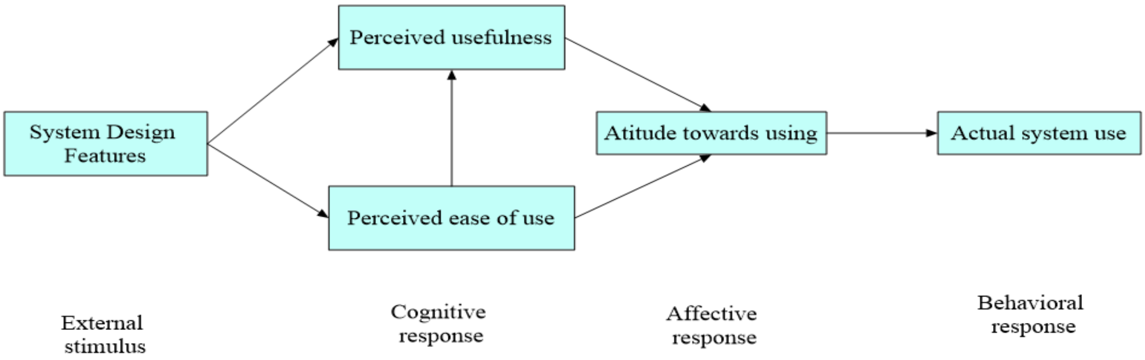


Figure 1: Technology acceptance model

2.3 Empirical Literature Review

2.3.1 Related Works

A review of the literature about road signs recognition revealed several approaches that can be divided into three themes: road sign colour and shape recognition, vehicle to roadside infrastructure communication, and vehicle to vehicle communication. These are briefly described here

(i) Theme 1: Road signs colour and shape recognition

Several road safety studies have been conducted using a device onboard a vehicle to detect and recognize road signs. The study García-Garrido *et al*. (2012) developed a traffic sign recognition system that uses a vision camera mounted on a vehicle. Based on the colours and shapes of the road signs, the system detected and recognized them.

Two studies Farhat *et al*. (2019) and Hechri *et al.* (2015) found that road signs could be recognized using their colours and images with an average accuracy of about 93% and 95%, respectively. However, recognizing road signs based on colours and images presents numerous challenges. These include lighting conditions that vary naturally with the time of day and weather conditions; images that have been buffed by a moving vehicle's vibration; fading of paint on the sign; and occlusion of the sign by obstacles such as a tree, street lamp, or buildings.

Another study by Ling and Seng (2011) used a mobile phone, the study used a smartphone back camera to recognize traffic signs and alert drivers for an incoming sign. The phone was placed on a windscreen for the camera to face the road. The distinct advantage of the system was that it did not require additional hardware. However, the main problem experienced was the low detection rate, light variation, and weather conditions.

Autonomous driving technologies have been emerging over the past few years. They integrate many technologies geared to providing driving safety, including sensing, localization, perception, decision making, as well as the smooth interactions with cloud platforms for high-definition map generation and data storage (Liu *et al.,* 2019).

The autonomous vehicles possess camera that can sense colours of road traffic signs. However, cameras have certain shortcomings. Illumination conditions affect their performance drastically, environmental variables from weather conditions to surrounding human behaviour, are highly indeterministic and difficult to predict (Yurtsever *et al.,* 2020). Furthermore, the system failure may lead to accidents (Davies, 2018; Lavrinc, 2014; Lee, 2019; McFarland, 2016).

(ii) Theme 2: Vehicle to Roadside Infrastructure Communication

Other approaches have used mobile devices on a vehicle and communication infrastructure on the road. The study Rajale *et al.* (2014) developed a road signs alert system based on GPS and a wireless Radio Frequency Identification (RFID) technology. A database of road signs and their location was created. Radio frequency identification transmitters were placed at the location of the road signs, and an RFID receiver was placed in the vehicle. Using the system, drivers were alerted about road signs ahead at some predetermined specific distance before the road signs were encountered.

However, the use of RFID transmitters in two-way traffic could be limited, in the sense that their signals might be detected by vehicles traveling in the opposite direction. Thus, this situation can be misleading the drivers. Also, the devices are expensive, require a constant power supply and regular maintenance.

Few studies have used WLAN mobile device technology to provide information about road signs. Katajasalo and Ikonen (2009) used wireless transmitters fitted on road signs to send traffic signs information to drivers through a WLAN mobile device within the vehicle. However, when the transmitters were close to each other, the separation of the relevant traffic sign information for the vehicle was problematic. Bhawiyuga *et al*. (2017) developed a communication system consisting of two devices; a Road Side Unit (RSU) deployed on a road sign and an On-Board Unit (OBU) deployed in a vehicle. Information about the road signs ahead was wirelessly communicated to drivers using the two units. Information transfer between modules was hindered by the speed of the vehicles in terms of delay and packet loss. Also, the attenuation in wireless signals decreased as the transmitter-receiver increases distance.

Another study by Toh *et al*. (2019) proposed the use of WiFi connectivity for wireless digital traffic signs. The study was capable of transmitting the traffic sign information wirelessly in the vehicle displays. The drivers were informed at an average distance between 70 and 98 meters. However, the device required constant power supply. In addition, when a driver travelled at a speed greater than 60 km/h, the average distance was not enough to provide alerts timely.

Other challenges of RSU reported by Faezipour *et al*. (2012) were that prioritization and queuing were a challenges due to the number of data processed from many nodes.

(iii) Theme 3: Vehicle to Vehicle Communication (V2V)

The approach of V2V communication is used to interchange information between automobiles on a network. In this approach, the broadcast information can include warnings while traveling on a similar road. The V2V wireless technology works as an automated system to control and properly inform drivers by exchanging information.

The review by Liang *et al*. (2015) showed that inventions for road safety use a long-range wireless communication system between entities on the road. The Vehicular Area Network (VAN) allows nearby automobiles to communicate and exchange data. Several studies in the area of vehicle-to-vehicle communication have been conducted and have accomplished a considerable achievement. However, the most challenging issues were connectivity between V2V and Vehicle to Infrastructure (V2I) and mobility that allows VAN to change its topology quickly. Another challenge was violation of privacy and security of the driver.

The study by Faezipour *et al*. (2012) reported that one of the significant challenge of V2V communication is a cooperate network communication between various vehicle manufacturers. The sensitive issue what broadcast information can one manufacture grant and others cannot. Engoulou *et al*. (2014) and Liang *et al*. (2015) noted that the Information between vehicles must be transmitted at a proper time without excessive delay and high accuracy to avoid rear-end collision.

2.4 Conceptual Research Framework

Several stages were completed in this study has depicted in the framework Fig. 2. The first step was to review literature of the relevant related studies in order to gain insights about road signs identification. Several approaches were noted in the review. Studies uses on-board devices, mobile device on vehicles, and wireless technology to provide information to drivers. The literature observed that a GPS mobile device sensor can accurately track the user mobility and can provide more closely located locations that are respectively within a driver's driving range.

The next step was to collect data from the stakeholders and identifying the requirements of the system. Data collected were on the system functional and non-functional requirements, the prototype's goals and expectations. Furthermore, current and potential issues which would need to be addressed during the design process were identified. The next step was to design a system by sketching the front-end and back-end, as well as architectural, data flow, and use case diagrams. Furthermore, the existing related system was taken into account during the design phase. Using a validation test guide, the developed system was pretested in the study area. Finally, the results were analysed.

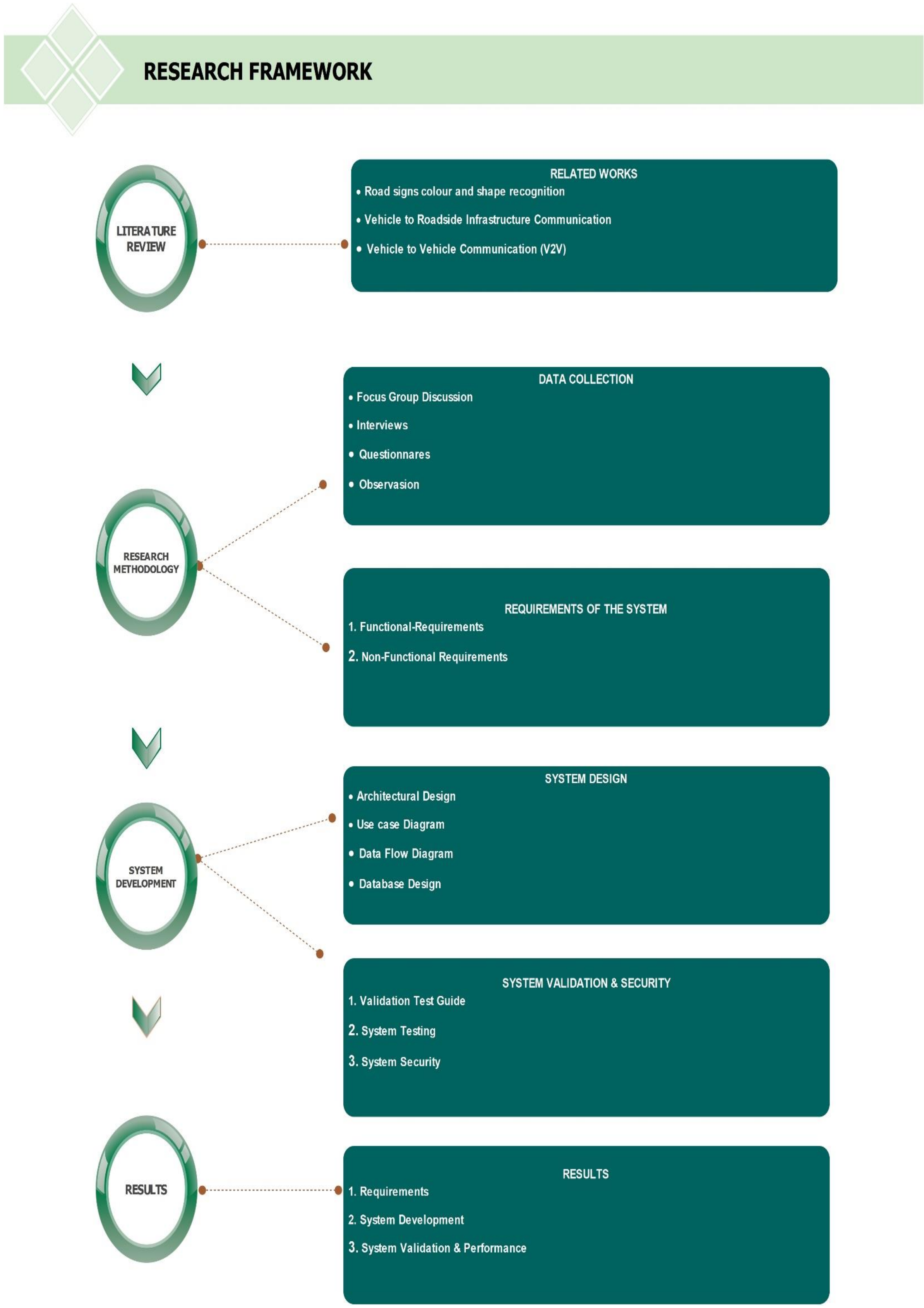


Figure 2: Conceptual research framework

CHAPTER THREE

MATERIALS AND METHODS

3.1 Introduction

This Chapter provide information about the study area, study design, study population, sample size, sampling technique, data collection methods, as well as materials and methods for the study.

3.2 Study Area

This study was conducted in Tanzania along the Arusha to Moshi highway. The road stretch is 80 kilometers long; travel time by car is approximately 01 hour 30 minutes at a speed of 60 km/h. The study area was chosen for convenience and economic reasons, as the road connects to other business cities and neighbourhood countries like Kenya and Uganda. Along the highway, there are numerous warnings and prohibitor road signs. Pedestrian crossings, animal crossings, road humps, bumps, and slippery roads are among the warning signs. Prohibitor road signs include 50 km/h and 30 km/h speed limits as well as no vehicle overtaking.

3.3 Study Designs

Qualitative and quantitative study designs were used. Qualitative study was used to identify the requirements of the proposed system. Quantitative study was used in evaluating the system's performance and user acceptability of the developed system.

3.4 Study Populations

The study populations were stakeholders involved in road safety, as well as public and private vehicle drivers operating on the Arusha – Moshi highway.

3.5 Sample Size

A feasible sample was taken for each study population. There was one representative from the Arusha regional LATRA office and one representative from the Arusha District Police traffic office. Also, the study included 25 public bus drivers and 20 public mini-bus drivers, and 10 private drivers. This sample was deemed adequate to provide required information.

3.5.1 Sampling of Participants

Participants were chosen using purposeful sampling. Stakeholders chosen from Police and LATRA were those who had optimal insights into the issues being explored. Inclusion criteria for the drivers were having a valid driver's license, owning a smartphone, and being willing to participate in the study.

3.6 Data Collection Methods

For collaboration and a thorough understanding of the problem, the study used a mixed-method approach. Focus Group Discussions (FGD), interviews, and observations were used as qualitative data collection methods. Also, a questionnaire was used as quantitative data collection method.

3.6.1 Focus Group Discussion

(i) Focus Group Discussion with Public Bus Drivers

Before developing the road signs alert system, two focus groups discussions were held with public bus drivers: One with 13 participants and another with 12 participants. The Focus Group Discussions were conducted by the researcher and a research assistant. The researcher led the discussions, while the assistant took notes. Issues explored were drivers' familiarity with road traffic signs, road signs found on the Arusha – Moshi highway, drivers' experiences with road traffic rule violations, and their expectations for the road signs alert system that will be designed. (Appendix 1).

3.6.2 Interviews

(i) Interview with the Traffic Police Officer

The interview with a spokesperson from the Traffic Police Department focused on the scope of road traffic accidents, the major causes, and the measures used to control road traffic accidents. Furthermore, the interview explored opinions on the proposed road sign alert system (Appendix 2).

(ii) Interview with Land Transport Regulatory Authority Official

The interview with a LATRA spokesperson focused on the successes and challenges of road transportation in Tanzania. Furthermore, LATRA's measures for reducing road traffic accidents and opinion on the development of a road sign alert system were explored (Appendix 3).

3.6.3 Questionnaires

(i) Questionnaires for Drivers

Each driver received proper installation and training on how to use the system. The drivers were requested to use the system frequently, and after 3 to 4 weeks, data was retrieved from their phones. Also, they filled a questionnaire which investigated the system's performance, potential usefulness, attitude towards using, user behaviour, as well as the drivers' acceptability of the system. The questionnaire contained items on a five-point Likert scale, where 1 represented “strongly disagree” and 5 “strongly agree (Appendix 4).

3.6.4 Observation

Driver log files were used to measure parameters during the observation. The logs file contains important information such as the distance over which alerts were issued, specific coordinates when alerts were issued, and the accuracy of the coordinate released within a user radius.

3.7 Data Analysis Method

Analysis of qualitative data was done by reading through the notes and identifying common responses and consensus opinions. The Statistical Package for Social Sciences (SPSS) for Windows software version 16 was used to analyse the questionnaire data. Frequency distributions of relevant variables were computed.

3.8 Ethical Issues

The Nelson Mandela African Institution of Science and Technology (NM-AIST) provided me with a letter introducing my research to stakeholders. All participants provided written informed consent to participate in the study. Participation in the study was voluntary, and all data collected were kept strictly confidential.

3.9 Proposed Work

3.9.1 Materials

The proposed system was developed on android studios. Materials used are described below|:

(i) Sensors

The system uses the mobile phone in-built GPS sensor, IMU, accelerometer, and gyro-sensor. The GPS sensor is used to determine coordinates, calculate vehicle speed, and distance from road signs.

A smartphone's accelerometer and gyroscope sensors are used to determine its orientation and switch the screen appearance between portrait and landscape views for a running application.

The use of an IMU sensor aids in the measurement of speed, displacement, and acceleration as a vehicle moves from one location to another.

(ii) Location-Based Service (LBS)

Location-Based Service (LBS) is a general term used to describe the technology used in finding the location of the device used (Ikasari & Widiastuti, 2021). The commonly used location-based service is a navigation system and tracking to determine the real-time address or position of the mobile device. The LBS is accessible by the mobile device through a mobile network.

(iii) Distance Measurement

In this study, distance is defined as the length in location between two points on the earth's surface. The first is a moving vehicle's geometric position, which can be determined as the vehicle moves from one position to another. The second is the location of the road signs, which were collected and saved in the built-in database. When the distance is determined, the calculated distance is converted into meters. The desired distance was 250 meters prior to reaching the road sign.

(iv) Haversine

The haversine formula is used to calculate the length of a great circle between two points on the Earth's sphere. According to Mahmoud and Akkari (2016), the formula produces approximations of real-world distances. It calculates the distance from the road signs coordinates stored in a JSON array based on the driver's geographical navigation position. The alert is generated by determining the point that is closest to the predetermined points. The closest distance was set to be in a close range of 250 meters in order to reach the point.

3.9.2 General Equations

$$a = sin^2\left({}^{\Delta\emptyset}/_2\right) + \cos\emptyset 1 * \cos\emptyset 2 * sin^2\left({}^{\Delta\lambda}/_2\right) \quad (1)$$

$$c = 2 * \text{asin}\sqrt{a} \quad (2)$$

$$d = R * c \quad (3)$$

Given above are the equations for haversine formula. It is a measure of the great circle distance on the Earth’s surface.

