Embedded System for Vehicle Speed Monitoring

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Declaration

I declare that this work has not been previously submitted and approved by Strathmore University or any other university. To the best of my knowledge and belief, this dissertation contains no material previously published or written by another person except where due reference is made.

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Dedication

I dedicate this dissertation to God, my family for their continuous encouragement and support, to all my classmates for the support granted throughout the masters' period, the lecturers for their guidance and finally, to my supervisor Dr. Joseph Orero, for his advice throughout the research period.

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Abstract

Speed violations have been classified among the major causes of road accidents in developing countries. Speed control on roadways is critical in reduction of the number of road accidents reported on a day to day basis. It is important to specify speed limits on different sections of the roads in order to alert motorists and drivers of speed regulations at any given time.

This study aims to develop a system to help motorists maintain the specified speed limits on roads and capture speed violations in real time. The system is comprised of the following critical parts: an embedded system to be deployed in the vehicle, android mobile application and a web application. The embedded systems' main functionality is to capture speed violations and transmit data to the central processing server. It is composed of a capacitive display unit, GSM/GPS module, 3 axis accelerometer and an audio buzzer. All these components are integrated to form one functional unit.

This research adopted agile software development methodology since it was more flexible to the changing requirements of the users and the developer was able to go back and change the system with user views and recommendations in mind. System testing was done to ensure all functionalities met the specifications. The following tests were performed: Unit and integration testing, user testing, functionality testing, and compatibility and acceptance testing. All aspects were deemed to be working according to the requirements.

Keywords: Speed violations, Embedded system, Speeding, GSM module, GPS module, Microcontroller, speed limit, accidents, mapping, display unit

List of abbreviations/Acronyms

DFD: Data Flow Diagram

GPRS: General Packet Radio Service

GPS: Global Positioning System

GSM: Global System for Mobile Communication

GUI: Graphical User Interface

HMI: Human Machine Interface

LCD: Liquid Crystal Display

MNO: Mobile Network Operator

NTSA: National Transport and Safety Authority

PDA: Personal Digital Assistant

PMS: Pavement Management System

PSV: Public Service Vehicle

Definitions of terms

Android	Android is a Linux-based, open-source operating system designed for use on cell phones, e-readers, tablet PCs, and other mobile devices (Educause, 2010).
Public Service Vehicles	These are motor vehicles which are licensed to carry passengers for hire or reward (Bowry, 2015).
Human-Machine Interface	Software application that presents information to an operator or user about the state of a process (Kamal, 2008)
Zigbee:	A wireless technology designed to use low-power digital radio signals for personal area networks (Zigbee Alliance, 2005)
Microcontroller	A small computer on a single integrated circuit containing a processor core, memory, and programmable input/output peripherals (dharm, 2012).
Speeding	The act or instance of operating a motor vehicle or motorboat faster than allowed by law
Embedded system	this is any sort of device which includes a programmable component but itself is not intended to be a general purpose computer (Kamal, 2008).

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Chapter 1: Introduction

1.1 Background of the study

According to World Health Organization, approximately 1.25 million people lose their lives as a result of road traffic crashes in the world annually (World Health Organization, 2015) . The majority of these people are in developing countries. Road crashes are currently the ninth major cause of death worldwide and are projected to rise by 65% by the year 2020, placing it third after major killers like malaria, Tuberculosis and HIV/Aids (Asingo Patrick O, 2007). In Kenya, about 3000 people are involved in road accidents every year. Preston O. Chitere and Thomas N. Kibua explain that this statistic translates to 68 deaths per 1000 registered vehicles (Kibua, 2004).

A press release in 2012 categorizes causes of road accidents into five: irresponsible driving, poor traffic regulation enforcement, poor road conditions, pedestrian related causes and un roadworthy vehicles. Margret Ireri explains that 71% of road accidents are caused by speeding vehicles in Kenya. She further says that after many accidents, passengers say that the driver was at high speed and disobeyed traffic regulations (Ireri, 2012). Speeding on Kenyan roads has become a norm over the past years, leading to accidents which contribute negatively to the economy of the country. The National Transport Service Authority advises drivers to always maintain the specified speed limits on the roads.

Speed is considered to be at the core of the road safety problem all over the world and greatly affects the risk of being involved in an accident (SafetyNet, 2009). At a higher speed, it is more likely that a driver will lose control of the vehicle, fail to anticipate on coming hazards and equally misjudge speed of other vehicles. Additionally, speed affects the extent of injuries to the road users involved in an accident. Figure 1.1 shows the relationship between speed and accident risk as established by researchers over the years (SafetyNet, 2009)

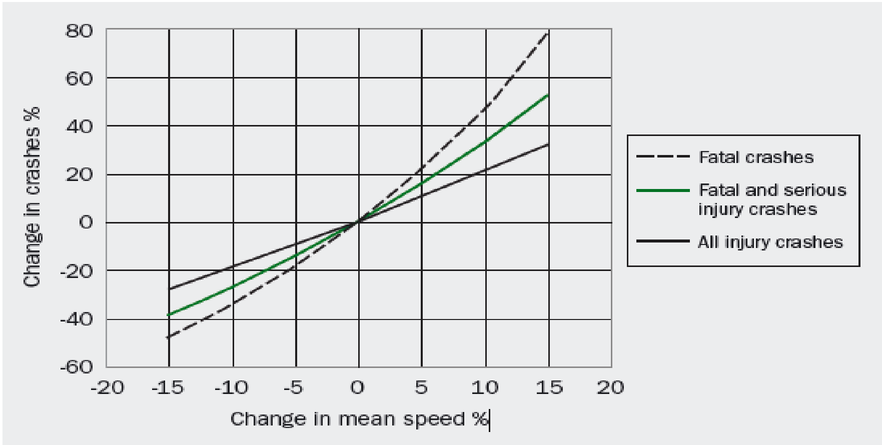

Figure 1.1: Relationship between speed and occurrence of accidents

According to the European Commission, 40 to 50% of the motorists travel faster than the stipulated speed limit. Typically, 10 to 20% of these drivers exceed the speed limit by more than 10 km/h. The commission further explains that drivers must be aware of local speed limit zones at all times. This can be achieved by proper and consistent labelling and marking of speed limit areas (The european commission, 2015).

With this in mind, it is important to change how the current system operates though it may come with its problems which will be addressed in this study. This includes finding the best architectures to use for monitoring speed violations on roads and alerting drivers of the various speed limit zones along their routes. If implemented well, the system will be efficient and reliable in alerting drivers about speed limit zones and in case of violation, transmits location, time and vehicle registration data to the specific agency.

1.2 Problem Statement

In Kenya, there lacks an efficient and effective system for transport agencies to monitor speed violations by the agency drivers on the roads. The transport agencies and individual vehicle owners do not play any role in influencing speed maintained by the drivers and do not keep track of speeding violations committed. This brings about the need to have a system that enable transport agencies to constantly keep track of speed violations and informing drivers of the speed limit regulations on roads . The government has put measures such as speed guns in an effort to the track speed limit offenders though it is not effective since it is difficult to keep track of offences at all times. Instead, traffic police use them as a tool for corruption through collecting bribes from motorists exceeding the specified speed limit (Asingo Patrick O, 2007).

Additionally, NTSA speed limit regulations are periodically changing along particular roads. Motorists are either not aware of these speed limit zones or tend to forget hence being ruled as traffic offenders. Transport agencies should embrace technology to give notifications and audio alerts to the drivers as they navigate from one speed limit zone to the next. This can be facilitated by mapping the speed limit zones and using audio alert system to aid drivers during navigation.

1.3 Research Objectives

i. To investigate approaches taken to curb speeding of public service vehicles in Kenya,
ii. To investigate how a mobile application and embedded system can be applied to help curb speeding of PSV on roads,
iii. To design a system for mapping speed limit zones and viewing speed violations along specific roads and routes,
iv. To test the functionalities of the system,

1.4 Research Questions

i. What are the approaches taken to curb speeding of public service vehicles in Kenya?
ii. How can a mobile application and embedded system be applied to help curb speeding of PSV on roads?
iii. How can a system for mapping speed limit zones and viewing speed violations be designed and developed?
iv. How can the functionalities of the system be tested?

1.5 Justification of the Research

With the implementation of this system, PSV drivers will be notified in real time as they navigate from one speed limit zone to the next. In Case of a violation, an audio alert is triggered to notify driver about the speed violation. The system transmits the speed violation information to a server which is accessible to the agency supervisor and vehicle owners. This enables the stakeholders to generate reports showing various speed violations over a particular period of time.

1.6 Scope of the Research

This system mainly targets the transport industry where vehicles are registered under an agency.

This study offers a prototype of the system. An embedded system consisting of Microcontroller, GSM/GPS module, accelerometer, display unit and audio buzzer is integrated to form a functional unit. The display unit show a map of speed limit zones along sections of two major highways in Nairobi: Thika Road and Mombasa Road. The audio buzzer is triggered once the driver exceeds the specified speed limit. The GPS module detects the location of the vehicle at a particular time. The GSM module is a transceiver aimed at sending and receiving data. An android mobile application will be developed to display speed violations to the vehicle owners. A web based application will also be developed for supervisory/administrative roles by the transport agency.

1.7 Limitations of the Research

Developing a system to help make the monitoring of speeding vehicles efficient on Kenyan roads comes with its challenges. The inclusion of an additional hardware component in the vehicle to monitor and analyze speed is a major limitation. This system will require mobile application users to have an android mobile application and internet connectivity so as to receive speed violations in real time.

Chapter 2: Literature review

2.1 Introduction

This section of the study aims to review literature about the speeding of Public Service Vehicles in Kenya. It focuses on the attempts made to curb speeding of Public Service Vehicles on roads, technologies and ICT solutions adopted to curb speeding, measures and regulations set by the government, the various models and architectures used in speed detection and reporting and how to test the system that has been developed.