Where:

∅ represents latitude, λ represents longitude.

R is the radius of the Earth (mean radius = 6371 km); a represents square of half the chord length between the points.

C represents the angular distance between two points (in radians).

D is the distance in meters.

$\Delta\emptyset = (lat2 - lat1) * \frac{\pi}{180};$

$\Delta\lambda = (long2 - long) * \frac{\pi}{180};$

Note that angles need to be in radians.

3.9.3 System Development Approach

(i) Rapid Application Development (RAD)

During the development of the system, the Rapid Application Development (RAD) Model was used. This model is an agile-based software development methodology that focuses on optimizing a working prototype of the software or module and using it to gather user feedback. This method shortens the time it takes to plan the software requirements. The researcher, key stakeholders, and potential clients communicate during the requirements stage to determine the goals and expectations for the developed prototype. The model facilitates early prototyping and iterative design. Iterative design aids in the correction and addition of missing information prior to the final release. Furthermore, iterative design aids in the application’s improvement. Additionally, current and potential issues would need to be addressed during the design process. The data gathered from the focus group discussion with key stakeholders was used to determine the initial user preferences. Based on the data gathered, clients collaborate closely with the designer during the design stage to ensure their basic needs are met. Furthermore, before interacting with the mobile application, the volunteers demonstrated how the prototype works. Finally, all of the discovered bugs were worked out iteratively. The driver’s test it, and then they get together to discuss what worked and what did not before the final product is released.

(ii) Road Mapping

A software was created and used to map road signs, coordinates, and distances accurately. By modifying the location class used in this study, the recorder app was obtained. The application was created using the public class location manager from the study. This class provides access to the system location service and enables the mobile application to receive periodic device updates. Using the location change method, this class was configured to return coordinates in the 0-10-meter range with an accuracy of a user radius of less than 5 meters. After setting and calculating, the mobile application saves coordinates. These settings enabled the researcher to carefully record the coordinates of the road signs. The coordinates of a specific location were recorded, so that the coordinates of the road signs from Moshi to Arusha were properly registered. These data were then stored in the proposed JSON database.

(iii) System Design

The system was built on the Android Studio IDE using the Java programming language. As described in the section below, the developed system has two main modules: vehicle navigation map and vehicle speed information modules.

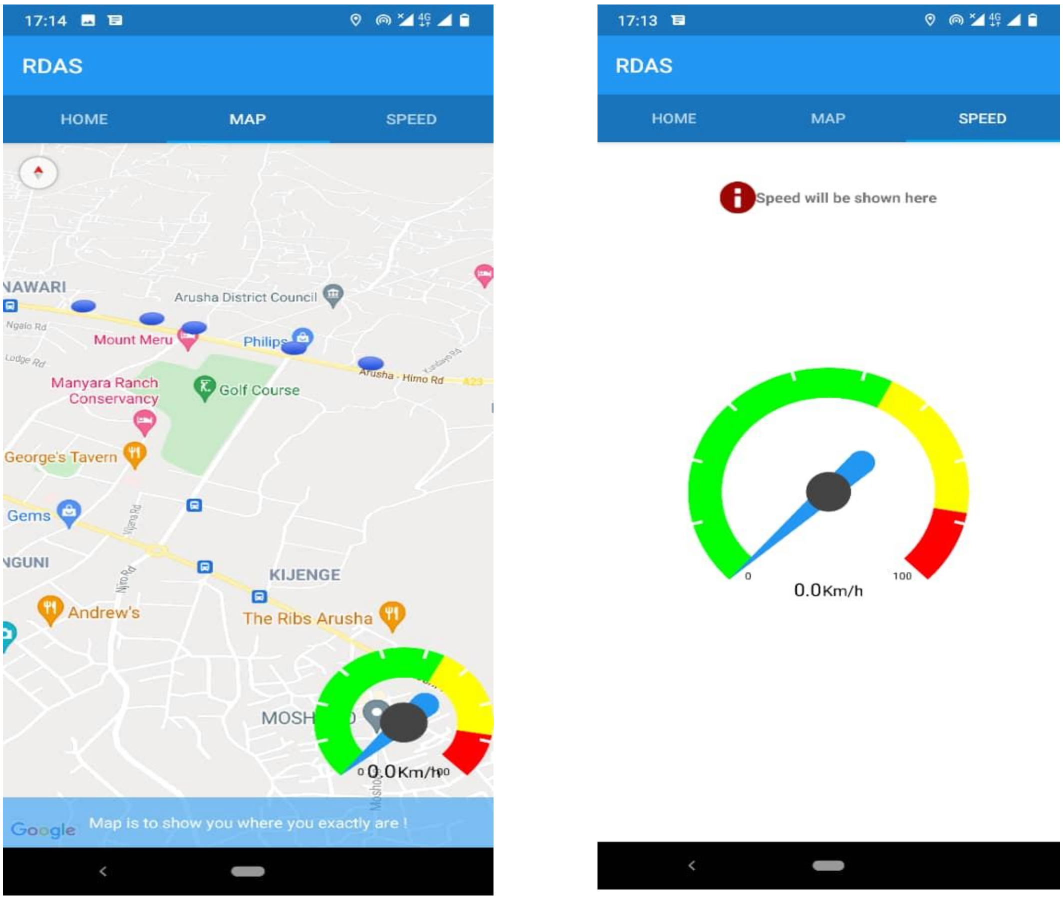
Map Module

The Map module, as shown in Fig. 3 (a), is the system's main module. This module is based on a GPS service, which allows a background service to track user navigation via an inbuilt GPS sensor. This sensor sends a location update to the system, which aids in calculating the distance between the vehicle and the road signs. Additionally, within this module, drivers can see the position of the vehicle, the position of the road signs ahead, hear the voice alert, and see a picture of the alert ahead on the released alert.

Furthermore, this module includes a small map screen that displays the current speed in kilometers per hour. This module assists drivers to stay aware by providing real-time information and improving vehicle safety and driving performance.

Speed Module

The Speed module displays the vehicle's current speed as tracking communicates with GPS satellites in the background, as shown in Fig. 3 (b). When a driver accelerates, decelerates, or stops the vehicle, this module displays speed information. This module also includes a toggle button for setting the speed limit alert.



(a) (b)

Figure 3: (a) Map module; (b) Speed module

Architectural Design

Figure 4 depicts the proposed system architecture design. The system is made up of a mobile app, a database server, a satellite, and road signs. The proposed study is developed with the help of an Android application. The collected road sign position (coordinates location) is properly saved in an integrated offline database known as JSON. The use of an offline database helps to reduce performance latency. This critical information will be provided to drivers in a sufficient proposed range of 250 meters. Furthermore, it aids in the reduction of bandwidth usage and the correct resolving the network coverage problems. Finally, the highway posts are determined by JSON using satellite and GPS data.

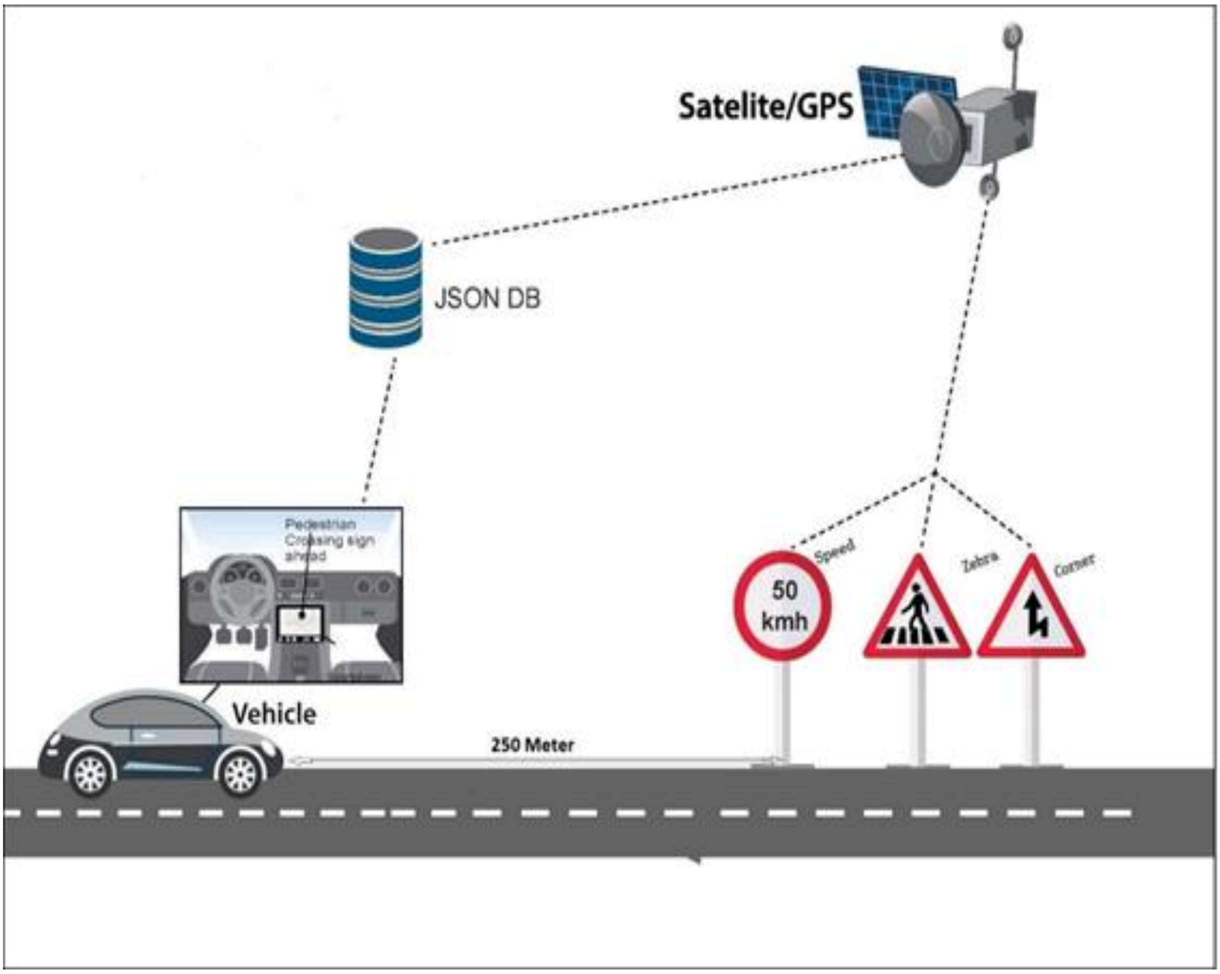


Figure 4: Architectural design

Use case diagram

The use case diagram, as shown in Fig. 5, is used to describe how a user interacts with the system. The system has two types of users: system administrator who is a LATRA personnel to monitor the system and drivers as described in Table 1 and Table 2, respectively.

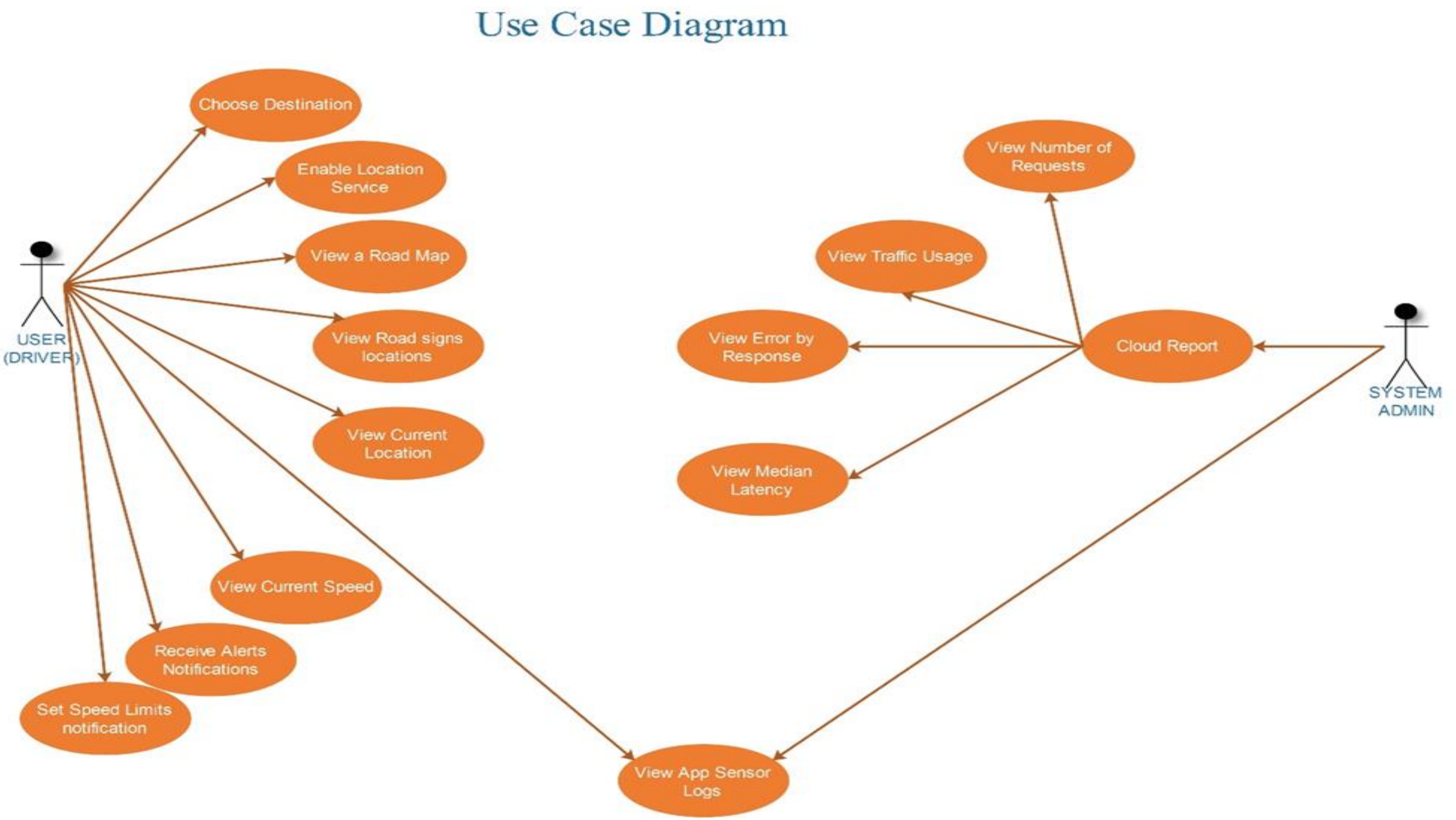


Figure 5: **Use case diagram**

Table 1: Description of administrator use cases

Use case	Description	Actor
View app sensor logs	The administrator can view the GPS sensor logs such as distance, accuracy and alert released	Administrator
Cloud report	The administrator can view cloud metric report such as number of requests, traffic usage, errors reported, latency	Administrator
View number of requests	Administrator can view number of API requests made by users	Administrator
View traffic usage	Administrator can be able to view daily, monthly traffic usage by users	Administrator
View error by response	Administrator can be able to view error reported by response	Administrator
View median latency	Administrator can be able to view if application is experience high latency	Administrator

Table 2: Description of drivers use cases

Use case	Description	Actor
Choose destination	User can be able to select the destination route i.e., either it is from Arusha to Moshi or Moshi to Arusha route	Driver
Enable location	User can be able to allow access to location service	Driver
View a roadmap	User can view a road map. Moreover, user can perform events such as zoom in-out and touch	Driver
View road signs	User can view locations where road signs were spotted	Driver
View current location	User can view the current location as well as navigation when moving from one position to another	Driver
View current speed	User can view the current speed when accelerating or decelerating from one position to another	Driver
Receive alerts	User can receive both image and voice alert when the vehicle is approaching to the road signs	Driver
Set speed limits alerts	User can set speed limit alert	Driver

Data Flow Diagram

- **How the System Works in Front-End**

This system's front-end workflow is depicted in Fig. 6. The system can be operated by the user by carrying out the tasks outlined in a flowchart. The user must correctly install Application Apk and launch the application by opening the icon on an Android phone. When launching an application, the user must specify the destination address. After correctly selecting the desired destination, a welcome screen will appear on the mobile screen. The user must grant GPS access to the device's location settings. Following the welcome screen, the application's default screen is a home screen where the user must press the start button to allow GPS services and background tracking. In addition, this screen has a toggle option to set a speed limit alert.

A Map is the second screen of an application. This screen displays navigation, speed, and the mapped position of the road signs. Google Application Interfaces (APIs) are used to display a Google Map. This system employs an offline JSON database to store longitude and latitude, reliable road post information, and alerts to be issued in relation to the road post. The background tracking will constantly communicate with GPS satellites to provide the vehicle's current location and speed. The final screen depicts speed. This screen will only show the vehicle's current speed because tracking will constantly communicate with GPS satellites in the background.