2.2 Speeding of Public Service Vehicles in Kenya

According to Preston Ochere (2010), Public service vehicles are considered as the most dominant mode of transport in Kenya. The drivers of PSV are among the younger generation who have attained secondary education and passed a driving test exam. They work long hours with poor and unreliable remuneration. This poor working conditions coupled with poor training and a consistent lack of discipline on the roads have been found to account for the low level compliance to the set traffic rules and regulations in place. This in turn leads to high rate of road accidents and associated fatalities (Preston, 2010).

In 2004, John Michuki, who was the minister for Transport at the time re-activated a number of traffic regulations which were named "Michuki" rules. Among them was the regulation that all Public Service Vehicles should be fitted with a speed governor to limit speed to 80 Kilometers per Hour. These rules were enforced for a period of time before being set aside and ignored by the stakeholders in Public Transport (Chitere, 2014).

Kenya police reports reveal that 85.5% of road accident and crashes are caused by poor driver behavior. PSV drivers have been blamed for careless driving, incompetence, speeding and a series of other vices leading to road accidents (Nyakeri, Media Printing of Road Traffic Accidents in Kenya: Praxis, Patterns and Issues, 2015).

Kenya ranks among the countries with the highest rate of road accidents globally with an average of 3,000 accidents annually. According to Ireri, over 71% of reported road accidents are attributed to speeding. To achieve the vision 2013, the Kenyan government recognizes transport industry as one of the pillars to achieving its development goals and therefore the government is not only invested in improving the road infrastructure but also road safety. In 2012, The National Transport and Safety Authority (NTSA) was established as the lead authority in Kenya for road safety and transportation (Nyakeri, Media Priming of Road Traffic Accidents in Kenya, 2015). In the year 2013, NTSA reported that more than 13,000 people were involved in road accidents mostly due to speeding. The graph below shows the major causes of accidents in different parts of Kenya.

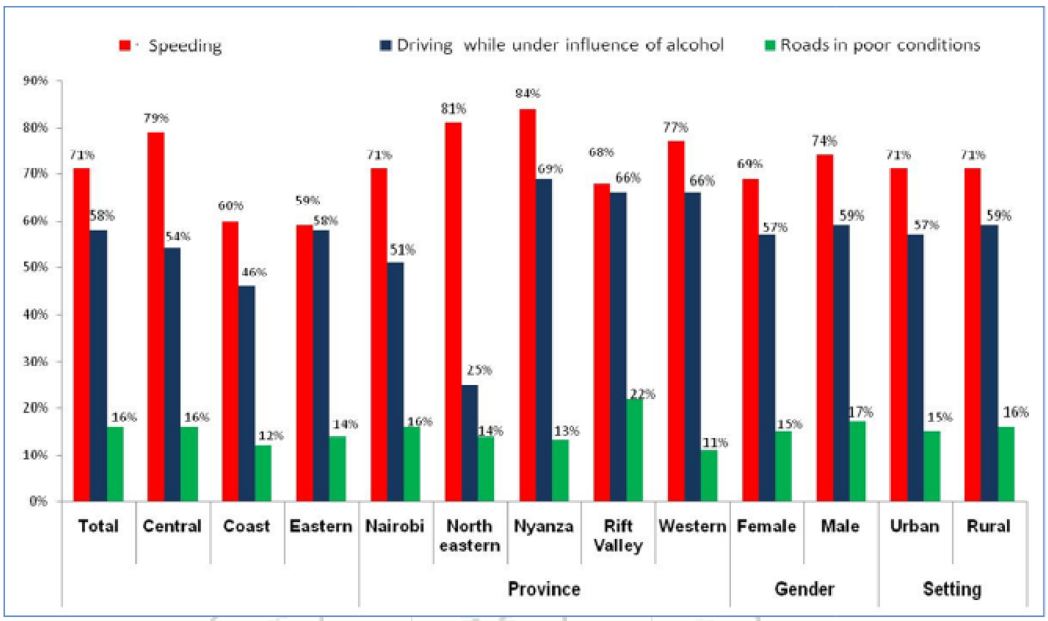

Figure 2.1: Causes of road accidents in Kenya *(Nyakeri, Media Priming of Road Traffic Accidents in Kenya, 2015)*

There are multiple reasons as to why drivers speed on roads. This section investigates factors which contribute to speeding in relation to public service vehicles. Travelling at a high speed enables drivers to arrive at their destinations in the shortest time possible. This has always be considered a very important factor to PSV operators since they seek to generate as much revenue as possible in the shortest time.

$$Time = \frac{distance}{Speed}$$

Equation 2.1: Calculating time *(SoftSchools)*

According to the equation about, time taken from source to destination is inversely proportional to the speed, hence, the higher the speed, and the shorter the time period.

Some cases have been reported where the PSV drivers are purported to over speed just for the fun of it. A sense of thrill and achievement is derived from speeding past the set regulations. This raises the chances of accident occurring exponentially as it affects other innocent drivers on the roads. Drivers tend to optimize level of risks they engage in and speed on roads that they perceive have little to no law enforcement activity. According to World Health Organization (WHO), a number of surveys worldwide demonstrate that up to 90% of drivers on the roads think that they are generally low risk drivers hence believe that they can travel at speeds higher than the limit (World Health Organization, 2008).

Pressure from the fleet management and employers for PSV drivers to be more productive also contributes to speeding. They break speed limit regulations in an effort to meet timelines and maintain timetable and even race to pick up passengers and goods.

2.3 Speeding Issues in Kenya

2.3.1 Corruption and bribery

NTSA Chairman, Mr. Kinyanjui, admitted to corrupt officers receiving bribes for traffic offenses committed by PSV operators on roads. The traffic police have been caught on camera several times receiving bribes and featured in corruption indices reports leading to the vice. The traffic arm of the Kenyan police was reported as the most corrupt institution in Kenya by the East African Bribery Index Report (Nyakeri, Media Priming of Road Traffic Accidents in Kenya, 2015). According to the Huffington post, bribing police officers is the main means of resolving traffic fines in Kenya (Lorch, 2012). To curb this, he further stated that the government was considering introduction of instant speeding tickets to traffic offenders.

2.3.2 Speed limit uncertainty

According to Pravin Bowry, Kenyans are uncertain about the various speed limits on roads. This is attributed to the Highway authority failing to place clear signs on roads to specify speed limits (Bowry, 2015). Recently, NTSA issued a directive of 50km/h on Nairobi metropolitan roads and other major highway sections. These directives need to be further enforced by putting up clear indications and signs to alert motorists. During holidays and public holidays, speed limits are altered on motor ways without motorist awareness.

2.3.3 No tangible Evidence

Speed Traffic police position speed cameras on specific areas on the major roads in Nairobi. Once a speeding violation is recorded, they are expected to flag down the motorists immediately. Unfortunately, this is not the case on Kenyan roads. The traffic police flag down vehicles several kilometers from where the offence was allegedly committed. There is no record information about the car registration number, speed exceeded and location of offence. This provides a loop hole for corruption and bribery by the police.

2.4 Measures to Curb Speeding on Kenyan Roads

There is no single solution to the problem of excess and inappropriate speeding on roads. Kenyan law requires that speed is maintained by motorists at all times. Speeding as an offence has not been properly enforced by the traffic regulators since evidence of speeding is required before issuance of a speeding ticket. Despite this, measures have been taken to ensure motorists maintain the required speed limits.

2.4.1 Traffic Regulation Enforcement

Preventing speeding by law enforcement and traffic regulations is only effective at a certain place and time. Speeding on roads is a major cause of accidents leading to over 50% of reported cases (Gikaru Wilfred G, 2015). Boniface Ekechukwu explains that motorists are unable to make accurate and efficient decisions due to the lack of adequate traffic situation information leading to loss of lives (Asogwa, 2012). This is particularly evident on Kenyan roads where speed limits are not well defined.

According to the traffic amendment bill 2014 (section 42 of Cap 403) the speed limit near schools and health facilities in 30km/h. It is 110km/h on dual carriage roads for private motor vehicles and 100kp/h for single carriage highways. Section 70(5B) of the Traffic Act allows for a grace speed limit of up to 20kp/h above which penalties are imposed to the driver (Republic of Kenya, 2014). Speeding motorists are held accountable for any penalties accrued in the event of a violation. The Kenya Law required traffic offenders to appear in court within a 48 hour period since service notification by traffic police.

2.4.2 Speed detectors

A speed gun is a device used to measure the speed of moving objects. Speed cameras are used by traffic police to register speed violations and identify the vehicle registration number (Institute for road safety research, 2013). These speed cameras can be placed in fixed positions alongside the road or handheld as shown below. According to the National Transport and safety authority, speeds are being monitored following installation of new cameras in major parts of Nairobi County (Bowry, 2015).

Figure 2.2: Speed Camera in Nairobi, Kenya *(NJOROGE, 2015)*

Motorists will be fined a maximum of KES 25, OOO if they defy the new speed limit of 50kp/h for vehicles bound for the Central Business District. This roads include sections of Mombasa Road, Langata Road, Ngo'ng Road, Waiyaki Way, Kiambu road and Thika road. The traffic amendment Act 2014 states the following charges if speed limit is exceeded.

Table 2.1 : speed limit fines in Kenya *(Juma, 2015)*

Speed Exceeded	Fines (KES)
5 to 10 Km/h	10000
11 to 20 km/h	15000
Above 31km/h	25000

Speed guns have proven to have a particular level of success in monitoring speed on roads. Most motorists arrested while speeding are usually not aware of the acceptable speed limit on a particular road. This is attributed to the non-existence of clear speed limit signs along the roads. Section 70 (1A) imposes an obligation on the highway authority to place speed limit indications on roads. However, the highway authority in Kenya fail to place clear signs on roads to mark speed limits hence leaving drivers susceptible to uncertainty while driving (Bowry, 2015).

2.4.3 Speed bumps

Speed bumps have been universally accepted as a measure to caution motorists on speed reduction (Manyara, 2013). Manyara continue to explain that according to the Kenya Standard 7741, the limit for the height of speed bumps ranges between 10 cm to 15cm. Kenyan roads are laden with bumps with a height to width ratio of 1:10. In some areas, the local communities take it upon themselves to construct speed bumps in an effort to reduce speed on residential roads. This "non-engineered' speed bumps are dangerous and akin to placing a tree truck on the roads. They are large and unmarked mound of sand that lead to vehicle damage and discomfort to motorists hence making the situation worse.

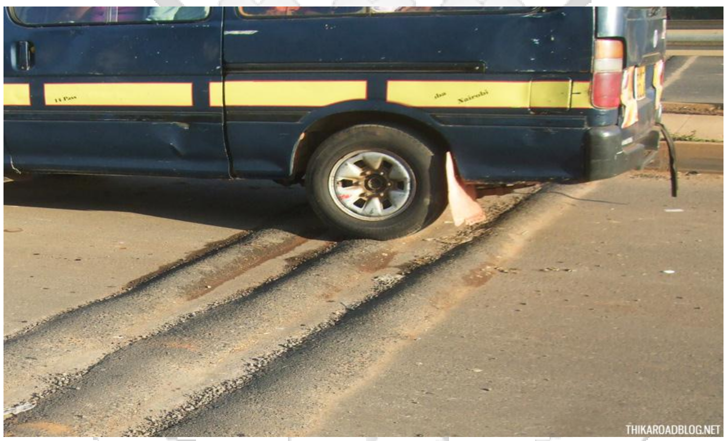

Figure 2.3 : speed bumps on Kenyan roads *(Mohammed, 2015)*

2.4.4 Speed governors

The governor consists of a rotating shaft, which is driven by the diesel engine. A pair of flyweights is linked to the shaft and they rotate as it rotates. The centrifugal force caused by the rotation causes the weights to be thrown outwards as the speed of the shaft rises. If the speed falls the weights move inwards.The government of Kenya set regulation concerning the use of speed governors for the public service vehicles (PSVs). All commercial vehicles are required by law to not exceed the speed of 80kp/h on any given road (Mitullah, 2007). This solution meets the challenge of being tampered with by the owners and drivers. The motorists insist on having a tinker switch hidden somewhere within the drivers cabin which render the speed limiter useless. Additionally, government agencies have failed to follow-up on the set regulations. Patrick Asingo and Winnie Mitullah in their paper conclude that the measures implemented do not seem to be successful in reduction of speed on roads. The proposed system will have ways of going around this to ensure that drivers adhere to speed limits and that other rules of the road are obeyed.

2.4.5 Speed Signs

A speed sign is a recommendation by a governing body used to inform motorists when it may be non-obvious that the safe speed is below the legal speed. NTSA is responsible for setting up speed signs along roadways in the country to inform drivers about speed regulations. Regulations limiting speed below the legal 80KPH have been passed since NTSA was established as the lead authority in Kenya for road safety and transportation.

Figure 2.4: Traffic Speed Limit Sign *(Gikaru Wilfred G, 2015)*

According to Nourdine (2014) traffic signs in front of vehicles may not be often seen by drivers, because of their different perceptions and lack of self-consciousness to surrounding environment.

2.4.6 Information awareness and responsibility

Organizations have made it part of their Corporate Social Responsibility initiative to caution drivers and road users about speeding (Gikaru Wilfred G, 2015). Messages on careful use of roads such as “arrive alive” “Do not Speed” “Drive Carefully” are used to alert motorists of the dangers and effects of speeding on roads.

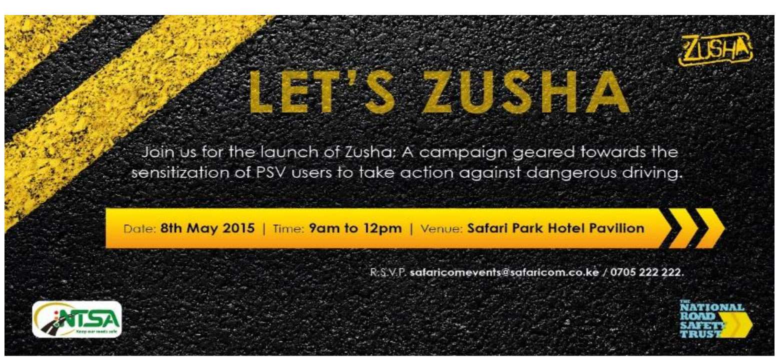

Figure 2.5: Campaign to curb speeding in Kenya *(Zusha, 2010)*

Several corporate organizations including Safaricom Limited, East African Breweries Limited and NTSA have launched campaigns targeting motorists to slow down on roads. This media campaigns are highly effective in combating this calamity. Along the major dual carriage highways, Thika road and Waiyaki way, remains of damaged vehicles have been put up as constant remainders about the effects of careless driving.

Figure 2.6: Speed kills warning on Kenyan Road *(Arrive alive, 2014)*

2.5 ICT Solutions for speed management

2.5.1 Automatic Speed alert systems

Speed alert systems warns drivers when they exceed the posted speed limit in order to minimize the role that speeding plays in road accidents (Higgins, 2013). SpeedAlert was developed in Australia to help drivers avoid speeding tickets. It links real time location information and speed obtained with aid of a Global Positioning System (GPS) to a database of stored speed limits on the drivers' mobile device. Once a driver exceeds the speed limit, the speed is shown on a PDA device and an alert sound if the driver fails to slow down (Britt, 2006). Bluetooth technology is used to connect the PDA and the motorist's mobile device. This system does not provide mapping of speed limit zones and consumes high amounts of device power in transmitting data.

Figure 2.7: automatic speed limit alert systems *(Britt, 2006)*

2.5.2 Speed Limiters

This technology has been introduced by car manufacturers where the driver can set the maximum speed of navigation and then get warning signals when the speed is exceeded. In fact, other speed limiters have been introduced to maintain speed to a specified maximum (Prosper , 2006).

2.5.3 Cruise control

Cruise control, also known as speed control or auto cruise is a system that controls speed of vehicles. Motorists have access to speed-limit information in the vehicle hence can maintain a steady speed without need for the driver to keep the accelerator pedal depressed (Prosper , 2006). Once the driver has activated the system and made a desired speed setting, the engine Control Module compares the actual speed of the vehicle as detected by the accelerometer with the preset speed in the ECM and generates a signal with the difference between the two speeds. This signal is transmitted to the control area to maintain speed to the preset vehicle speed (Bengtsson, 2001).

2.5.4 Intelligent speed adaptation

The intelligent speed adaptation system combines the functions of speed limiter and speed alert system. In this case, the vehicle can be limited not to exceed a particular speed limit. In Sweden, the implementation of the ISA has proven successful on a small scale perspective, but large scale implementation has proved difficult due to quality and legal issues (Prosper , 2006).

2.6 Existing Research in area of study

There are a number of systems that have been developed globally to curb speeding. These systems rely heavily on ICT technologies discussed above for implementation. They seek to notify drivers of traffic regulations on roads as well as monitor traffic violations. Some of these systems are directly connected to the authorities to provide real time information regarding speed violations on the roadways.

2.6.1 Driving assistance system

According to Nourdine Aliane (2014), majority of traffic violations, such as speeding or ignoring stop signs, are unintentional since they occur due to a lack of concentration by the drivers. She further explains that a driving assistance systems for alerting drivers about their negligent behavior on the road and warning them to be more vigilant should be considered a primary solution for preventing accidents. This system uses Traffic Sign detection and recognition technology to detect and read traffic regulation signs along the roads. It consists of an embedded system with a processor module for real time image processing. The processor module (mini-ITX) integrates external devices such as GPS unit, card reader and a touch pad screen which provides an interactive GUI (Nourdine Aliane, 2014).

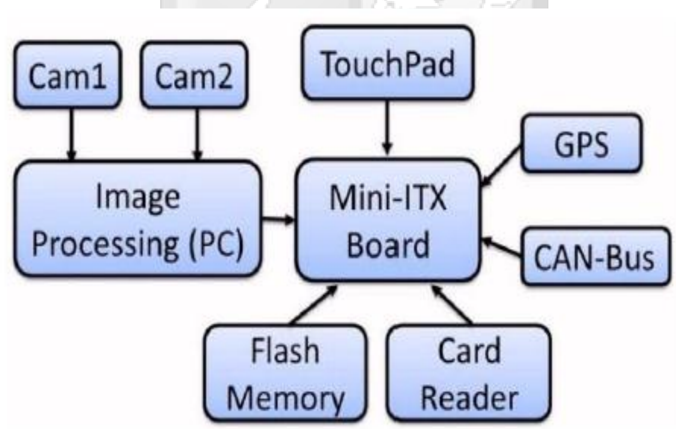

Figure 2.8: Driving assistance system *(Nourdine Aliane, 2014)*

The front end Human-Machine interface (HMI) gives the users direct access to multiple functionalities. The interface displays the last four captured traffic signs and displays on the screen. In the event of a traffic violation, a warning signal is emitted through the vehicles loud speakers.