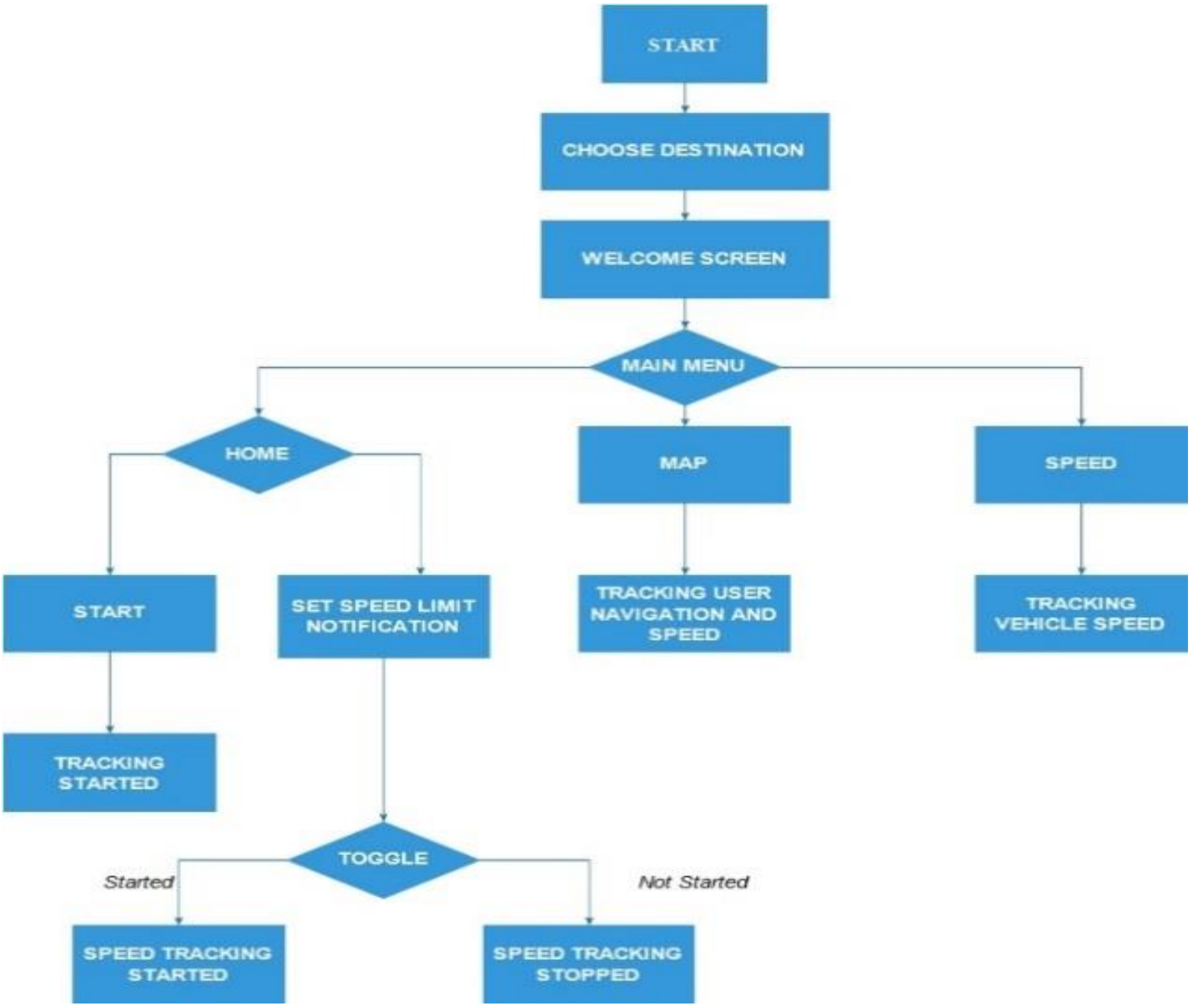


Figure 6: Front-end data flow

- **How Alert is Issued in Back-End**

Figure 7 depicts the proposed work back-end data-flow. The system in-built database contains a JSON data exchange format. The file string contains arrays of coordinates in decimal degrees format. Furthermore, JSON file string contains information about road signs, their geometric positions, and the type of alert to be issued.

Upon pressing a start button, the system starts from the main activity. Within this activity, a background tracking activity continuously communicates with GPS satellites and provides the vehicle's current location. Following the start of the background service, the tracking activity begins, carefully evaluating the accuracy of the coordinates broadcasted. This technique affects the results of location estimates and distance calculations during navigation. The study begins by testing the system with a narrow range of threshold values for accuracy and sufficient distance. When the coordinates are released, our first condition is to see if the accuracy within a user radius is less than 10 meters. The study considers any accuracy that exceeds that limit to be erroneous. On the other hand, if these conditions are met, the function uses the haversine method to calculate distance. Using a For-loop, a code is repeatedly executed each time with different values. Haversine will immediately begin calculating the distance in meters between the current vehicle position and an upcoming road sign stored in the JSON file. When the sufficient distance to waypoints is within 250 meters, a voice alert will be conveyed to the driver. On the other hand, if these two conditions are not met, the system will not notify the driver.

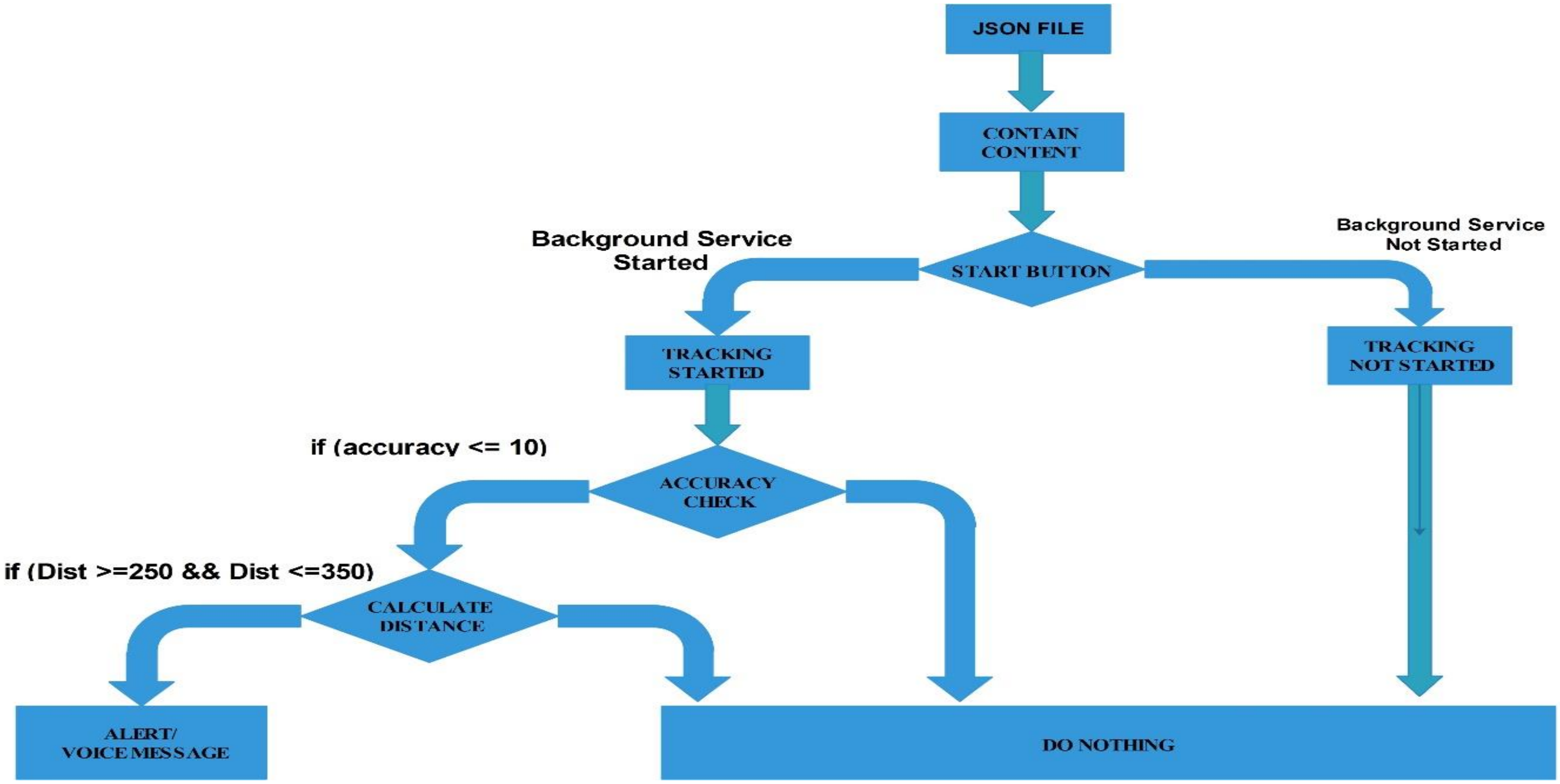


Figure 7: Back-end data flow

(iv) Database Design

JSON Array of Objects

The road signs were stored in a JSON array of objects, as shown in Fig. 8. The array object values are made up of string and number. Furthermore, by using a for loop these values are instantly accessed.

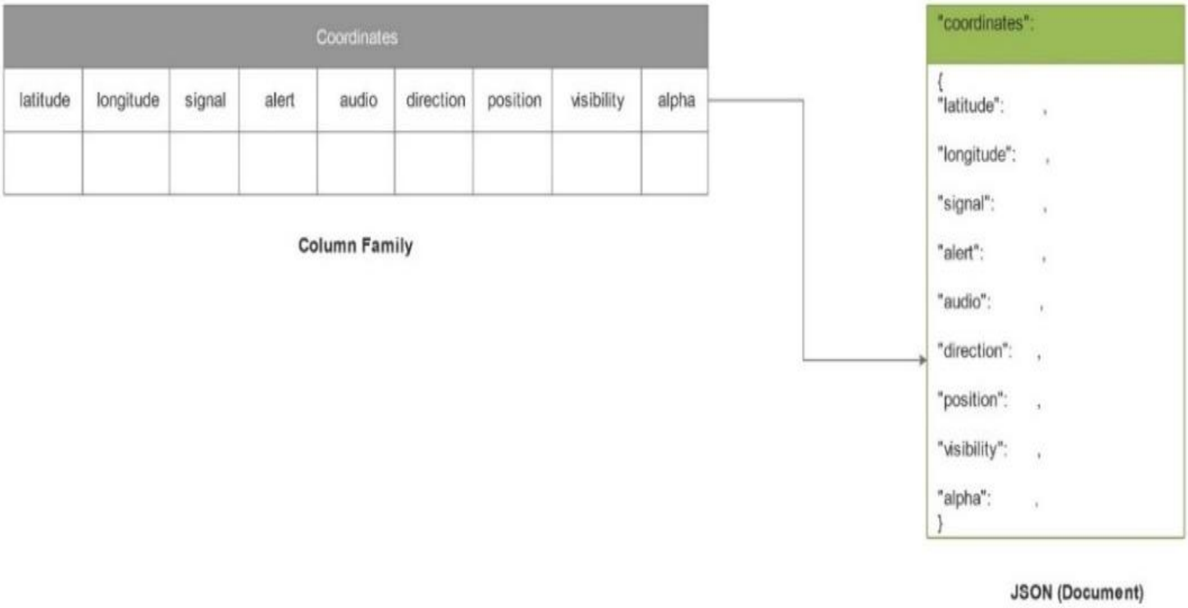


Figure 8: JSON array objects

JSON Database

During the system's development, JSON was used. It correctly presents data in the form of an array and an object in a human-readable data format. As shown in Fig. 9, the JSON array typically consists of nine column lists of longitudes, latitudes, signals, alerts, audio, direction, position, visibility, and alpha. Where longitude and latitude contain the waypoint coordinates. In addition, the signal, alert, and audio columns store the relevant alert. While direction, position, visibility, and alpha store the destination route, road sign names, and visibility.

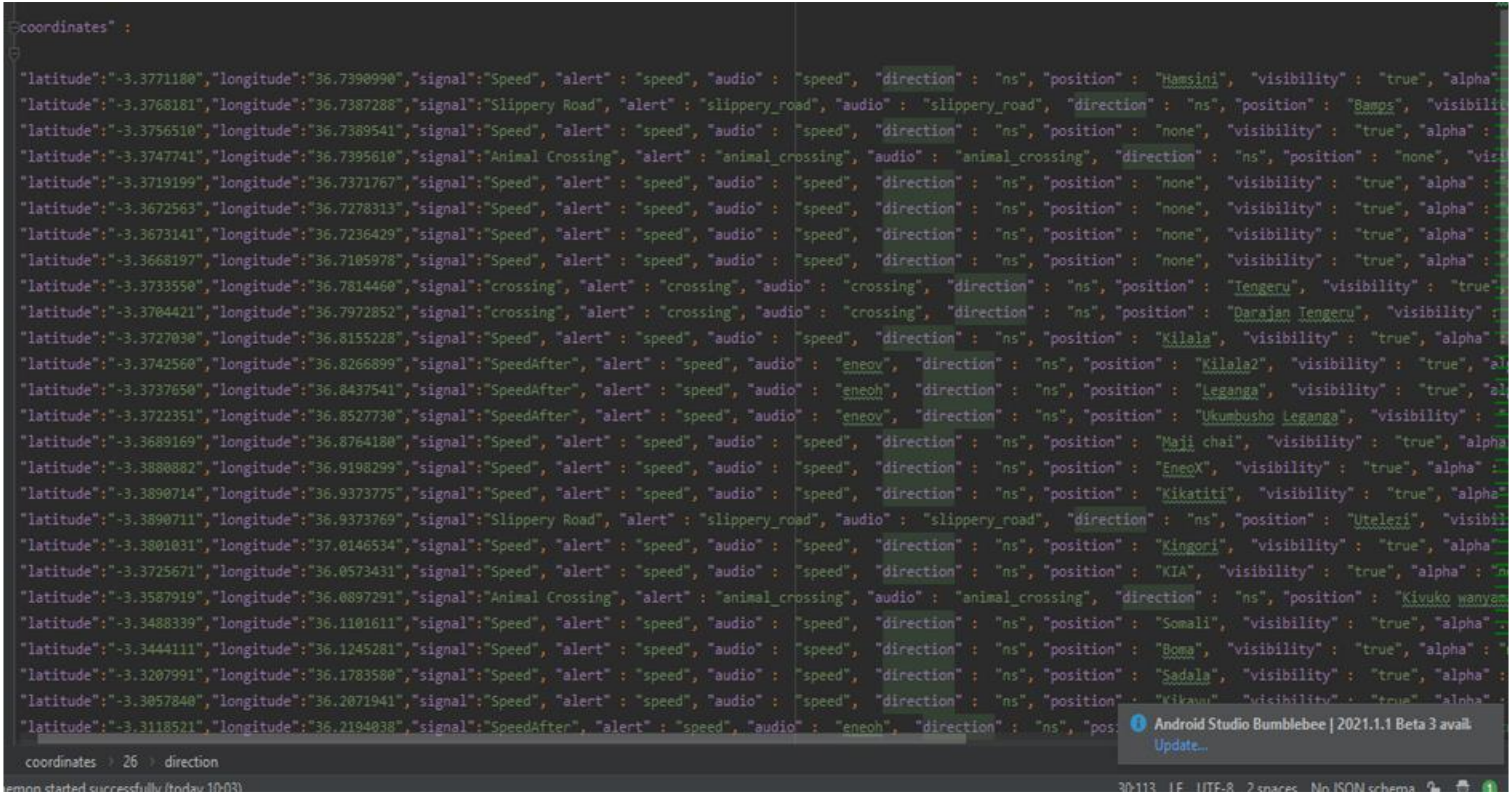


Figure 9: **JSON database**

(v) Tools

Android Studio

Android studios is an Integrated Development Environment (IDE) for developing Google Android applications. The system was properly implemented in this environment because it allows for faster coding and iteration. Furthermore, the tool is a visual layout editor that allows you to build by dragging elements into the editor.

Google Cloud Console

Google Maps is a platform that provides satellite images of streets and roads. The Google Cloud Console is an extremely useful tool for Web Administration UI. It offers information on data analysis metrics such as traffic response, error response, and median latency. To manage the developed system, the mobile application was integrated with this monitoring tool.

Google Map API

The API is a set of communication protocols that communicates with google services. It helps to include a map on our application. In addition, the API key was generated from a console in order to authenticate requests associated with the developed system during runtime. The following APIs were implemented in this study; Software Development Kit (SDK)-Map, stack driver profiler, and Places API.

SDK -Map SDK for Android

The Maps SDK for Android is a useful tool in the Google Cloud Console for including maps in applications. This tool was enabled so that the user could view map navigation on their Android device. This tool also assists in determining the number of direct requests made to the developed system, as well as user gestures such as zooming, dragging, and clicking.

JSON (Data Format and Data Structure)

Java Script Object Notation (JSON) is a human-readable and machine-readable open data interchange format. It is independent of any programming language and is used as a standard API output in a wide range of applications (Amazon Web Services, 2021). The JSON properly presents data in array and object formats. The JSON array contains a list of coordinates and an alert corresponding to the post destination.

3.9.4 System Application Development

The system was developed with the Android Studio IDE, and the application runs on a standard Android smartphone. The geometric position of the road sign was collected and saved in the application database. After every 3-5 meters, the fastest interval of 1-10 nanoseconds was set, and the location priority request was set to high. In a for-loop, the haversine function calculates the distance between the current navigation point and the nearest road signs stored in the JSON array. Furthermore, the system navigation location's accuracy within a user radius returns geolocations of less than 10 meters. The alert (voice and road sign image) is generated by determining the closest point from a set of predetermined points. To reach a point when the alert was set to be released by function, the closest distance was set to be within a range of 250 meters. If this condition is met, the driver should take the necessary actions, such as reducing speed by applying brakes and driving attentively.

To display the map with road signs, the system makes proper use of Google Maps APIs. Furthermore, the proposed work includes a screen that displays the driver's current moving speed as well as an option button for setting the speed limit alert.

The system can also provide critical information in any of the network's drops down to the Edge network to improve real-time performance. The use of an offline database aids in the reduction of bandwidth usage and the correct resolution of the network coverage problem. This database will not require network connectivity (mobile data) to function properly. Rather, it stores information about road signs locally.

Furthermore, the study followed the Confidentiality, Integrity, and Availability (CIA) triad to improve system security. This is a model for guiding information security policies. Android is more vulnerable to data breaches and malware attacks (Garg & Baliyan, 2021). Access to information must be restricted to prevent unauthorized data sharing. By doing so, the mobile application is secured by limiting access to the API key. The method includes the application package as well as the SHA-1 signing certificate fingerprint. The key was generated and added to the Manifest file of the application. Only the requests made with the API key were authenticate each user of the system.

Finally, the framework Application Package (Apk) was generated by Android Studio and installed on the drivers' smartphones. The application was built using the package com.rdas.rdas. The applications generate an Apk file that is 11MB in size:

(i) Proposed Distance

The data in Fig. 10 show the mathematical relationship between the driver's average linear speed and the time it takes to reach a waypoint when an alert is first received. When alerts are issued, the spotted distance is 250 meters. This is a reasonable warning distance for drivers to respond to alerts. The audio alert can last up to 0.05 seconds. For example, the driver is driving at an average linear speed of 60 km/h and is 250 meters away from a road sign. The vehicle will only take 15 seconds to come across a symbol. In our opinion, the application audio alert with a maximum length of 0.05 seconds will be issued within 15 seconds prior to the sign.

The Formula for Average Linear Speed

$$Linear\ Speed \equiv \ {}^{\Delta Distance}/_{\Delta Time\ taken} \tag{4}$$

Given above Equation 4 is the average linear speed formula. It is the measure of the change in linear speed with respect to time over a given time period.

Where:

ΔDistance represents the change in distance.
ΔTime represents the time taken by the vehicle to traverse the given distance.

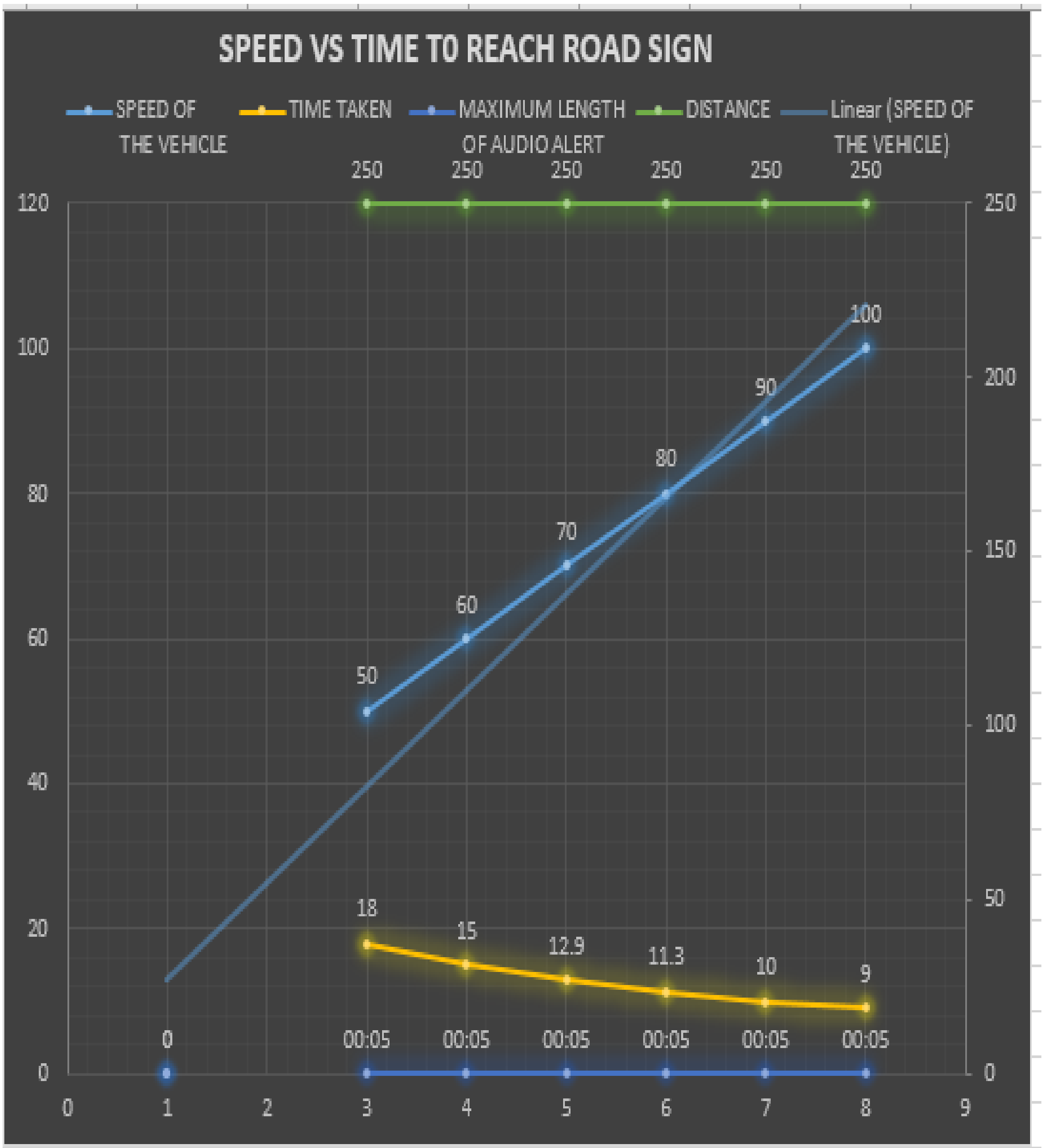


Figure 10: **Average vehicle linear speed Vs Time taken when alert is first received**

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Results

This chapter presents the study results and discussion of the key findings.

4.1.1 Participants' Characteristics

This study included one LATRA Regional Manager, one Arusha Regional Police Officer, and 55 frequent drivers who travel the Moshi-Arusha route. Out of the 55 drivers, 25 were public bus drivers, 20 were public mini-bus drivers, and 10 were private drivers. Table 3 shows the age and highest education level distribution of public bus drivers.

Table 3: Age and education level distribution of public bus drivers

Characteristic	Frequency
Age group	
28-32	10
33-37	6
38-42	5
43-47	3
48-50	1
Highest education level	
Primary	16
Secondary	6
Post-Secondary	3

The ages ranged from 28 to 50 years, most being in the 28 – 32 years age group. The drivers were in in the prime working age. It is important that this age group be safeguarded from road traffic accidents because it contributes significantly to the national economy. Majority of the drivers had basic education, which was sufficient to enable them to use a mobile application.

4.1.2 Requirements of the System

The first objective of this research was to identify user and system requirements. This section presents the findings of user and system requirements found during the study. These requirements have been classified into two groups; functional and non-functional. The functional requirements were found during discussion with participants, the non-functional requirements were identified by the researcher after determining the functional requirements.

(i) Functional Requirements

The behaviour of the system is defined by functional requirements. This is what the system should do if it is working properly. According to the findings, a mobile application should meet the functional requirements outlined in Table 4 and Table 5.

Table 4: Functional requirements for drivers

Requirement category	Requirement description	System actor
Set speed limit alert	Users should set a speed limit alert	Drivers
Map visibility	System should allow user to view the map	Drivers
Road signs	The system should allow the user to see the road signs	Drivers
Receive alerts	The system should provide alerts timely	Drivers
Speed meter	The system should show the speed of the vehicle	Drivers

Table 5: Functional requirements for system administrator

Requirement category	Requirement description	System actor
Logs	System should show the sensor logs	Administrator
View number of requests	System should be able to view number of APIs requests made by users	Administrator
View traffic usage	System should be able to view daily, weekly, and monthly application traffic usage in web UI	Administrator
View error by response	System should view error reported by application response in web UI	Administrator

(ii) The Non-Functional Requirements

The non-functional requirements define what the system should be able to do. They describe the system's quality properties. According to the findings, a mobile application should meet the non-functional requirements listed in Table 6.

Table 6: Non-functional requirements

Requirement category	Requirement description
Security	The system should authenticate users
Response time	The system should respond quickly upon user's request
Reliability	The system should perform the intended tasks for a specific time
Usability	The system should be easy to install and simple to use
Scalability	The system should be able to add new features
Robustness	The system should be able to function under different circumstance of disturbance
Operating system	The system should be platform independent i.e., android OS
Portability	The system should be able to operate on android smart devices such as Android car kit TV, android smartphones, android tablets
Availability	The system should be available all the time when required
Performance	The system should be able to perform well under different conditions
Accessibility	System should be accessible by many users

4.1.3 Focus Group Discussion Results

Experienced public bus drivers were asked about the types of road signs they are familiar with and those found on the Arusha-Moshi highway. Furthermore, they were questioned about highway traffic rule violations and their expectations of the road sign alert system that was to be designed. This useful information was critical in guiding the research on the specific type of alerts to be included in the system. The majority of drivers were aware of the following road signs: 50 km/h speed limits, pedestrian crossings, speed humps, speed bumps, strong winds, sharp corners, and no vehicle overtaking. According to the majority of drivers, the road signs found on that highway were: 50 km/h speed limits, pedestrian crossings, speed humps and bumps, and no overtaking.

There was consensus by the drivers on traffic rules violations. On several occasions, all drivers had been fined for breaking traffic laws while driving along the Arusha-Moshi Highway. The primary reasons for the fine were exceeding the 50 km/h speed limit and failing to stop at a pedestrian crossing.

Regarding the drivers' perspectives on the system under development, all agreed that the system would be useful not only for avoiding traffic fines, but also for preventing traffic accidents.

4.1.4 Interview Results

The interviews with a spokesperson from LATRA and the Traffic Police Department, revealed that traffic accidents are a major issue in Tanzania. The most common causes of traffic accidents cited are driver factors, followed by road factors. Failure to carefully observe road signs and driving under the influence of alcohol were among the driver factors. Poor road condition as a result of poor design or a lack of periodic maintenance was the most significant road factor. The initiative to design a road sign alert system was hailed by the two spokespersons. They asserted that the system would force drivers to follow traffic laws, thereby preventing accidents. As a result, drivers and passengers' lives will be saved. Furthermore, once the system has been proven to be effective, it could be used by public and private drivers.

4.1.5 Developed System

As shown in Fig. 11 and 12, the system is designed and tested on Android smartphones, Android car multimedia car players, and Android tablets. The system has an appealing user interface for both devices, and it responds gracefully to different screen sizes and orientations. A successful installation of the mobile application is as simple as opening the APK and following the basic installation steps. Finally, when only using an application, the user must grant access to storage and location.

(i) Route Selection

The user is required to open an application on his android smartphone. After opening, the route selection will prompt. The driver is carefully needed to choose their intended destination, as shown in Fig. 11 (c).

(ii) Enable Location Tracking

The user is required to allow location access by turning ON location to allow location tracking. A button to start GPS is found on the home screen. This privileged access will allow GPS to provide a real-time coordinate to the mobile devices, as shown in Fig. 11 (d).

(iii) Set Alert on Speed Limits

A set speed alert is found on the home screen, as shown in Fig. 11 (e). The user has an option toggle to set a speed limit alert. The buzzer prompts when a speed limit exceeds.

(iv) Road Map

A map screen, as shown in Fig. 11 (f), displays maps to mobile users. This interface displays a map of the locations of road signs. Depending on the route chosen, these visible signs are represented by blue or green small circles. The blue circles will appear only after the user has carefully selected the intended Arusha-Moshi destination. When the user carefully selects the intended Moshi-Arusha destination, the green circles will be displaced. To determine the number of requests, the map has been properly integrated with Google Maps API. This map also shows when the user moves from one location to another.

(v) Speed

The speed screen displays the speed of the current user. As shown in Fig. 12 (g), this speedometer comes in three different colours: green, yellow, and red. The first colour is green, which represents a ready-to-go signal. All speeds less than 80 km/h will be displayed in this colour. Furthermore, this colour indicates that the driver is traveling at the government-recommended speed for public vehicles.

The second colour is yellow, which represents a warning signal and will be displayed for all speeds greater than 80 km/h but less than 120 km/h. This colour gives the impression that you are driving at a faster speed. Rather than increasing speed, the driver signalled a decision to slow down.

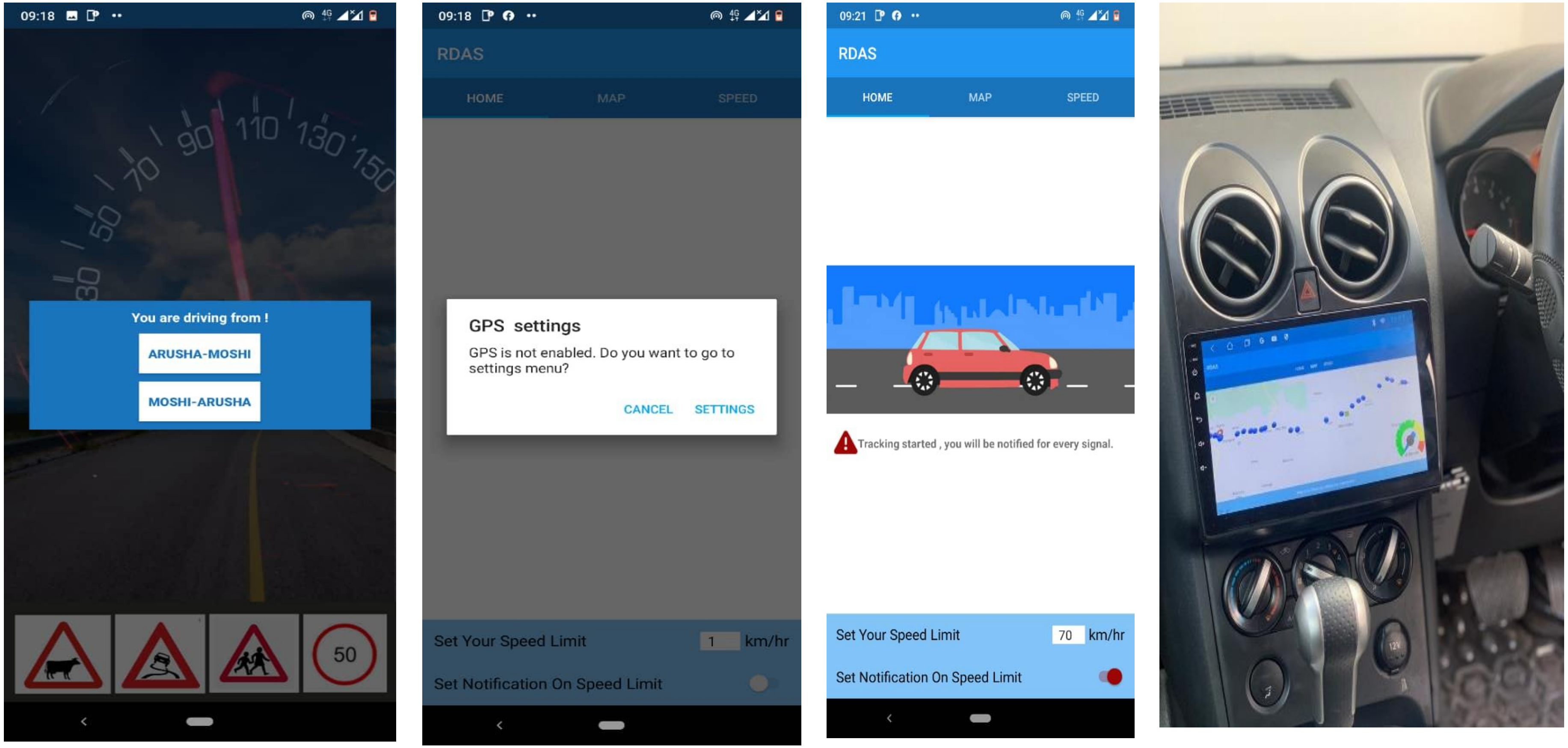
Finally, the red colour is the most noticeable. In our mobile app, the colour represents a danger signal, which makes sense when a driver is traveling at speeds greater than 120 km/h.

(vi) Alerts

This is an important audio message, as well as the image shown to the drivers. The voice is provided by a female voice agent. The female voice was more familiar to the participants because it was widely used in smart devices and navigation systems. In addition, in a noisy environment, the female voice is easier to hear than the male voice. When users are with a range of 250 meters prior to the road signs, the information is instantly conveyed to them. Furthermore, when the alert is issued, the image of the road sign will be displayed, as shown in Fig. 12 (h).