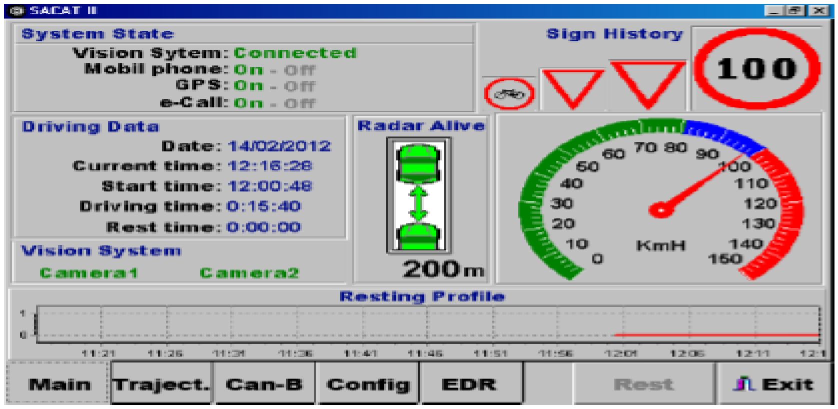

Figure 2.9: Human-Machine Interface for driving assistance system *(Nourdine Aliane, 2014)*

A record of the speed violations is maintained to allow drivers to retrieve their own data and hence evaluate their speeding behaviours. The figure below shows a snapshot of the tool that was implemented to retrieve traffic violation record. This system also enables the drivers to analyse their driving behaviours by generating a geographical map showing violations captured during a round trip. This helped drivers to retrieve hidden data about the images of the surrounding where a violation occurred.

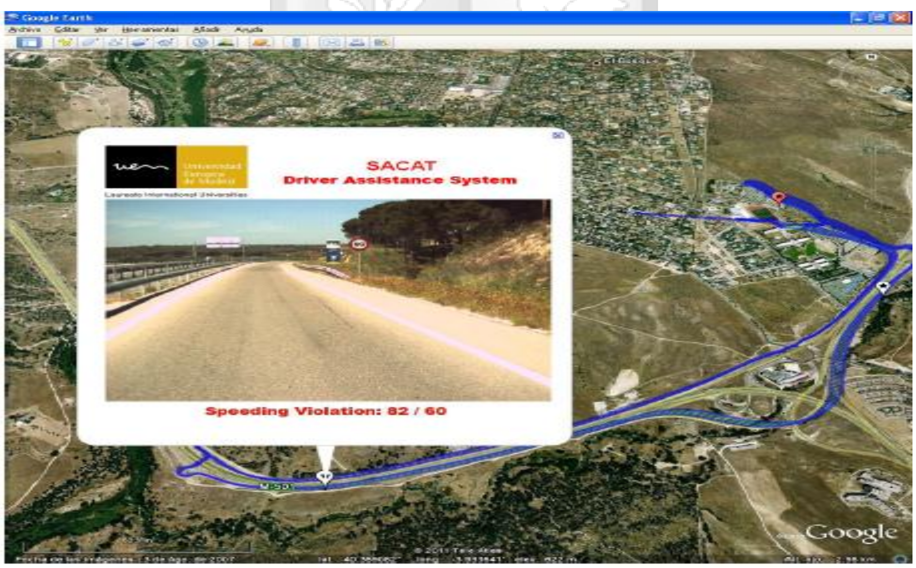

Figure 2.10: Map Interface showing speed violation *(Nourdine Aliane, 2014)*

2.6.2 Speed Violation Management system

This is an intelligent Speed Adaptation system for monitoring, registering and reporting of speed violations. The drivers' behaviour is monitored and a penalty amount calculated. Speed limit information is sent with the help of Zigbee wireless protocol to a particular lane on the road. The present speed of the vehicle is captured and compared with the speed limit and if exceeded, it should be controlled manually. In the event that the speed is not manually reduced, a system automatically reduces the speed of the vehicle (Shende, 2015).

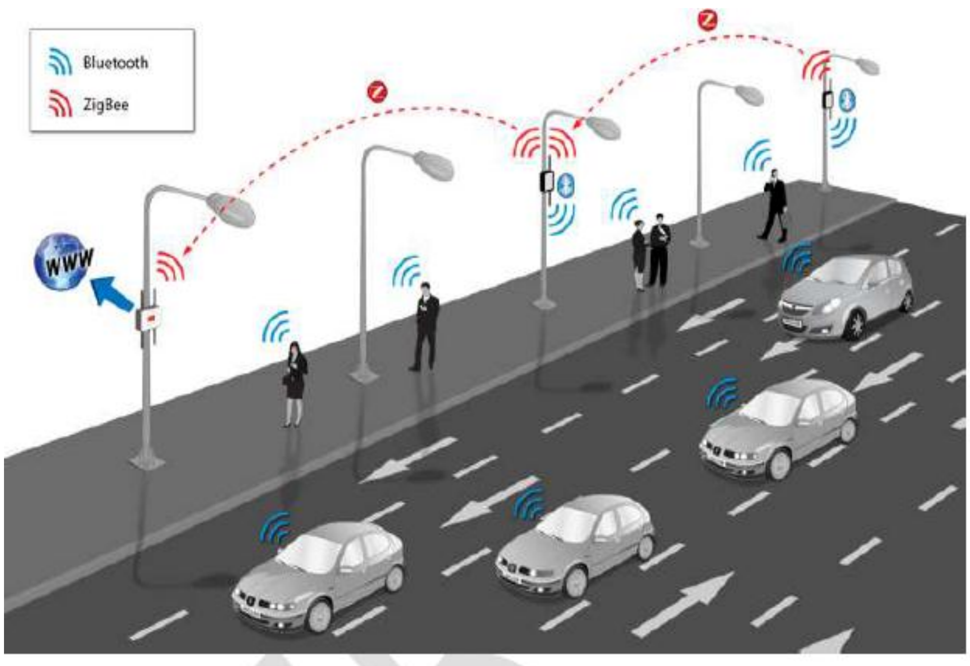

Figure 2.11: Speed Management and control System *(Shende, 2015)*

2.6.3 Speed Monitoring System

This system consists of the following components; GPS receiver, Microcontroller, GSM shield and an LCD Display unit. The GPS receiver obtains the location of the vehicle on the road. The Microcontroller unit is used to compare the speed captured with the speed limit and determine cases of speeding while the LCD display unit provides a visual interface showing the current speed and speed limit. If the speed of the vehicle is exceeded, an alert message is generated and SMS notification sent to the authorities' database.

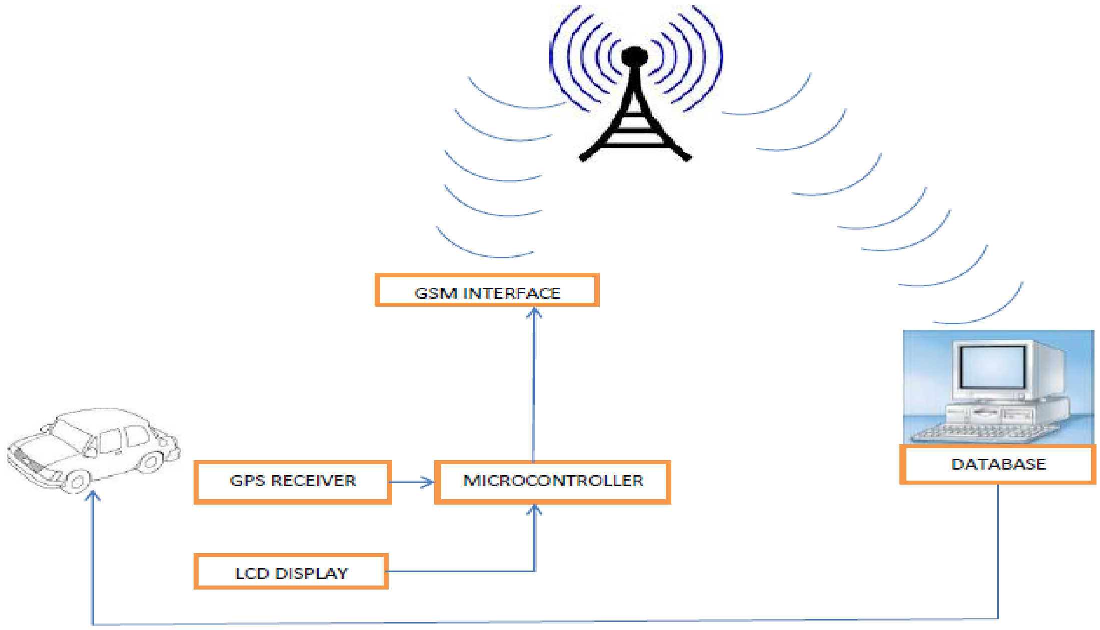

Figure 2.12: Speed management system *(KAIRU, 2012)*

2.7 Existing Speed Management Systems

2.7.1 Intelligent Speed Adaptation System

Intelligent Speed Adaptation system is an in-vehicle system that uses Global Positioning system to determine the location of a vehicle in relation to the speed limit in force at that particular location. It is a driver's assistance system which helps comply with the speed limit regulations within an area (Commision, 2009) . Experiments were carried out in Sweden and Netherlands to determine effectiveness of this system. A positive effect was noted as the driving speeds were slower and homogenous. The functionalities achieved from ISA include:

i. An in vehicle alert system to warn the driver that the speed limit is being exceeded. This is purely an informative system and the driver has an option of slowing down or not.

ii. Automatically limits the speed if it is exceeded. This system is mandatory or voluntary and the driver has an option of switching it on or off.

After implementation of this system in Sweden and Netherlands, a survey was carried out to determine its efficiency and effectiveness. Approximately 25% of the European drivers gave the opinion that the ISA system proved to be very useful as it restrains vehicle within the speed limits.

2.7.2 Automatic speed Cameras

Speed Cameras are the most widely speed management systems in the world. It has been adopted in countries such as Australia, Austria, Israel, Norway and the United Kingdom. They have proved to be more efficient compared to the traditional police enforcement since they generate majority of the speeding Tickets. This system is implemented by positioning two cameras at a selected position on the road. Upon detection of a speeding vehicle, one camera takes a snapshot of the license plate- usually the rear plate while the other camera measures the average vehicle speed over a particular distance. The second camera uses radar technology to measure the speeds.