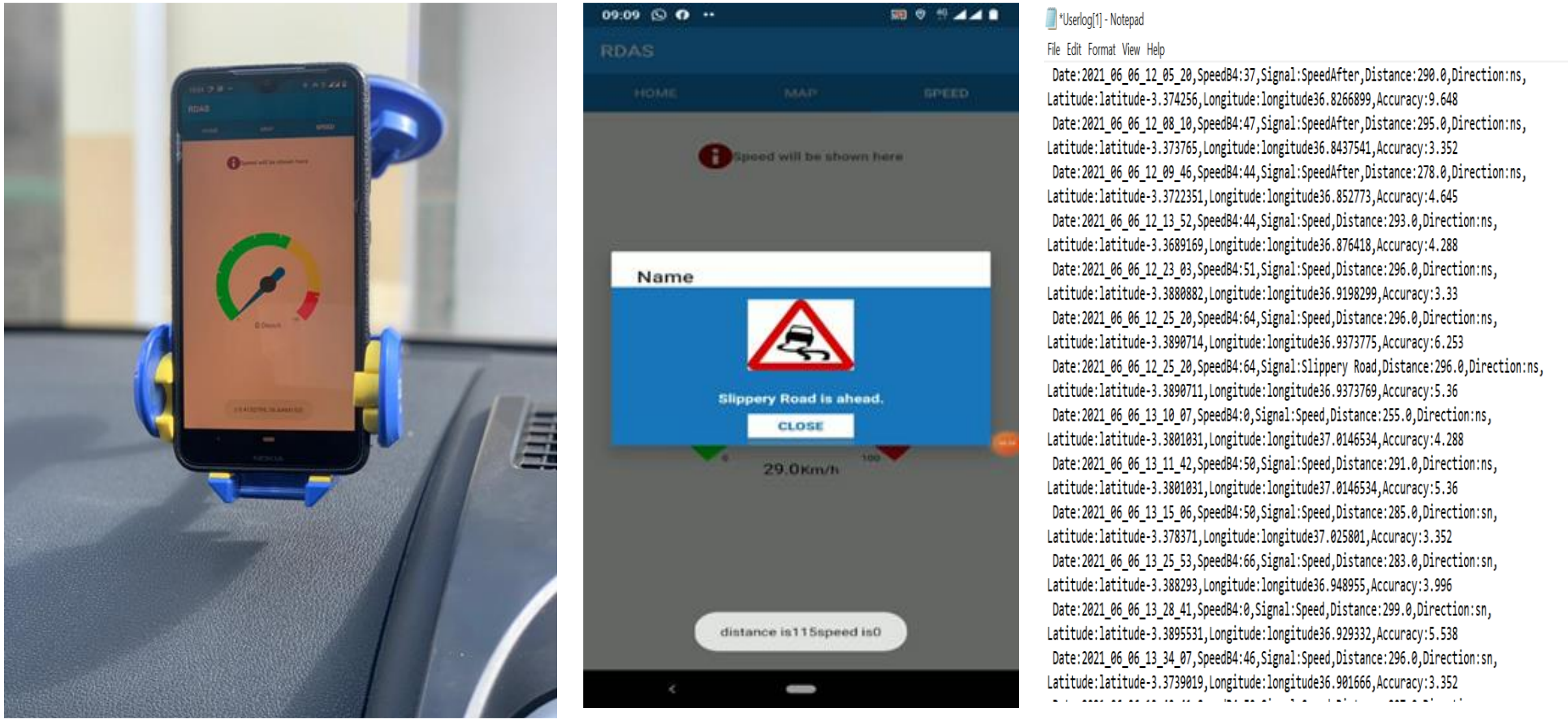
(vii) Sensor Log

As shown in Fig. 12 (i), this is a log file that contains a log which is written when an alert is instantly released. The logs file contains important parameters measured to monitor the driver's performance when using a mobile application such as the distance over which alerts were issued at a distance of 250 meters, specific coordinates when alerts were issued, and the accuracy of the specific coordinates to be within a user radius of geolocations less than 10 meters. A file also contains a specific type of alert released, date, and time as tangible proof that the appropriate alert was released.



(c) (d) (e) (f)

Figure 11: (c) Destination (d) Enable access (e) Speed alert (f) Map screen



(g) (h) (i)

Figure 12: (g) Speed screen (h) Image alert (i) Sensor logs

4.1.6 Web Application System Implementation Results (Google cloud platform)

To carefully monitor timely user traffic with an application, a web application tool Google cloud platform was properly integrated with our mobile application. Furthermore, it offers an important tool and API service for carefully managing applications.

(i) Cloud Dashboard (Google cloud platform console)

The system cloud dashboard provides a convenient summary of cloud reports from mobile users to the system administrator. As shown in Fig. 13, the dashboard provides a high-level view of the state of mobile applications. For example, the number of requests, traffic responses, and latency. Additionally, errors reported by the cloud can be indicated.

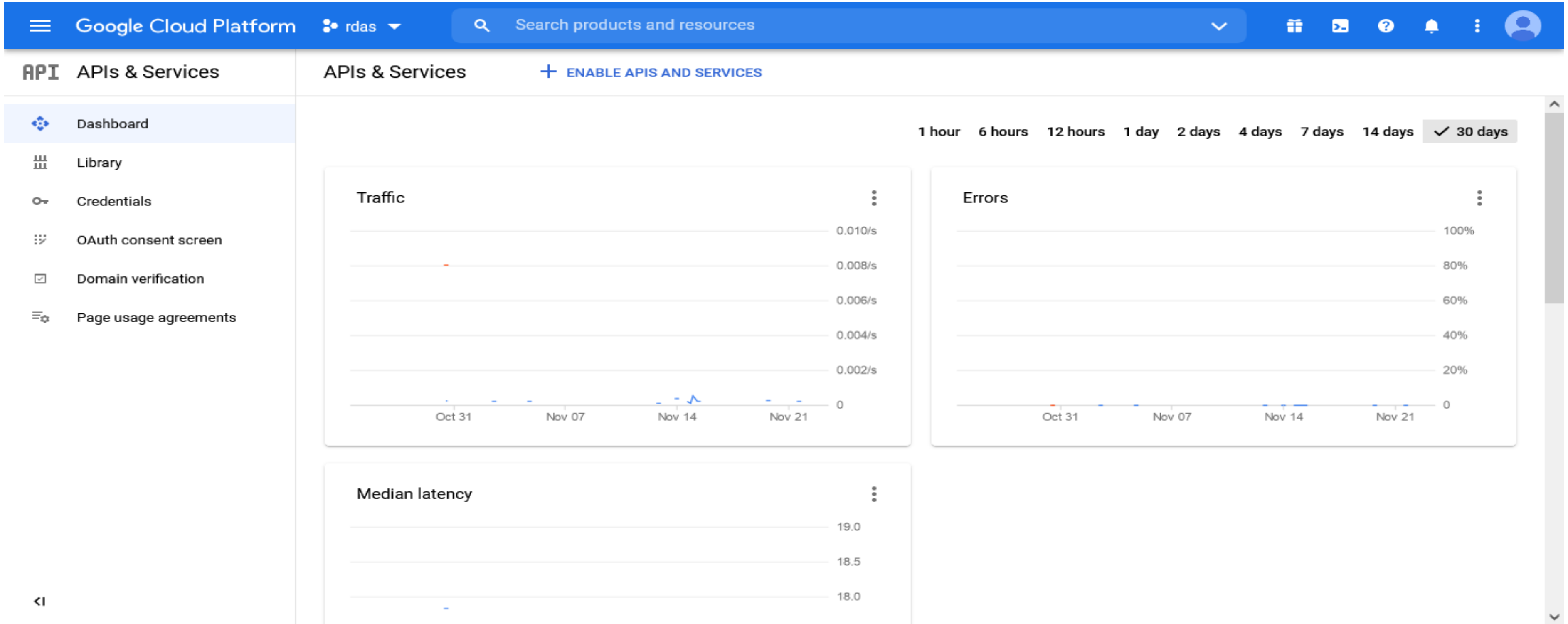


Figure 13: Cloud dashboard

4.1.7 Developed System Validation

The system validation test was carried out to check the compliance of the system elements with its purpose and functions. Furthermore, the system testing, system performance testing was performed to uncover the vulnerability of the system and the real-time system resources utilization.

(i) System Validation

The functional test was carried out to test the system's features that were created to meet the needs of the test. This was accomplished by taking each test case through its paces, as shown in Table 7 various Validation Phases in the V-Model test results.

Table 7: Validation guide

Requirement	Validation test data	Status
Route selection	Clickable button Other part	Passed
Access to use location service	Enabled GPS/location Disabled GPS/location	Passed
Map visibility	With location ON With Location OFF	Passed
Road signs visibility	With Internet ON With Internet OFF	Passed
Audible alerts	When the distance is less than 250 meters When the distance is greater than 350 meters	Passed
Image alerts	When the distance is less than 250 meters When the distance is greater than 350 meters	Passed
Speed limit set	At a speed greater than specified speed At a speed less than specified speed	Passed

From Table 7, it can be seen that the developed system had all intended requirements

(ii) System Testing

System testing is a phase of the Software Development Life Cycle (SDLC) that checks whether the actual software meets the intended expectations and is defect-free. The goal was to identify the flaws in the software. The developed study was tested using the V-Model. Each development stage below was tested sequentially and finally the software products met user expectations.

Unit Testing

Unit testing is a type of low-level testing that aids in the detection of bugs during the coding process. During unit testing, individual modules were tested to ensure that they all function in accordance with user requirements. The results of the tests are shown in Table 8.

Table 8: Unit testing

Unit	Test performed	Status
Route selection	Test whether route is selected	Passed
Access to location	Test whether app requires access to location	Passed
Access to storage	Test whether app require access to storage	Passed
Map visibility	Test whether map is visible to the app	Passed
Road signs visibility	Test whether road signs are placed	Passed
Speed limit set	Test whether the speed limit is configured	Passed

From Table 8, it can be seen that all tested modules were found to function in accordance with user requirements.

Integration Testing

The integration test was carried out to ensure that the system modules communicated with each other. Two modules that are dependent were integrated each other during integration testing. The results of the tests are shown in Table 9.

Table 9: Integration testing

Integrated module	Test performed	Status
Map module	Test the combination modules for road signs allocation	Passed
	Test whether user can navigate from one location to another	Passed
	Test whether requests are associated to users	Passed
Speed module	Test whether application determine speed	Passed
	Test the speed limit alert	Passed

From Table 9, it can be seen that integration testing was successful

Entire System Testing

Entire system testing is a type of testing which involves testing the system’s product functionality. It involves testing the entire system. The hardware and software issues were uncovered during this test. The test results are shown in Table 10, which indicate that the testing was successful.

Table 10: Entire system testing

Test case	Test performed	Status
Distance determination	Test whether the app determines distance	Passed
Alert release	Test whether app provides alerts	Passed
Speed violation release	Test whether alert provides alerts when speed limit is violated	Passed
Accuracy determination	Test whether app determines accuracy of the coordinates	Passed
Coordinates determination	Test whether app releases coordinates when user navigates	Passed
Sensor logs file-written	Test whether app records a log when alert is released	Passed
Traffic response	Test whether app generates traffics to the Google cloud dashboard	Passed

4.1.8 System Performance Testing

The Android profiler is a useful tool in Android studios that provides real-time application information such as CPU usage, efficient memory allocation, active network, and battery. Optimizing apps resources utilization secures diverse points of interest like conserving the device battery life.

The mobile application was deployed and tested on different mobile devices vendors. Some mobile users are running older versions of an operating system while other users have updated to the latest and greatest version. For the experiment purpose a Nokia 7.2 was used since it was running with a new version of Android operating system and a test being able to track and fix bugs with a new release of android O.S.

The experiment was done to determine the resources used by a mobile application. This valuable information is used to carefully optimize the performance of the potential application by identifying outstanding performance related issues. The implemented system was installed on the smartphone: (Nokia 7.2, Android 10 API Level 29, Octa-core (4x2.2 GHz), 6 GB RAM, Li-Po 3500 mAh non-removable battery, IPS LCD 6.3 inches). The car was driven along a predetermined route while a compatible phone was connected to a PC that can visually track resources. Meanwhile, the raw data of resource utilization readings were being monitored in real time.

The mobile application was carefully evaluated based on two activities: background and foreground. The ultimate goal was to efficiently visualize the instant energy consumption of the potential application when running on a smartphone. During the time when the system is running, the app was visually inspected what is going on in the background. The profiler reveals what happens during the application's successful execution in the foreground and background. In both cases, the android profiler typically displays the graphs of energy utilization from using the application. The timelines listed below are included in the resource profile.

(i) Event timeline

This timeline depicts activity in the running application as it progresses through various states. These states include user interaction with an app, such as screen rotation and screen touching events. The timeline can also display activities while an application is running in the foreground or background.

(ii) CPU timeline

This timeline displays the running application's real-time CPU usage in terms of total available CPU time and the number of threads. The timeline depicts usage as a percentage. You can also carefully compare your application's usage against other system processes.

(iii) Thread activity timeline

This timeline includes exclusive lists of all threads that typically belong to the application process. It shows active threads, waiting, and stopping for I/O operation.

Foreground Activities Results

Figure 14 shows the results of the foreground activity measurements on the Android device. The results show a significant percentage of CPU, Memory and Energy usage as follows.

(iv) CPU usage

The CPU usage profile has the distinct advantage of displaying how specific functions consume CPU percentage time. The process gently assists in properly understanding how the mobile application is executed and how valuable resources are allocated correctly. The usage was carefully measured using an Android profiler tool, as shown in Fig. 14, and the following results were obtained. When carefully testing a mobile device, the application CPU usage contributes to 12% of the total system CPU usage when the system is gently running without any touch event activity.

(v) Memory Usage

A memory profile in the Android profiler is used correctly to identify the memory usage of applications. The critical component displays a real-time utilization of the running app, which aids in the detection of application memory leaks, freezing, and crashing. The memory utilization was calculated as shown in Fig. 14. The following are the results of a profiler sampling memory on a regular basis. The application uses a total of 261 MB of memory, with graphics taking account for a significant chunk of that usage.

(vi) Energy Usage

The energy profile in Android Profiler was used correctly to identify the energy usage of applications. It employs a model that estimates the amount of energy consumed by each resource. The CPU, network radio, and GPS sensors are all carefully monitored by the model.

Finally, it provides a variety of points of interest, such as searching for issues related to unnecessary energy usage. The application was carefully examined based on energy utilization activities, which cause battery drain and excess power consumption in order to stay awake.

The usage was measured as shown in Fig. 14. The experiment test came up with the following results: the application contributes a light amount of energy. Furthermore, system events such as frequent location requests have contributed to significant energy consumption.

Figure 14: **Foreground activities resources utilization**

Background Activities Results

Figure 15 depicts the results of background activity measurements on Android devices. The mobile application was minimized and allowed to run in the background in order to carefully evaluate activities. The results show that the CPU usage drops by up to 1%. In addition, the energy profile is at low energy consumption. Furthermore, the application memory usage was reduced to 227 MB of memory, the system killed some processes that consumed an insufficient amount of RAM, and the main activity was immediately terminated. Furthermore, the most recent data about the navigation screen could not be refreshed in some rare cases, and the application was simply required to restart. On the basis of the results of the experiments, we can conclude that running a mobile application in the background consumes less energy for each resource on a mobile device. However, the application cannot provide better performance in terms of providing drivers with the most recent navigation updates and road sign alerts.

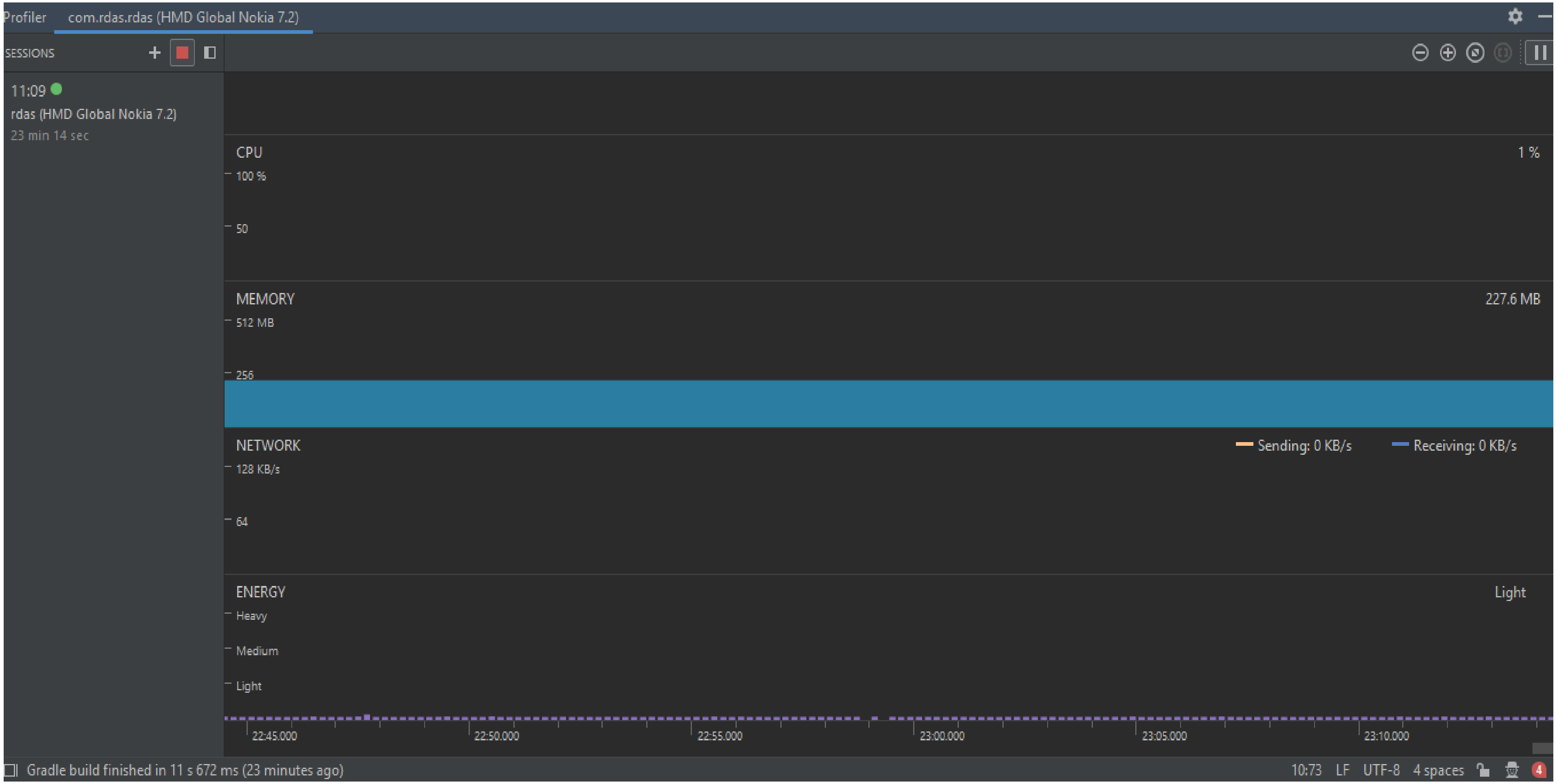


Figure 15: Background activities resources utilization

4.1.9 Evaluation

The performance output of a system on mobile devices varies depending on its practical use. The evaluation was carried out in this experiment when the mobile application was running on foregrounds and backgrounds. This experiment was carried out solely to demonstrate the importance of these fundamental concepts. The experiment begins with foreground services. The foreground activities were carefully evaluated in this experiment. Finally, the background services experiment was carried out. Background activities were critically evaluated and minimized during the mobile application in this experiment to carefully observe the actions.

On the basis of results of the testing, the running an application in the foreground results in better performance in providing appropriate alerts to mobile users. The system runs at a high frequency, and appropriate alerts are released gradually over a long period of time at a safe distance of 250 meters. This system may have a limitation that affects resources such as energy, memory, and CPU on any mobile device's power consumption. When a mobile application is minimized, it produces better resource performance indicators than when it is in the foreground.

However, in some cases, the most recent data about the navigation screen could not be refreshed, necessitating a restart of the application.

(i) Users’ Perception on the Developed System

The system was evaluated in a real-drive environment. After properly using the mobile application, user’s perceptions were measured. The Technology Acceptance Model was used for testing user’s perception hypotheses. The results are shown in Table 11.

Table 11: Users perceptions on developed system

Constructs	Items	Question	Frequency response				
			5	**4**	**3**	**2**	**1**
Perceived Usefulness (PU)	**PU1**	The mobile app is easy to install, learn and use	32	23	0	0	0
	PU2	The information is useful and could be helpful	39	16	0	0	0
	PU3	The contents and features of the app are meaningful	35	20	0	0	0
Perceived Ease Of Use (PEOU)	**PEOU1**	I will need technical assistance in using the mobile application	0	0	0	14	41
	PEOU2	I faced a challenge while using the system	0	12	13	12	18
	PEOU3	The system can also be used without the use of internet in the areas where networks drop to Edge	23	25	7	0	0
	PEOU4	The mobile app is interactive	33	22	0	0	0
Attitude Toward Using (ATU)	**ATU1**	The road signs alerts given are beneficial to me.	45	10	0	0	0
	ATU2	Alerts were given at an ideal distance for me to take action	48	7	0	0	0
	ATU3	The mobile app helps me to avoid road traffic accidents	44	11	0	0	0

Constructs	Items	Question	Frequency response				
			5	4	3	2	1
Behaviour Use (BU)	**BU1**	Internet connectivity works perfectly with the mobile application	39	16	0	0	0
	BU2	I did not get any compatibility problem with my smartphone	31	24	0	0	0
	BU3	Once the system has been developed for wider use, I would like to use the application	48	7	0	0	0

Hypothesis 1: Perceived Usefulness (PU)

The scale included three items PU1, PU2, and PU3 that measure overall participants Perceived Usefulness of the study. The participants were asked three questions and the results are shown in Table 11. In the item PU1, participants were asked about the easiness of the application installation, learning, and use. Results show that 23 (42%) and 32 (58%) participants agreed and strongly agreed, respectively.

In the item PU2, participants were asked if information generated from the system is useful and could be helpful. Results indicate that 16 (29%) and 39 (71%) participants agreed and strongly agreed, respectively.

In the item PU3, participants were asked if the contents and features of the app are meaningful. The results indicate that 20 (36%) and 35 (64%) participants agreed and strongly agreed, respectively. From the above findings it can be deduced that all 55 participants (100%) found the application to be useful.

Hypothesis 2: Perceived Ease of Use (PEOU)

The perceived ease of use was measured by four items PEOU1, PEOU2, PEOU3, and PEOU4. In item PEOU1, participants were asked if they will need technical assistance while using the mobile application. The results are shown in Fig. 16.

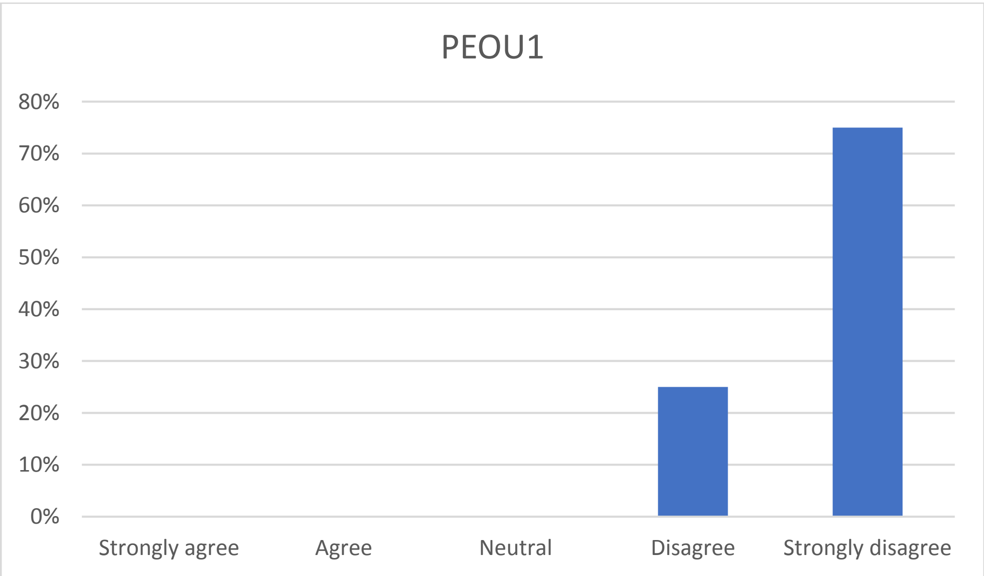


Figure 16: Need of technical assistance

From Fig. 16, it can be seen that all participants disagreed that they will need technical assistance in using the mobile application.

In the item PEOU2, participants were asked if they faced any challenge while using the mobile application. The results are shown in Fig. 17.

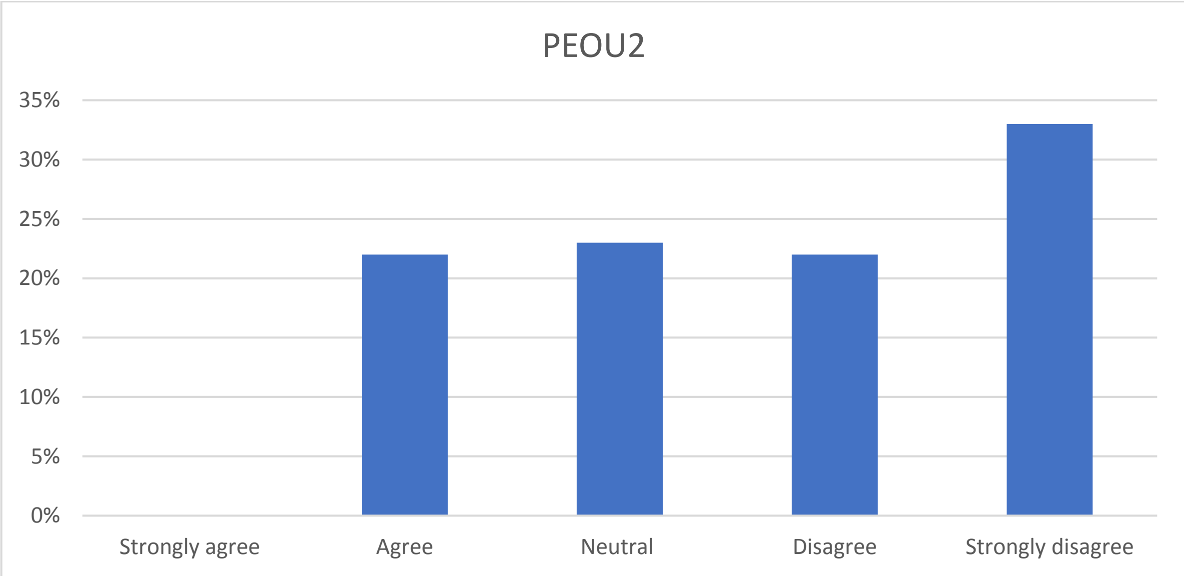


Figure 17: **Faced challenge while using the mobile application**

From Fig. 17, it can be seen that most participants did not face any challenge and less than 25% faced challenge while using the mobile application.

In the item PEOU3, participants were asked if the system can also be used without the use of internet in the areas where networks drop to Edge. The results are shown in Fig. 18.

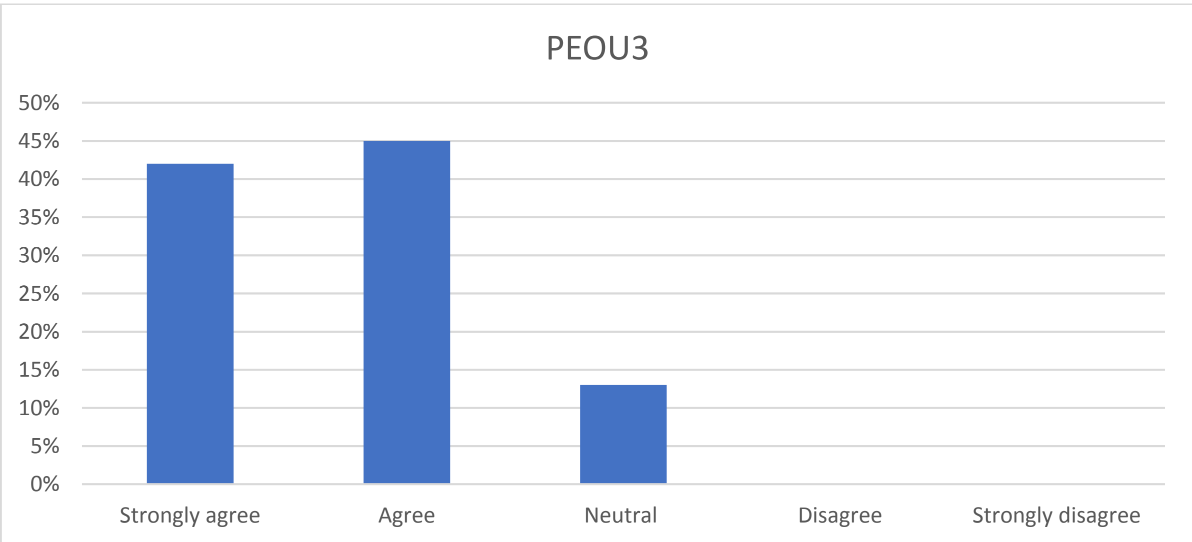


Figure 18: **System can be used without internet in the areas where network is unavailable**

From Fig. 18 it can be seen that the majority of participants agreed that the system can also work and provides alerts in the areas where the network connectivity drops.

In the item PEOU4, participants were asked if the mobile application is interactive. The results are shown in Fig. 19.

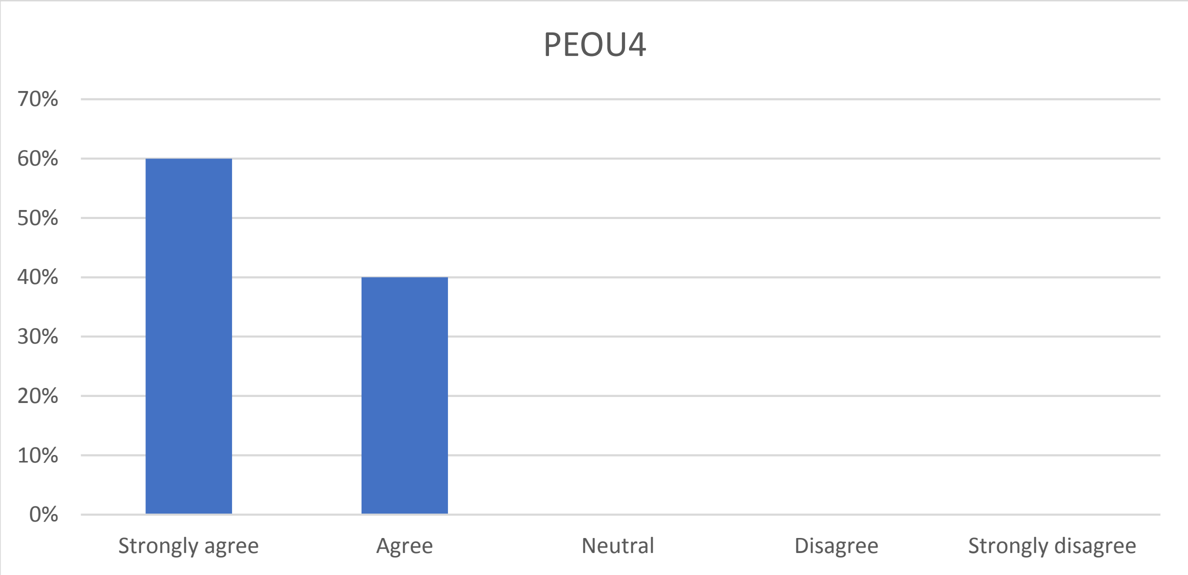


Figure 19: Mobile application is interactive

From Fig. 19 it can be seen that all participants agreed that the mobile application is interactive.

From the above findings, it can be deduced that participants perceived that the system is easy to use.

Hypothesis 3: Attitude towards Using (ATU)

The scale included three items ATU1, ATU2, and ATU3 that measure overall participants' attitude towards using the system. Participants were asked three questions and the results are shown in Table 11.

In the item ATU1, participants were asked if the road signs alerts given are beneficial to them. The results show that 10 (18%) and 45 (82%) participants agreed that the road signs are beneficial to them.

In the item ATU2, participants were asked if alerts were given at an ideal distance for them to take action. The results show that 7 (13%) and 48 (87%) participants agreed that alerts were given at an ideal distance.

In the item ATU3, participants were asked if the mobile app helps them to avoid road traffic accidents. The results show that 11 (20%) and 44 (80%) participants agreed that the mobile application helps them to avoid accidents.

From the above findings it can be deduced that all 55 participants (100%) had positive attitude towards using the system.

Hypothesis 4: Behaviour Use (BU)

The behaviour to use the system was measured by three items BU1, BU2, and BU3.
In the item BU1, participants were asked if the internet connectivity works perfectly with the mobile application. The results are shown in Fig. 20.

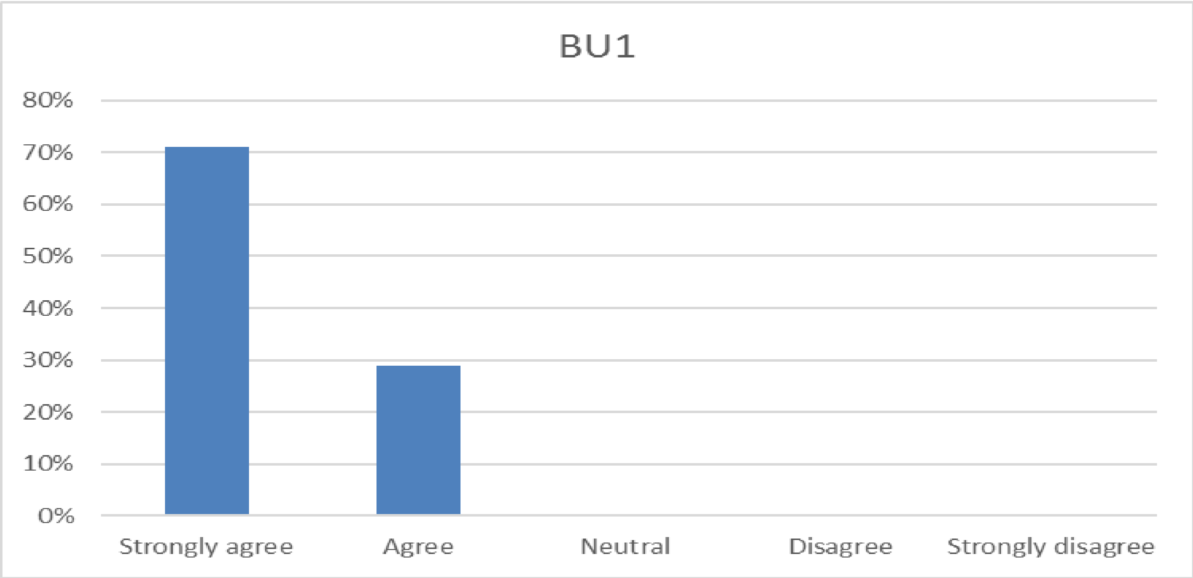


Figure 20: Internet connectivity works perfectly with mobile application

From the Fig. 20, it can be seen that all participants agreed that the mobile application internet connectivity worked perfectly with their mobile devices.