Netherlands is currently testing a system that uses a set of three speed cameras installed within a three kilometer stretch of major highways. Images of the license plates for the vehicles are captured and stored only for a period long enough to enable the system to perform a search for the vehicle license plate. The system calculates the speed of the vehicle once a match is detected and if the speed exceeds the speed limit, the details of the vehicle are stored as evidence of speed violation (Research, 2013).

Figure 2.13: Speed Camera in Netherlands *(ITS International, 2013)*

2.7.3 Mapping speed limit zones

In Ireland, map-based bye-Laws are produced with the use of maps only. This provides an efficient way to deliver speed limit laws since they are easy to read and be displayed on a web portal (Department of Transport, 2015). Speed limit zones reinforce drivers' assessment of safe speed as well as act as a guide to the nature of the road.

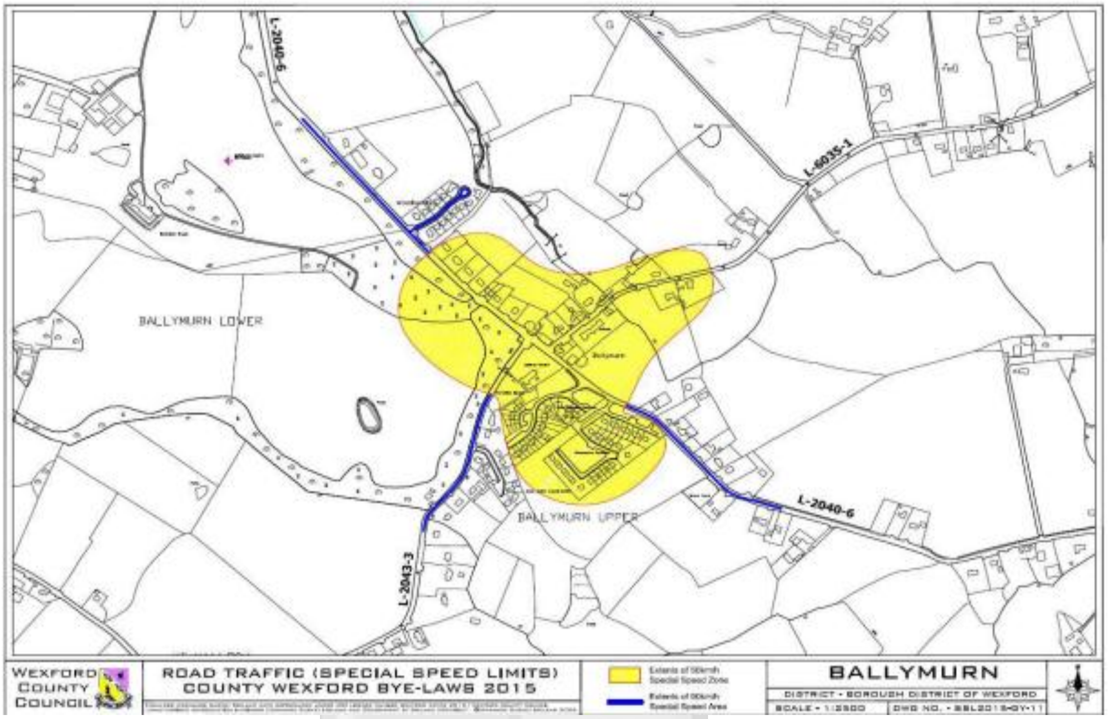

Figure 2.14: Galway county council and Wexford County Council *(Guidelines for setting and managing speed limits in Ireland, 2015)*

A Pavement Management System (PMS) was designed and developed for the Local Government Management Agency in Ireland. This system aims to achieve a standardized approach to management of more than 91,000 km of Irish roads (Department of Transport, 2015). It includes a computer based system and mobile application focusing on planning and recording of road improvement programs. The mobile application, MapRoad PMS allows the local authority to map speed limit signs in their areas of jurisdiction. The information is uploaded to the mobile app and allows users to create and modify speed limit sections and zones (Department of Transport, 2015).

A motorists is allowed to sync any pending uploads of speed limit zones updated by the local authorities to their android device. Additionally, it allows for data capture, where a road user can enter speed limit data and capture images as well as location of the speed limit signs. This data is synchronized to the users' device and can be viewed on the map.

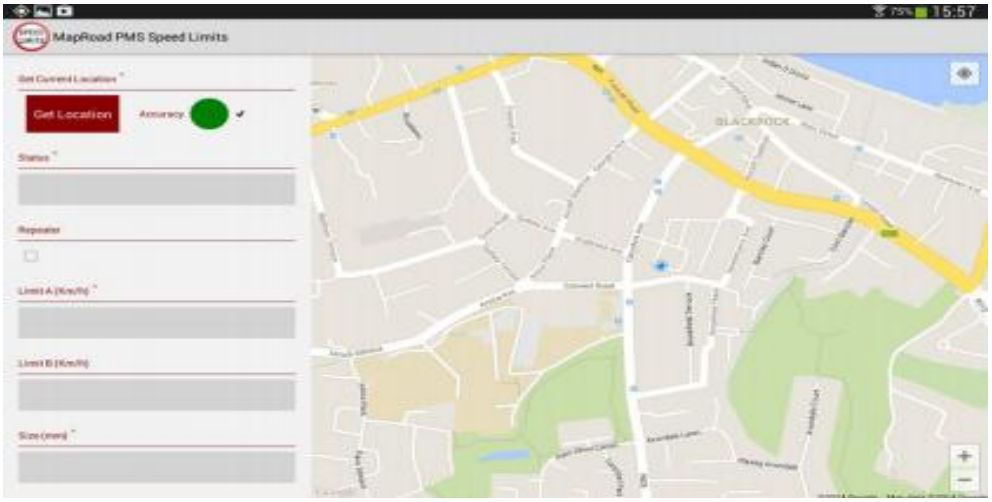

Figure 2.15: map view of PMS system *(Guidelines for setting and managing speed limits in Ireland, 2015).*

The PMS System captures speed limit information with aid of speed limit signs on the roads. The application is developed to assist in capturing the sign post locations. It is the primary method of recording the speed signs while the browser is used for entering location data and removing information (Department of Transport, 2015).

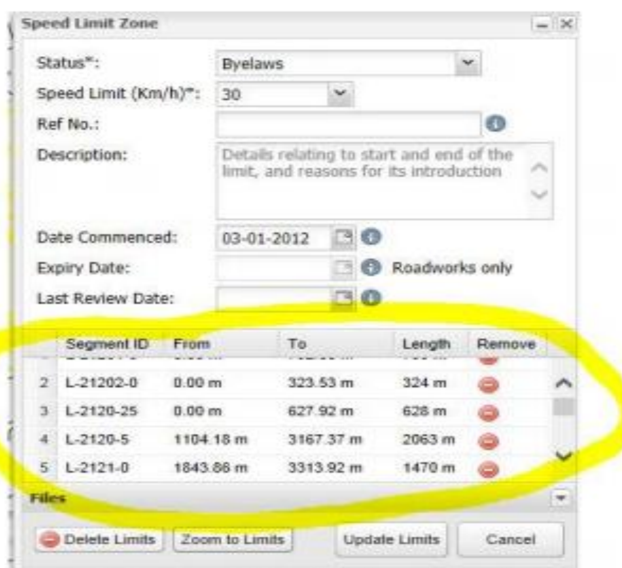

Figure 2.16: Speed limit zoning *(Guidelines for setting and managing speed limits in Ireland, 2015)*

This system allows users to feed data about speed limit zones in sections of the roads as shown in the figure above. This zones are comprised of the segment ID, the distance and speed limit within that particular distance. Additionally, road users are allowed to input information related to a particular speed limit sign.

Figure 2.17: setting up speed limit sign data *(Department of Transport, 2015)*

2.7.4 Traffic Violation Reporting

Most developed countries have implemented an online portal through which vehicle owners can view and pay for traffic violations to the regulatory bodies. In Qatar, the ministry of Interior is responsible for providing this service. Motorists are requested for ID and vehicle license number or establishment ID. A list of all the violations is displayed with records about date/time, location, description, violation and the amount due.

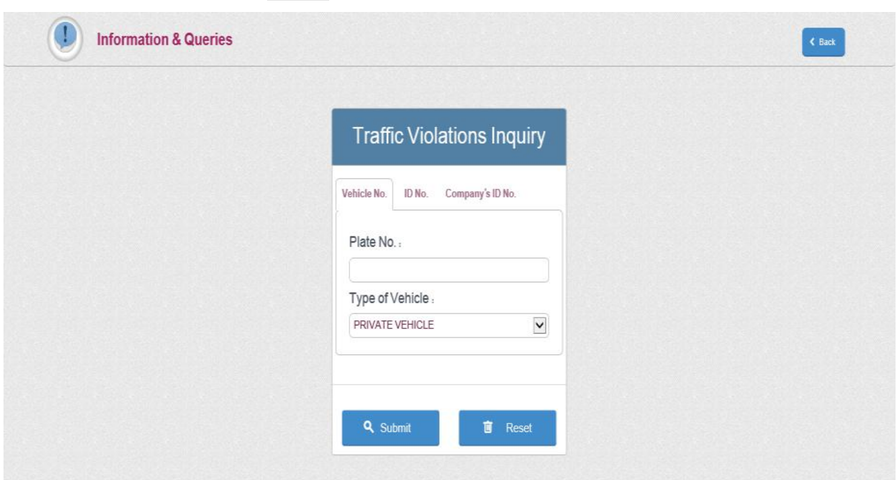

Figure 2.18: Online Portal to view violations and pay fines *(State of Qatar, Ministry of Transport)*

2.8 Speed Detection Technologies

There are a number of technologies and techniques developed in an attempt detect speed violations on roads. These technologies have been tested in various countries around the world including Kenya.