In the item BU2, participants were asked to state if they did not get any compatibility problem with their smartphones. The results are shown in Fig. 21.

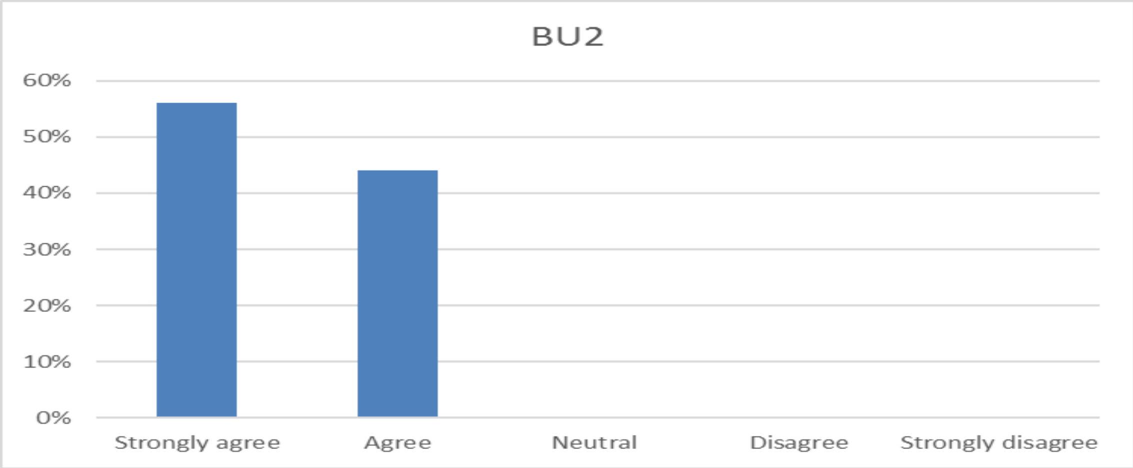


Figure 21: No compatibility problem with smartphones

From the Fig. 21, it can be seen that all of participants agreed that they did not get any compatibility problem with their smartphones.

In the item BU3, participants were asked if they will use the system once it has been developed for wider use. The results are shown in Fig. 22.

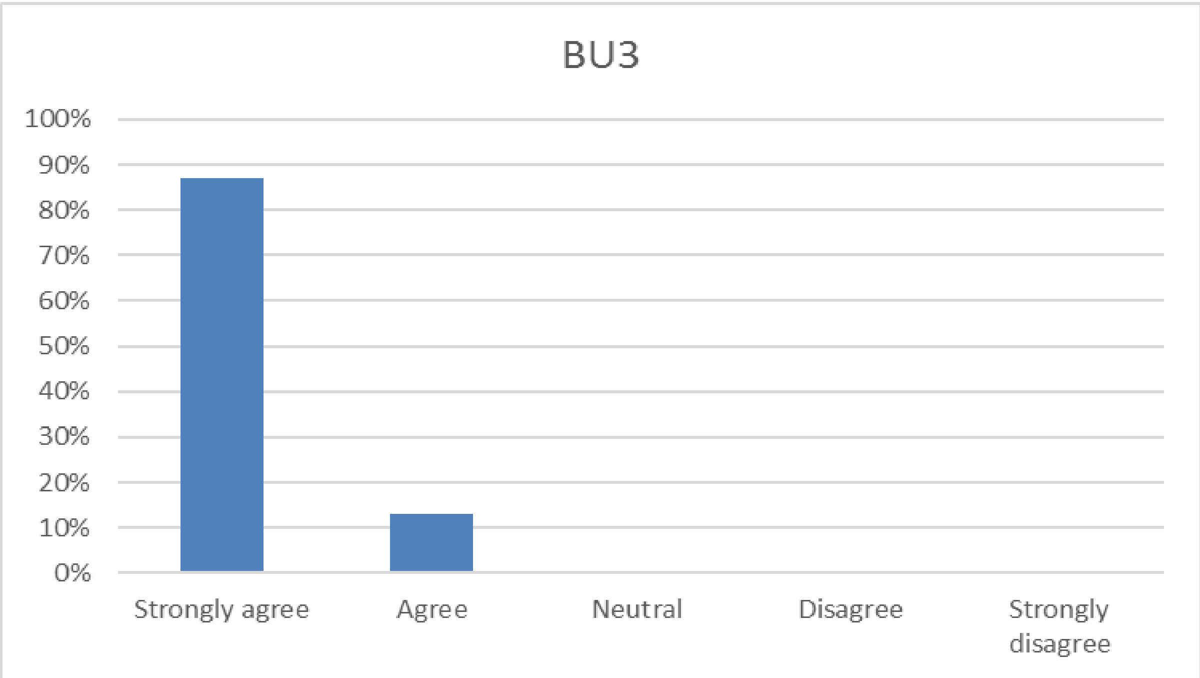


Figure 22: I would use the system once it has been developed for wider use

From the Fig. 22, it can be seen that all participants agreed that they will use the system once it has been developed for wider use.

From the above findings it can be deduced that all 55 participants (100%) are likely to use the system once it has been developed for wider use.

4.2 Discussion

This study developed and tested a prototype on a smart mobile phone. To determine the system requirements a field study and literature review were conducted to assess the existing related systems used to provide road sign information to drivers and speed control measures to avoid road accidents. During the requirements stage three stakeholders were involved in this study: A police officer, an official spokesman from LATRA, and drivers. A LATRA official provided information on the successes and challenges of highway transportation in Tanzania, as well as the measures used to control road traffic accidents. A police officer provided information on the scope of road traffic accidents, the major causes, and the police measures used to control road traffic accidents. Drivers provided information on their familiarity with road traffic signs, road signs found on the Arusha – Moshi highway, their experiences with road traffic rule violations. In addition, all the three stakeholders gave opinions on the system requirements. The information generated from this initial stage was invaluable in designing the road signs alert system.

The research successfully developed a system that alerts drivers about road signs ahead via voice and image alert. The successful development of a road signs alert system using an Android application provided an answer to the second research question. Through the use of RAD methodology, various system components, such as modules, use-case diagrams, architecture, and data - flow diagrams were analysed for a system based on the required pre-requisites.

The TAM was used to assess the usefulness of the system through hypothesis testing after being used by the drivers. The purpose was to examine factors whether the user will use the developed system. Similar to earlier studies; Park *et al*. (2012), Voinea *et al*. (2020) and Yang *et al*. (2021), this study confirmed that TAM could be considered as one of the theoretical models that are useful in understanding the behaviour intention to use the actual system. The results show that the system could be used to improve safety, and the contents of the system are meaningful. Also, drivers would like to use the system once developed for wider use.

Despite the presence of road signs on most Tanzanian highways, the placement of these signs requires careful thought and planning. Road signs must be placed at the furthest distance ahead of the intended warning. Most of the time, static roadway signs are seen too late at a close range of 10-50 meters for a driver to take an appropriate action gently. As a result of this situation, the drivers may violate traffic signs because it is difficult to take any action at such a close range. If drivers attempt to make a response at that close range, such as applying brakes, the incident may result in accidents.

The developed system in this study provided alerts on forthcoming road signs within 250 metres prior to encountering the sign. Based on prevailing speed and location, the alerts were within a timeframe of 15 seconds. This distance was adequate for the drivers to make appropriate response. As such, the occurrence of road traffic accidents can be reduced by using this road sign alert system properly.

The results indicate that the developed system has the benefits of high accuracy within a user radius of 10 meters, minimum bandwidth, and low-cost system. Further, the system has the potential to be used for provision of real-time information for drivers on other road features, thereby enhancing vehicle and passenger's safety. Such useful information can be a warning about impending road conditions such as intersections, roundabouts, railway crossings, and upcoming road works.

In addition to providing road signs alerts, the system included an independent module where the user can view his current speed and set a speed alert. This feature resembles the current VTS tracking device that produces a buzzer when a user exceeds the authorized speed limit. Hence, this feature can as well serve to regulate driver’s speed.

Previous works on road signs detection have used colours or images of road signs (Farhat *et al*., 2019; García-Garrido *et al*., 2012; Hechri *et al.*, 2015). These approaches faced some challenges such as buffling of images due a moving vehicle's vibration; fading of paint on the sign; and occlusion of the sign by obstacles. Other works have used a device on-board a vehicle that communicates with an infrastructure installed on the road (Rajale *et al.,* 2014). This approach also had some challenges such as the devices being expensive and requiring a constant power supply and regular maintenance. The system developed in this study is devoid of all these challenges.

An important limitation found with the system developed in this study was power consumption by the smartphone. To overcome this, the Energy Patch framework tool proposed by Banerjee *et al*. (2017) can be used, which is immune to this challenge and can reduce energy consumption by 60%. Future researchers should focus on overcoming this challenge.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

Road accidents cannot be eliminated completely, but they can be reduced by improving driver safety. The system has been developed for provision of information to drivers about road signs ahead of them within 250 metres distance. The system utilizes the smartphone in-built sensor and APIs to detect user movement. These sensors determine locations coordinates accuracy, distance from the road signs, and vehicles speed. The developed system contains a database that stores information of these roads signs and their corresponding alerts. The developed system met users and designer's expectations in its performance with minimal limitations. The system has the benefits of high accuracy within a user radius of 10 meters, minimum bandwidth requirement, and low-cost system. The information generated by system is valuable in enhancing road safety by prevention of road traffic accidents, thereby rendering the system potential for wide scale use in road transport industry.

5.2 Recommendations

From the conclusion, the following recommendations were made:

(i) Features of smartphones should be used by the future works on this area to alert drivers on road signs and other road conditions ahead in attempt to reduce road traffic accidents.

(ii) Road construction authorities should ensure that road signs are placed at a distance convenient for drivers to take appropriate actions before encountering the actual road sign. It is recommended that the distance should be at least 250 metres.

(iii) Future works on this area should come out with measures to address the issue of power consumption by the mobile phone when it is used as a device for providing alerts to long route drivers.

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APPENDICES

Appendix 1: Public Bus Driver's Focus Group Discussion Guide

A SMARTPHONE-BASED ROAD SIGNS ALERT SYSTEM FOR VEHICLE DRIVERS' ASSISTANCE IN TANZANIA.

1. What types of road signs are you familiar with?
2. What types of road signs do you normally encounter on the road?

   Probe:

   a. Pedestrian crossing (Zebra crossing)
   b. Speed limits
   c. Speed bumps
   d. Speed humps
   e. Sharp corner
   f. Strong wind

3. Which of the road signs do you consider <u>most important</u> to you as a driver?

   Probe:

   a. Pedestrian crossing (Zebra crossing)
   b. Speed limits
   c. Speed bumps
   d. Speed humps
   e. Sharp corner
   f. Strong wind

4. Have you ever been fined due to traffic rules violation?
5. How often do you get fines from violating traffic rules?
6. What traffic rule(s) do you most often break and get fined?
7. If a system is developed to assist you know the road signs ahead of you on the road, would this system be helpful?

   Probe

   - How useful will it be?

8. What properties should the system have?

THANK YOU FOR PARTICIPATING

Appendix 2: Traffic Police Spokesperson Interview Guide

A SMARTPHONE-BASED ROAD SIGNS ALERT SYSTEM FOR VEHICLE DRIVERS' ASSISTANCE IN TANZANIA.

1. How big is the road traffic accident problem in Arusha district?

2. What are the major causes of road traffic accidents that you have seen?

3. What measures are used to control road traffic accidents?

   For each measure mentioned Probe about:

   - Effectiveness
   - Limitations

4. What are your views about the road signs alert system to be developed?

   Probe:

   - Its properties
   - Advantages
   - Disadvantages
   - Acceptability by stakeholders (LATRA, drivers, traffic police force)

THANK YOU FOR PARTICIPATING

Appendix 3: LATRA Spokesperson Interview Guide

A SMARTPHONE-BASED ROAD SIGNS ALERT SYSTEM FOR VEHICLE DRIVERS' ASSISTANCE IN TANZANIA.

1. What are the major successes of land transportation that you have seen?

2. What are the major challenges of land transportation that you have seen?

3. What measures are used to control road traffic accidents?

   For each measure mentioned Probe about:

   - Effectiveness
   - Limitations

4. What are your views about the road signs alert system to be developed?

   Probe:

   - Its properties
   - Advantages
   - Disadvantages
   - Acceptability by stakeholders (LATRA, drivers, traffic police force)

THANK YOU FOR PARTICIPATING

Appendix 4: Drivers Questionnaire After Using the System

A SMARTPHONE-BASED ROAD SIGNS ALERT SYSTEM FOR VEHICLE DRIVERS' ASSISTANCE IN TANZANIA

Questionnaire No.------------------------------ **Date-------------------------**

Driving Route---

No.	**Question**	**1=Strongly disagree, 2=Disagree 3=Neutral, 4= Agree 5= Strongly agree**				
		5	**4**	**3**	**2**	**1**
1	The mobile app is easy to install, learn and use					
2	The information is useful and could be Helpful					
3	The contents and features of the app are Meaningful					
4	I will need technical assistance in using the mobile application					
5	I faced a challenge while using the system					
6	The system can be used without the use of internet					
7	The mobile app is interactive					
8	The system gives alerts on road signs ahead of me					
9	Alerts were given before reaching the road sign at an appropriate distance					
10	The mobile app provides alerts that are useful and helpful					
11	Internet connectivity works perfectly with the mobile application					
12	I did not get any compatibility problem with my smartphone					
13	Once the system has been developed for wider use, I would like to use the application					

THANK YOU FOR PARTICIPATING

Appendix 5: Information Sheet for Police and LATRA Officials

My name is **Eric Masatu**, a student from The Nelson Mandela African Institution of Science and Technology, Arusha. I am doing a research that aims at developing **A Smartphone-Based Road Signs Alert System for Vehicle Drivers' Assistance in Tanzania**. The research will be conducted in Arusha and Kilimanjaro regions. You are being invited to participate in this research. Your participation is voluntary. I would like to tell you some information about the research. Please ask questions if there is anything you do not understand.

<u>What is the name of the research?</u>

The title of the research is "**A Smartphone-Based Road Signs Alert System for Vehicle Drivers' Assistance in Tanzania**"

<u>Who is in charge of this research?</u>

This research is being led by **Mr. Eric Masatu** from Nelson Mandela African Institution of Science and Technology, Arusha. Contact details are listed at the end of this information sheet.

<u>Why are we doing this research?</u>

We are doing this research in order to Develop and Test a Road Signs Alert System Using a Smart Mobile Phone that will provide information to drivers about road signs ahead of them before encountering the signs. The information generated by the proposed system will help drivers to take appropriate action for the forthcoming road sign such as stopping or reducing speed. In so doing, driving safety will significantly be enhanced, thereby minimizing road traffic accidents.

<u>How have we chosen you?</u>

We are asking you to join this research because you are an important stakeholder in as far as road safety is concerned.

<u>What does this research involve?</u>

The research uses an ICT-based system for digital storing of road traffic signs for an in-vehicle highway driver. The system will be installed on a smart mobile phone for use during the journey.

<u>What you will be asked to do?</u>

You will be asked to answer some questions which will help us in designing the system.

<u>Are there any benefits to me from participating in this research?</u>

The information you provide will enable us design a system for alerting drivers like about the road signs ahead, so that they take necessary measures, and in so doing preventing occurrence of road traffic accidents.

Will anyone else find out about what I have said?

All answers that you give to our questions will be confidential. Your answers will be stored on a secure computer, and only the researcher will be able to see them. The questionnaire used to collect your answers will be kept in a locked room.

What will happen if I do not participate in this research?

Your participation in the research is voluntary, it is your choice. If you choose not to do participate in this research, nothing bad will happen to you.

Who can I speak to if I have questions about this research?

If you have any questions or concerns about this research, you can contact the following people:

Mr Eric Masatu,
The Nelson Mandela African Institution of Science and Technology
P.O.Box 447,
Tengeru-Arusha.
Tanzania.
0766624230/0755300509

Dr. Ramadhani Sinde,
The Nelson Mandela African Institution of Science and Technology
P.O.Box 447,
Tengeru-Arusha.
Tanzania.
0769551025

Appendix 6: Information Sheet for Drivers

My name is **Eric Masatu**, a student from The Nelson Mandela African Institution of Science and Technology, Arusha. I am doing research that aims at developing **A Smartphone-Based Road Signs Alert System for Vehicle Drivers' Assistance in Tanzania**. The research will be conducted in Arusha and Kilimanjaro regions. You are being invited to participate in this research. Your participation is voluntary. I would like to tell you some information about the research. Please ask questions if there is anything you do not understand.

What is the name of the study?

The title of the study is "**A Smartphone-Based Road Signs Alert System for Vehicle Drivers' Assistance in Tanzania**"

Who is in charge of this study?

This study is being led by Mr**. Eric Masatu** from Nelson Mandela African institute of science and Technology. Contact details are listed at the end of this information sheet.

Why are we doing this study?

We are doing this research in order to Develop and Test a Road Signs Alert System Using a Smart Mobile Phone that will provide information to drivers about road signs ahead of them before encountering the signs. The information generated by the proposed system will help drivers to take appropriate action for the forthcoming road sign such as stopping or reducing speed. In so doing, driving safety will significantly be enhanced, thereby minimizing road traffic accidents.

How have we chosen you?

We are asking you to join this study because you are a driver who commonly uses the Arusha - Moshi highway.

What does this study involve?

The research uses an ICT-based system for digital storing of road traffic signs for an in-vehicle highway driver. The system will be installed on a smart mobile phone for use during the journey.

What you will be asked to do?

You will be asked to answer some questions which will help us in designing the system. After the system has been designed, the system will be installed on your mobile phone and asked to use it while driving on the Arusha-Moshi highway. After using the system, you will be asked some questions related to the system performance.

Are there any benefits to me from participating in this study?

The knowledge gained from the study will enable us design a system for alerting drivers like you on the road signs ahead, so that you take necessary measures, and in so doing preventing occurrence of accidents.

Will anyone else find out about what I have said?

All of the answers that you give to our questions will be confidential. Your answers will be stored on a secure computer, and only the researcher will be able to see them. The questionnaire used to collect your answers will be kept in a locked room.

What will happen if I do not participate in this study?

Your participation in the study is voluntary, it is your choice. If you choose not to do this study, nothing bad will happen to you.

Who can I speak to if I have questions about this study?

If you have any questions or concerns about this study, you can call:

Mr Eric Masatu,
Nelson Mandela Arusha,
P.O.Box 447,
Tengeru-Arusha.
Tanzania.
0766624230/0755300509

Dr. Ramadhani Sinde,
Nelson Mandela Arusha,
P.O.Box 447,
Tengeru-Arusha.
Tanzania.
0769551025

Appendix 7: Consent to Participate in Research

My name is **Eric Masatu** from The Nelson Mandela African Institution of Science and Technology, Arusha. I am conducting research that aim at **A Smartphone-Based Road Signs Alert System for Vehicle Drivers' Assistance in Tanzania** that will provide information to drivers about road signs ahead of them before encountering the signs. You are invited to participate in this research. You are free to participate or not to participate in the study. Failure to participate will not affect you in any way. Also, you can stop participating at any time when you feel so. There will be no payment of any sort for your participation. Other information about the research has been given to you in a separate form. We believe that the information obtained from this research will be useful in improving the system. If you agree to participate in this study, I request you to write your name and signature on this form in the space below.

WOULD YOU LIKE TO PARTICIPATE? **YES**………/**NO**………

(If the answer is **YES** provide your name and signature below)

I have read the information about the research/ or it has been read to me. I have had the opportunity to ask questions about it and any questions that I have asked have been answered to my satisfaction. I consent voluntarily to participate in this study.

Name ________________________________

Signature___________________Date_________________

THANK YOU FOR PARTICIPATING

Appendix 8: Mwongozo wa Majadiliano na Kikundi cha Cha Madereva

(A) Mfumo wa Tahadhari ya Ishara za Barabarani kwa Madereva wa Magari Tanzania

1. Ni aina gani za ishara za barabarani unazozifahamu?
2. Ni aina gani ya ishara za barabarani ambazo kawaida hukutana nazo barabarani?

   Dodosa juu ya:

   a. Alama ya kivuko cha waenda kwa miguu
   b. Kikomo cha kasi
   c. Mbele kuna matuta
   d. Mbele kuna matuta
   e. Kona kali
   f. Upepo mkali

3. Ni ishara zipi unadhani ni <u>muhimu sana</u> kwako kama Dereva?

   Dodosa juu ya:

   a. Alama ya kivuko cha waenda kwa miguu
   b. Kikomo cha kasi
   c. Mbele kuna matuta
   d. Mbele kuna matuta
   e. Kona kali
   f. Upepo mkali

4. Umewahi kutozwa faini kwa sababu ya ukiukwaji wa sheria za usalama barabarani?
5. Je ni mara ngapi unapata faini kutokana na kukiuka sheria za trafiki?
6. Ni sheria gani za trafiki unazovunja mara nyingi na kutozwa faini?
7. Kama mfumo ukitengenezwa wa kukusaidia kujua ishara za barabarani zilizoko mbele yako, je, mfumo huu utasaidia?

   Dodosa juu ya:

   - Utakuwa na manufaa gani?

8. Mfumo unapaswa kuwa na sifa zipi?

ASANTE KWA KUSHIRIKI

(B) Mwongozo wa Mahojiano na Ofisa wa Polisi wa Kikosi cha Usafirishaji Mkoa wa Arusha

Mfumo wa Tahadhari ya Ishara za Barabarani kwa Madereva wa Magari Tanzania

1. Tatizo la ajali za barabarani ni kubwa kiasi gani katika Mkoa wa Arusha?

2. Ni nini sababu kuu za ajali za barabarani?

3. Ni hatua gani zinazotumika kudhibiti ajali za barabarani?

   Dodosa juu ya:

   a. Ufanisi wa hatua
   b. Upungufu wa hatua

4. Je maoni yako kuhusu mfumo utakaotengenezwa kwa ajili ya kuwatahadharisha madereva kuhusu alama za barabarani zilizo mbele yao?

   Dodosa juu ya:

   a. Faida
   b. Hasara
   c. Kukubalika na wadau (madereva, polisi wa trafiki)

ASANTE KWA KUSHIRIKI

(C) Mwongozo wa Mahojiano na Ofisa wa Latra

Mfumo wa Tahadhari ya Ishara za Barabarani kwa Madereva wa Magari Tanzania

1. Je ni mafanikio gani makubwa mliyoyapata katika usafirishaji kwa njia ya ardhi?

2. Je ni changamoto gani kuu mlizozipata kuhusu usafirishaji kwa njia ardhi?

3. Ni hatua gani zinazotumiwa kudhibiti ajali za barabarani?

   Dodosa juu ya:

   a. Ufanisi
   b. Upungufu

4. Je nini maoni yako kuhusu mfumo utakaotengenezwa kwa ajili ya kuwatahadharisha madereva kuhusu alama za barabarani zilizo mbele yao?

   Dodosa juu ya:

   a. Faida
   b. Hasara
   c. Kukubalika na wadau (madereva, polisi wa trafiki)

ASANTE KWA KUSHIRIKI

(D) Maswali kwa Madereva Baada Yakutumia Mfumo

Mfumo wa Tahadhari ya Ishara za Barabarani kwa Madereva wa Magari Tanzania

Dodoso Namba .-------------------------------- Tarehe--------------------------

Safari anayoenda ---

Namba	**Swali**	**1=Ninakataa kabisa, 2=Ninakataa 3=Sina uhakika, 4= Ninakubali**				
		5	**4**	**3**	**2**	**1**
1	Programu ya simu ni rahisi kufunga, kujifunza na kutumia					
2	Taarifa hii ni muhimu na inaweza kuwa msaada					
3	Maudhui na vipengele vya programu vina Maana					
4	Nitahitaji msaada wa kiufundi katika kutumia programu ya simu					
5	Nilikabiliwa na changamoto wakati wa kutumia mfumo					
6	Mfumo unaweza kutumika bila matumizi ya mtandao					
7	Programu hii ya simu ni rahisi kutumia					
8	Mfumo umetoa tahadhari juu ya ishara za barabarani zilizo mbele yangu					
9	Tahadhari zilitolewa kabla ya kufikia alama ya barabara kwa umbali unaofaa					
10	Mfumo umetoa taarifa ambazo ni muhimu na zinasaidia					
11	Mtandao wa simu umefanya kazi kikamilifu kwenye mfumo					
12	Sikupata shida yoyote kuingiza mfumo katika simu yangu					
13	Mfumo umetengenezwa kwa matumizi makubwa, ningependa kuutumia					

ASANTE KWA KUSHIRIKI

(E) Fomu ya Taarifa Juu ya Utafiti kwa Ofisa wa Polisi na Latra

Jina langu ni **Eric Masatu**, mwanafunzi kutoka Taasisi ya Afrika ya Sayansi na Teknolojia ya Nelson Mandela, Arusha. Ninafanya utafiti ambao unakusudia kuunda **Mfumo wa Tahadhari ya Ishara za Barabarani kwa Madereva wa Magari Tanzania**. Utafiti huo utafanyika katika mikoa ya Arusha na Kilimanjaro. Unaalikwa kushiriki katika utafiti huu. Ushiriki wako ni wa hiari. Ningependa kukupa taarifa kuhusu utafiti huu. Tafadhali uliza maswali ikiwa kuna chochote usichoelewa.

<u>Jina la utafiti huu ni nini?</u>

Jina la utafiti ni " **Mfumo wa Tahadhari ya Ishara za Barabarani kwa Madereva wa Magari Tanzania** "

<u>Ni nani anayesimamia utafiti huu?</u>

Utafiti huu unaongozwa nami **Eric Masatu** kutoka Taasisi ya Afrika ya Sayansi na Teknolojia ya Nelson Mandela, Arusha. Maelezo ya mawasiliano yapo mwishoni fomu hii.

<u>Kwa nini tunafanya utafiti huu?</u>

Tunafanya utafiti huu ili kuunda mfumo ambao utatoa taarifa kwa madereva juu ya alama za barabarani zilizo mbele yao kabla ya kuzifikia. Mfumo huu utasaidia madereva kuchukua hatua zinazofaa kwa ishara ya barabarani iliyo mbele kama vile kusimama au kupunguza kasi. Kwa kufanya hivyo, usalama barabarani utaimarishwa sana, na hivyo kupunguza ajali za barabarani.

<u>Tumekuchagua vipi?</u>

Tumekuchagua ushiriki katika utafiti huu kwa sababu wewe ni mdau muhimu katika usalama wa barabarani.

<u>Utafiti huu unahusisha nini?</u>

Utafiti umakusudia kutengeeza mfumo wa kutoa taarifa za ishara za barabarani kidijitali kupitia simu janja ya Dereva wakati wa safari.

<u>Je unatakiwa kufanya nini?</u>

Utaulizwa maswali kadhaa ambayo yatatusaidia katika kutengeneza mfumo huu.

<u>Je kuna faida yoyote kwako kushiriki katika utafiti huu?</u>

Taarifa utakazotoa zitatuwezesha kutengeneza mfumo wa utoaji taarifa kuhusu ishara za barabarani, na kwa kufanya hivyo kuzuia kutokea kwa ajali.

Je mtu mwingine yeyote atafahamu juu ya kile nilichosema?

Taarifa ambayo utatoa itakuwa siri, na itahifadhiwa kwa usiri mkubwa kwenye Kompyuta. Fomu ya utafiti iliyo na taarifa zako itatunzwa mahali salama.

Je ni nini kitatokea ikiwa sitashiriki katika utafiti huu?

Ushiriki wako katika utafiti ni wa hiari. Ikiwa unachagua kutoshiriki katika utafiti huu, hakuna chochote kibaya kitakachokutokea.

Nani ninaweza kuongea naye kama nina maswali kuhusu utafiti huu?

Ikiwa una maswali yoyote kuhusu utafiti huu, unaweza kuwasiliana na watu wafuatao:

Bw. Eric Masatu,
The Nelson Mandela African Institution of Science and Technology
S.L.P 447,
Tengeru-Arusha.
Tanzania.
0766624230/0755300509

Dk. Ramadhani Sinde,
The Nelson Mandela African Institution of Science and Technology
S.L.P 447,
Tengeru-Arusha.
Tanzania.
0769551025

(F) Fomu ya Taarifa ya Utafiti kwa Madereva

Jina langu ni **Eric Masatu**, mwanafunzi kutoka Taasisi ya Afrika ya Sayansi na Teknolojia ya Nelson Mandela, Arusha. Ninafanya utafiti ambao unakusudia kuunda **Mfumo wa Tahadhari ya Ishara za Barabarani kwa Madereva wa Magari Tanzania**. Utafiti huo utafanyika katika mikoa ya Arusha na Kilimanjaro. Unaalikwa kushiriki katika utafiti huu. Ushiriki wako ni wa hiari. Ningependa kukupa taarifa juu ya utafiti huu. Tafadhali uliza maswali ikiwa kuna chochote usichoelewa.

Je Jina la utafiti huo ni nini?

Jina la utafiti huo ni " **Mfumo wa Tahadhari ya Ishara za Barabarani kwa Madereva wa Magari Tanzania**"

Ni nani anayesimamia utafiti huu?

Utafiti huu unaongozwa na **Eric Masatu** kutoka Taasisi ya Afrika ya Sayansi na Teknolojia ya Nelson Mandela, Arusha. Maelezo kuhusu mawasiliano na watafiti yameelezwa mwishoni mwa fomu hii.

Kwa nini tunafanya utafiti huu?

Tunafanya utafiti huu ili kuunda mfumo ambao utatoa taarifa kwa madereva juu ya alama za barabarani zilizo mbele yao kabla ya kuzifikia. Mfumo huu utasaidia madereva kuchukua hatua zinazofaa kwa ishara ya barabarani iliyo mbele kama vile kusimama au kupunguza kasi. Kwa kufanya hivyo, usalama barabarani utaimarishwa sana, na hivyo kupunguza ajali za barabarani.

Tumekuchagua vipi?

Tunakuomba ujiunge na utafiti huu kwa sababu wewe ni dereva ambaye hutumia barabara kuu ya Arusha - Moshi.

Utafiti huu unahusisha nini?

Utafiti umakusudia kutengeeza mfumo wa kutoa taarifa za ishara za barabarani kidijitali kupitia simu janja ya Dereva wakati wa safari.

Je unatakiwa kufanya nini?

Utaulizwa maswali kadhaa ambayo yatatusaidia katika kutengeneza mfumo huu. Pia, tutakuomba uturuhusu kuweka mfumo kwenye simu yako janja itumike wakati wa utafiti. Uwekaji wa mfumo na matumizi yake kwenye simu yako hautakugharimu pesa yoyote, ni bure.

Je Kuna faida yoyote kwako kushiriki katika utafiti huu?

Taarifa utakazotoa zitatuwezesha kutengeneza mfumo wa utoaji taarifa kuhusu ishara za barabarani, na kwa kufanya hivyo kuzuia kutokea kwa ajali.

Je mtu mwingine yeyote atafahamu juu ya kile nilichosema?

Taarifa ambayo utatoa itakuwa siri, na itahifadhiwa kwa usiri mkubwa kwenye Kompyuta. Fomu ya utafiti iliyo na taarifa zako itatunzwa mahali salama.

Je ni nini kitatokea ikiwa sitashiriki katika utafiti huu?

Ushiriki wako katika utafiti ni wa hiari. Ikiwa unachagua kutoshiriki katika utafiti huu, hakuna chochote kibaya kitakachokutokea.

Nani ninaweza kuongea naye kama nina maswali kuhusu utafiti huu?

Ikiwa una maswali yoyote kuhusu utafiti huu, unaweza kuwasiliana na watu wafuatao:

Bw, Eric Masatu,
The Nelson Mandela African Institution of Science and Technology
S.L.P 447,
Tengeru-Arusha.
Tanzania.
0766624230/0755300509

Dk. Ramadhani Sinde,
The Nelson Mandela African Institution of Science and Technology
S.L.P 447,
Tengeru-Arusha.
Tanzania.
0769551025

(G) Ridhaa ya Kushiriki Katika Utafiti

Jina langu ni **Eric Masatu** kutoka Taasisi ya Afrika ya Nelson Mandela ya Sayansi na Teknolojia, Arusha. Ninafanya utafiti ambao unakusudia kuunda **Mfumo wa Tahadhari ya Ishara za Barabara kwa Madereva wa Magari Tanzania** zilizo mbele yao kabla ya kukutana na alama. Umealikwa kushiriki katika utafiti huu. Uko huru kushiriki au usishiriki katika utafiti. Kushindwa kushiriki hakutaathiri kwa njia yoyote. Pia, unaweza kuacha kushiriki wakati wowote unapohisi hivyo. Hakutakuwa na malipo ya aina yoyote kwa ushiriki wako. Maelezo mengine juu ya utafiti umepewa kwa fomu tofauti. Tunaamini kuwa habari iliyopatikana kutoka kwa utafiti huu itakuwa muhimu katika kuboresha mfumo.

Ikiwa unakubali kushiriki katika utafiti huu, nakuomba uandike jina lako na saini kwenye fomu hii katika nafasi hapa chini.

UNGEPENDA KUSHIRIKI? **NDIYO**………/**HAPANA**………

(ikiwa jibu ni NDIYO andika jina lako na saini hapa chini)

Nimesoma habari juu ya utafiti / au nimesomewa. Nimepata nafasi ya kuuliza maswali juu yake na maswali yoyote ambayo nimeuliza yamejibiwa kwa kuridhika kwangu. Ninakubali kwa hiari kushiriki katika utafiti huu.

Jina ________________________________

Sahihi___________________ Tarehe_________________

ASANTE KWA KUSHIRIKI

RESEARCH OUTPUTS