2.8.1 Radar Technology

The principle of radar technology is dependent on transmission of electromagnetic waves to a moving or stationary object. Reflection of the waves result in a change of frequency and is interpreted by radar device in a speed calculation (Sukhdeep Singh, 2014). There are three ways adopted in the implementation of this technology

i. Stationary Supervised Speed Measurement with Radar

Speed measurement is performed with the radar device installed in a stationary vehicle. Traffic police can be able to monitor the speed of vehicles in real time and hence immediately inform the motorists of the traffic violation (mohammed, 2014).

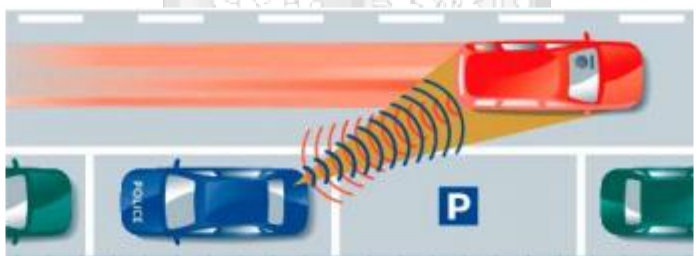

Figure 2.19: stationary speed measuring radar system (mohammed, 2014)

ii. Stationary Autonomous Speed Measurement with Radar

This system does not require constant supervision. The radar equipment is deployed in a fixed location. The speed violations of vehicles is automatically captured and either saved locally or transmitted to evaluation center.

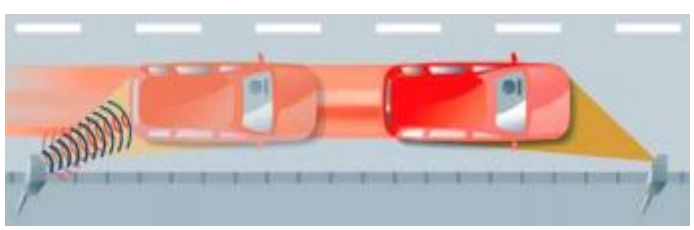

Figure 2.20: stationary autonomous speed measurement with radar (mohammed, 2014)

iii. Speed Measurement with Radar while Moving

This is also referred to as the moving radar. Gadgets that adopt this technology measure the difference in speed between the traffic patrol vehicle and the targeted motorists' car. This is commonly adopted on motorways. Radar systems have been widely adopted in speed guns all over the world since they can be installed on both moving and stationary objects. Despite their high cost, they are easy to install since they do not have a lot of hardware requirements.

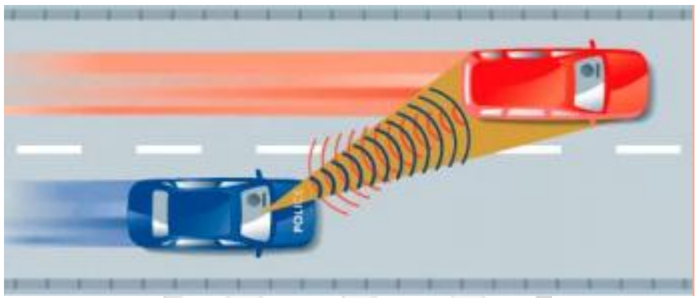

Figure 2.21: Speed measurement with moving radar (mohammed, 2014).

2.8.2 Laser Light system

The Laser light system relies on the reflection time of light to determine the speed of objects in motion. Laser guns are used in this technology. These devices are mostly handheld and manually operated. When measuring speed, the delay period between the infrared pulses transmitted to the vehicle and back to the receiver makes it possible to calculate the distance between the two objects. Through this, speed can be easily determined by dividing the distance captured with the time taken to transmit the infrared signal. Laser technique is mostly used within city limits or construction areas since the measurement distance is limited to 30 to 50 meters. Compared to the radar systems, laser light systems are more accurate and have less hardware installation requirements.

2.8.2.1 Average Speed Computer System

This system uses a programmed computer to determine the speed of vehicles on roads. It measures the distance travelled and divides it by the time it took to travel the distance. The key difference with the average speed computer system is that it can be used in stationary and moving mode (Jenoptik, 2009). They measure the average speed over a specified distance. This system uses Automatic Number Plate Reading (ANPR) digital technology and can be fitted above the roads since they can work day and night (Speed cameras UK, 2016).

Figure 2.22: Average Speed capture system *(Speed cameras UK, 2016)*

2.8.3 Vision Based System

This is one of the most intelligent and convenient methods in vehicle speed measurement. It uses two consecutive images captured form traffic camera system to determine the speed of an individual vehicle. The two images are transformed from image plane to 3D world coordinates. The difference of the two images is computed and mapped into one image. Finally, a block feature of vehicle closest to the ground is matched to estimate the distance and speed of vehicle.

2.9 Development Platform and Framework

The section of the literature review looks at how mobile devices are adopted and used within Kenya. It also seeks to explain the different types of frameworks for developing mobile applications.

2.9.1 Penetration of Mobile devices in Kenya

Kenya has been rated among the fastest growing economies in Africa with respect to mobile and internet penetration. Its mobile and internet penetration is among the highest at 83% and 58% respectively. As at September 2014, the total number of mobile subscribers increased to 32.8 million. According to Zab (2015)., the estimated number of internet users across all Mobile Network Operators (MNOs) stands at 26.1 million where 99.9% access the internet through mobile data. She further explains that 58% of all phones sold in the country were smartphones with the remaining 42% as feature phones.

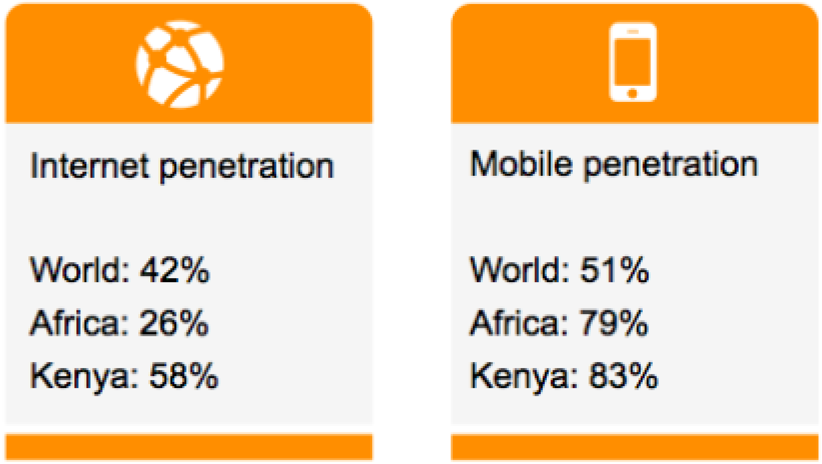

Figure 2.23: Mobile and Internet Penetration in Kenya *(Zab, 2015)*

All the above shows that it is important to develop a mobile application since more people will be able to access it.

2.10 Summary

This research has pointed out existing systems adopted in different parts of the world in an effort to curb speeding. These systems adopt varied methodologies and strategies which have proved efficient to an extent beyond which they are easily manipulated. The situation in Kenya has been clearly highlighted and from the evidence provided, there is so much more that can be done to enhance current existing systems.

The system will help solve the problem of speeding on the roads through providing motorists with mapping zone data in Nairobi County. Additionally, it will provide tangible evidence of speed violations hence creating accountability to the involved parties.

Chapter 3: Research Methodology

3.1 Introduction

This chapter explains the research method, location of the study, purpose of study, data collection techniques and data analysis adopted. This section looks at the system development methodology adopted in the proposed system. The approaches applied in system analysis, system architecture, system design, system development, and implementation and testing.

3.2 Agile Software Development Methodology

Agile software development methodology was selected as it ensures that users of the system and developer work closely to achieve the set objectives. It adopts iterative development and releases multiple versions to the users for verification. It is a continuous design process that accepts change and tests throughout the development process.

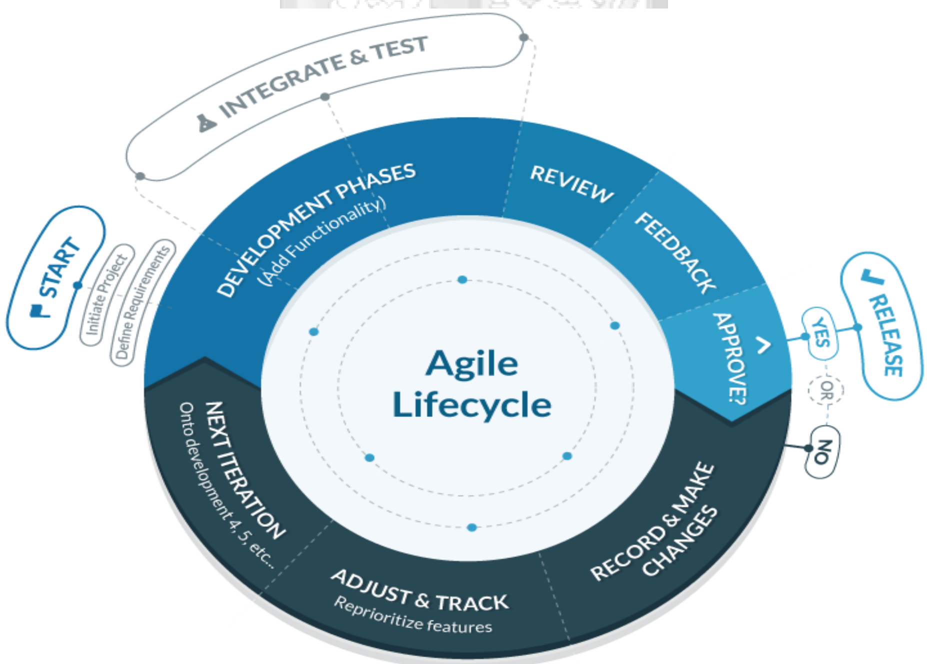

Figure 3.1: Agile Development *(Burger, 2016)*

Figure 3.1 explains the steps that are followed in Agile Methodology from the start to release stage. Unlike other software development methodologies, agile is more flexible and provides developers with room for error and change. It is more people oriented as it considers inputs from customers and end users. This software development process is more adaptive to change at all stages of development. It involves getting customer feedback on a regular and frequent basis and making necessary adjustments.

3.3 Research Design

This study used two research methods

- Qualitative research method

Qualitative research method helps to gain a deeper understanding of the operation of current systems. It helped in understanding how speed limit regulations are monitored by PSV agencies and vehicle owners and how PSV operators know about the various speed limit regulations on roads. Personal interviews was the main tools adopted to collect relevant facts about this research.

- Quantitative research method

Quantitative research was used in collecting statistical data from the target population. The researcher adopted the use of online and manual Questionnaires as well as analyzing journals and documents as the main data collection tools. This sought to determine the number PSV Agencies who would be willing to adopt the system and the percentage who thought it was a good idea.

3.3.1 System Architecture

The system is composed of three major sections; embedded system, Mobile application and the web application. The embedded system is composed of a microcontroller, GSM module, GPS module, accelerometer and a buzzer. Android architecture is used to develop the mobile application. The web application was constructed using the Yii framework written in PHP5 since it is open source, provides security as part of the framework, offers good performance and is easy to scale and customize. MySQL database management system was used to store application data for both mobile and web application. MySQL database is open source and provides full compatibility with PHP and the Yii framework.

3.3.2 System Analysis

There are 3 approaches in information system development section; data-oriented, process oriented, and object-oriented approaches. The object-oriented method combines processes and data into single entities called objects (University of Missouri , 2001) . OOA escalates the understanding of problem domains because OOA promotes a smooth transition from the analysis phase to the design phase and offers a more ordinary way of establishing specifications. This study focuses on use-case modeling and class modeling to explore the various approaches that are conducted in the analysis of the system. In the object-oriented system development life cycle, use-case modeling is established in the analysis phase. Use-case modeling is done in the initial stages of system development to help the developers gain a perfect understanding of the functional requirement of the system without worrying about how those requirements will be applied (University of Missouri , 2001).A use-case model consists of use cases and actors. An actor is an external entity that interacts with the system and a use case denotes a sequence of activities initiated by an actor to achieve a precise objective (Hoffer, 2001)

3.3.3 System Design

Object-oriented system design (OOD) involves defining the context of a system followed by the architecture of the system. The static and dynamic parts of the context are defined. The static part is composed of a block diagram of the entire system which is broken down into several subsystems. Design class diagrams entails comprehensive modeling to translate the models into programming code and for data modeling. The research adopted design class diagram to embrace classes which comprise the main methods, objects and interactions of the system (Sparks, 2001). Entity Relationship Diagram (ERD) and collaboration diagram was used to demonstrate the relationships between objects and events within a system. Use case diagrams are adopted in modelling the dynamic part which describes how the system interacts with the environment. The system requirements, specification, system functionality and architecture details are defined during system design for the embedded system. The functionality of the embedded system is usually fixed and handled by the built in software which is closely related to the hardware.

3.3.4 System Implementation

Android platform was used to develop the mobile application. The web application was constructed using the Yii framework written in PHP5. MySQL database management system was used to store application data for both mobile and web application. Embedded system components were integrated through soldering and pin configuration procedures. The GSM module, GPS module, capacitive display, accelerometer and buzzer unit were connected to the microprocessor. Arduino IDE was used to run C++ code in the processor which enabled communication between components. An SMS to web gateway was implemented as the communication channel between the embedded system and the web application.

3.3.5 System Testing

System testing was divided into two major sections, developer testing and user Assessment testing. Developer testing was carried out to ensure that the functionalities were working well. Developer tests included: unit testing, integration testing, compatibility testing and functionality testing. These tests were carried out at different stages of development of the system. User assessment testing aimed at getting the users feedback on the completed system.

3.4 Target Population

The target population was split into two groups, population prior to system development and the population after the system was developed. The first group helped to see need of the system while the second group was to verify the system meets all specified requirements. The first group selected was the PSV agencies. Interviews and questionnaires were used to carry out research to determine applicability of system. The transport agency drivers belonging to different agencies were interviewed to understand the situations on the roads. Additionally, vehicle owners who had registered their vehicles with the agencies were interviewed to evaluate the applicability of the proposed system.

3.5 Sample Size and Sampling techniques

As discussed in the research design, the researcher adopted both the Qualitative and Quantitative research methods. In Quantitative research, the required sample size was calculated before beginning the study. Simple random selection was the main sampling technique to determine the sample size. The sample population was chosen at random from the motorists and NTSA.

$$n = \frac{z^2 \ * p * q}{c^2}$$

Equation 3.1: Random Sampling *(Rusli, 2006)*

Where:

n = sample size.

z = z value (e.g. 1.96 for 95% confidence level).

p = sample proportion of successes, expressed as decimal.

q = 1-p

c = confidence interval, expressed as decimal.

Equation 3.2 shows the formulae that was used to derive the required sample size. All individuals in the target population had an equal chance of being in the sample population. But due to the large number of motorists in Nairobi, the research was done on a few since only one hardware component was developed in this project. The questionnaires were handed out to over 100 people from the public and calculated with a confidence level of 95% and a confidence interval of 1.43 (Creative Research Systems, 2012). The employees from NTSA and their seniors who were selected randomly plus 10 motorist were interviewed to get a feel of their experiences and views about the current system and what they consider should change.

3.6 Location of Study

This study targeted the transport agencies and agency stakeholders. This study was carried out on sections of two major highways in Nairobi County; Strathmore University-JKIA and Globe Cinema-Juja town. This sections were exclusively selected due to their diverse range of speed limits. The map section below shows the routes selected for mapping.

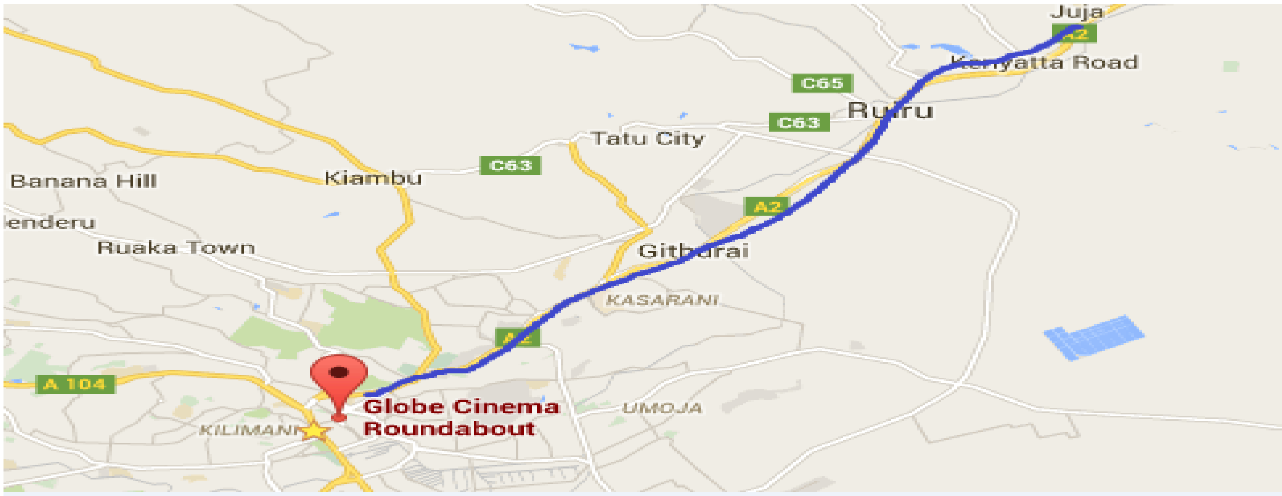

Figure 3.1: Route: Globe Roundabout to Juja town

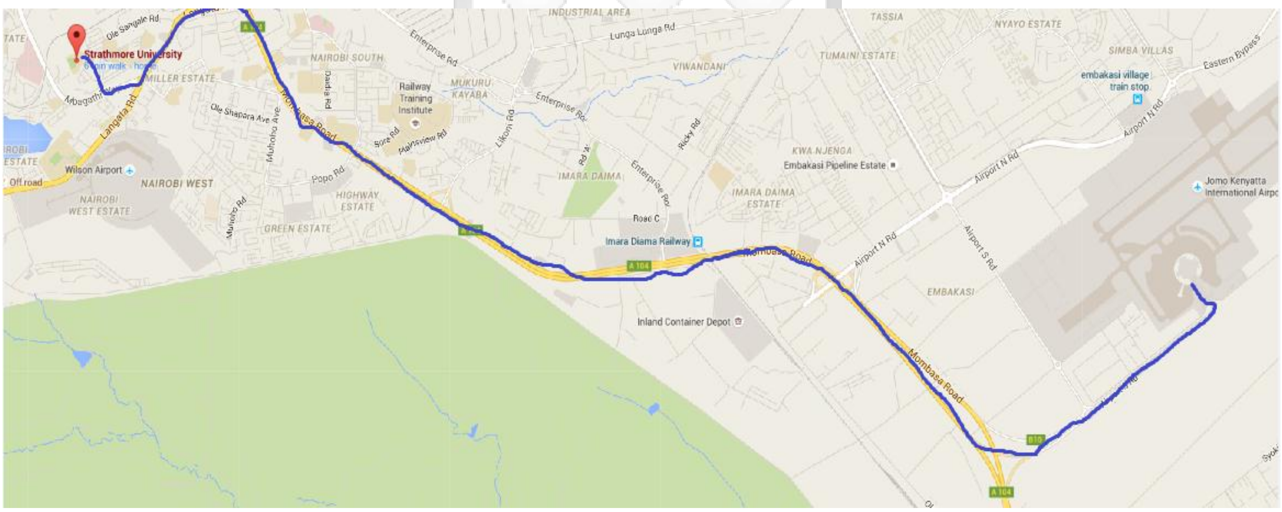

Figure 3.2: Route: Strathmore to JKIA

3.7 Research Quality Aspects

Research quality aspects is the degree to which the research was carried out correctly. Validity and reliability were used to test the quality aspects.

3.7.1 Validity

Validity determines whether the research truly measures that which it is intended to measure and how truthful the results are. Validity of the research is determined through asking a series of questions relevant to the study. It ensures that the researcher does not collect the wrong data and that the research questions yielded valid results.

3.7.2 Reliability

Reliability is the extent to which the yielded results are consistent over a period of time. The research instrument is required to be reliable and should reproduce similar results under a similar methodology. Croker and Algina (2011). say that responses to same questions may vary hence it is the work of researcher to ensure that the level of accuracy of the answers are the same or the degree of difference is minimal as this affects the reliability of the research especially for quantitative research. To achieve reliability in this research, a series of similar questions were asked but rephrased to test if same result is obtained during the piloting period.

3.8 Research Instruments

Questionnaires and Interviews were the main research instruments used in this study. The data collection process helped to analyze the current system and develop various user requirements and needs. This helped in formulating the core functionalities of the system, need for development and technologies to adopt in system implementation.

3.8.1 Personal interviews

Interviews were carried out with motorists who have been previously flagged due to a speeding offence to find out about their experiences. The vehicle owners whose vehicles had been registered under particular agencies were also interviewed in an effort to gain insight of how the current system works and to get their perspective and necessary changes.

3.8.2 Questionnaires

Online data collection techniques were carried out on the sample population. The main target were transport agencies and the general public to whom pre and post questionnaires were sent out to. Google forms was used in formulating the questionnaires and reviewing the responses received.

3.9 Data Collection

The data used in this research was collected from the identified target population above. First, permission to conduct the research was sought from the various PSV Agencies since part of the system is highly dependent on their input. Critically analyzing the operations of the organization in curbing speeding was done so as to understand procedures and regulations put in place. Interviews were carried out with the senior management in an effort to gather more information. Finally, interviews were carried out with the different categories of motorists.

3.10 Data Analysis Procedure

The data collected was analyzed using Google analytics as the questionnaires were sent via mail, they were prepared via Google forms and therefore made their processing fast and easy. This tool allowed for quantitative analysis to be done on the data collected. The researcher also used manual questionnaires in conducting the research as 90% of the transport agencies failed to provide feedback via google forms. This data was manually analyzed and represented in a graphical view. The response rate was calculated using the formula in equation 3.2 below

$$Response\ rate = \frac{Total\ number\ of\ respondents}{Sample\ size\ selected}\ x\ 100$$

Equation 3.2: Response rate Formula

This was then used to make conclusions with regards to whether the new system would solve the problems in place.

3.11 Summary

This chapter helped to decide on the population from whom data should be collected. It highlights on the various research methodologies and research instruments used to collect data from the target population and describes how the data collected is analyzed and how conclusions are deduced.

Chapter 4: Presentation of Findings and System Design

4.1 Introduction

This chapter focuses on presentation and analysis of data collected during the course of the research. The analysis was done in an effort to answer the research questions specified in chapter 1. It will also go through the process of designing the desired system based on the research findings analyzed.

4.2 Data Analysis

The research instruments used targeted the general public who use public means of transport, transport agencies, drivers and the owners of vehicles registered in particular transport agencies. Questionnaires handed out to the target groups above were aimed at understanding the current systems adopted in maintaining speed limits and speed violation reporting. A total of 115 respondents participated in the research. Pie Charts were used to illustrate the responses and aid in understanding results obtained. The response rate was calculated as shown in equation 4.1 below

$$Response\ Rate = \frac{115}{153} x100 = 75.16\%$$

Equation 4.1: Response Rate of study

4.3 User Responses

4.3.1 Speeding in Kenya

The responses below were obtained using google forms questionnaires where 83.3% of the sample population thought that speeding on roads highly contributed to road accidents. 16.7% thought that there were other causes of accidents on Roads. The responses of the 16.7% who gave a negative response during the survey has been captured in figure .This response shows that speeding is a major cause of road accidents and should be addressed.

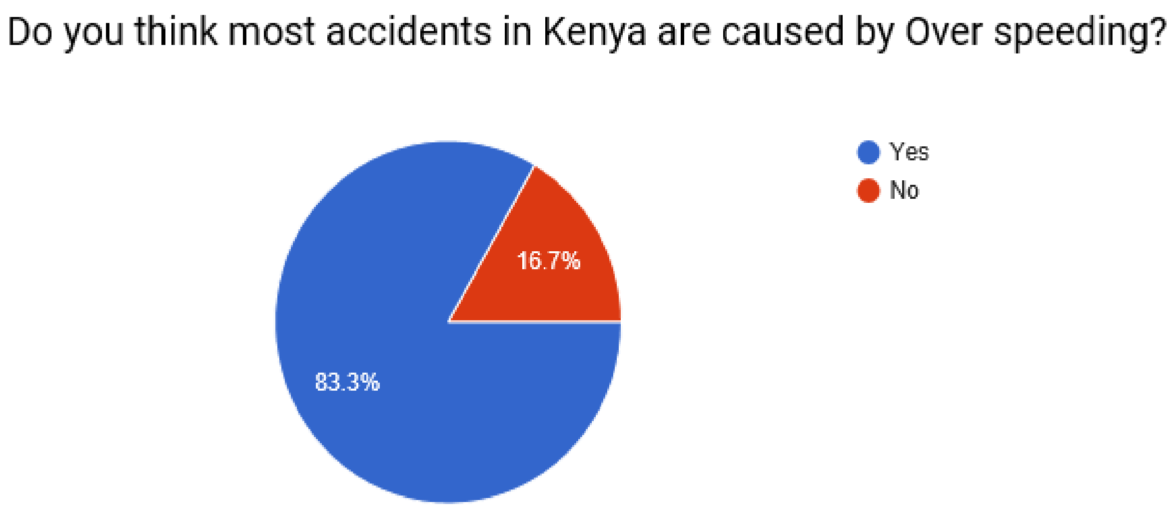

Figure 4.1: Speeding on roads

4.3.2 Current Systems in place

An investigation on whether the measures used to curb speeding for vehicles in the various transport agencies over the past few years have been efficient was carried out. 76.5% of the target population gave a negative response while 23.5 % thought that they were efficient. Figure 4.2 shows a graph of the user response provided. This shows that a more efficient system is required to be put in place to alert monitor speeding vehicles in Kenya.

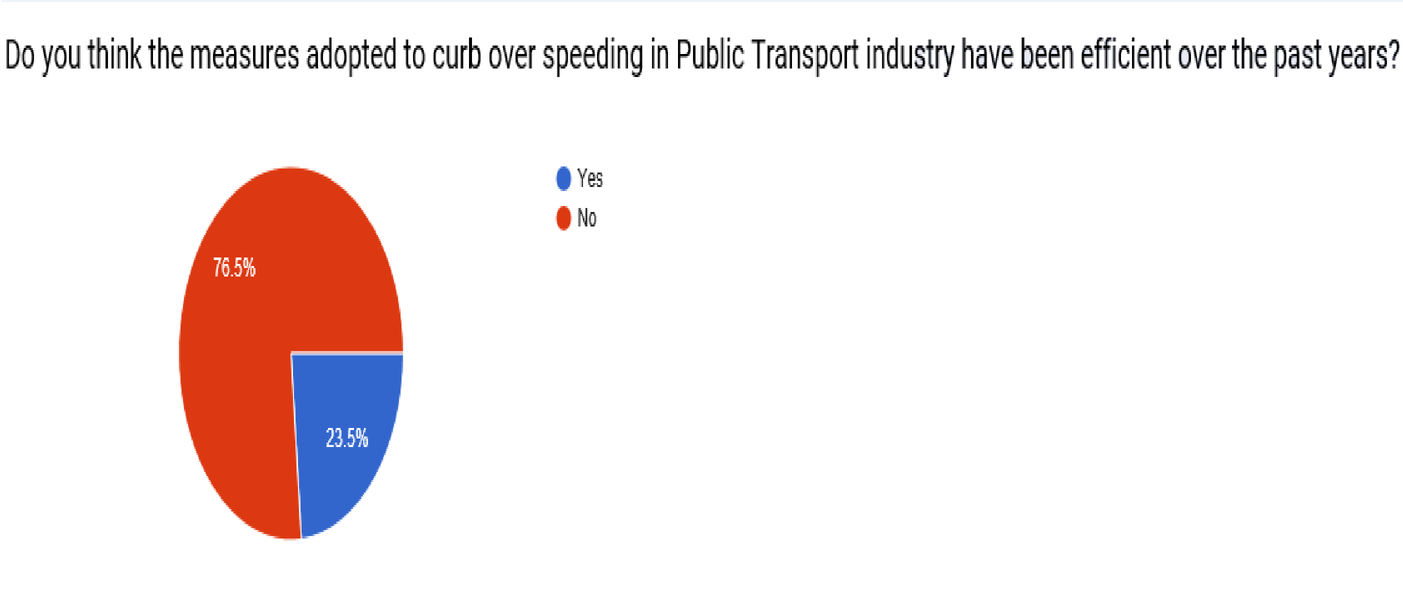

Figure 4.2: Efficiency of current system

4.3.3 Speed Limit Regulations

A research on whether drivers are aware of the speed limit regulations was carried out. 94.4% of the transport agencies and general public involved in the research thought that the drivers are aware of speed limit regulations set by the regulatory body. The figure 4.3 below shows the user response to the question.

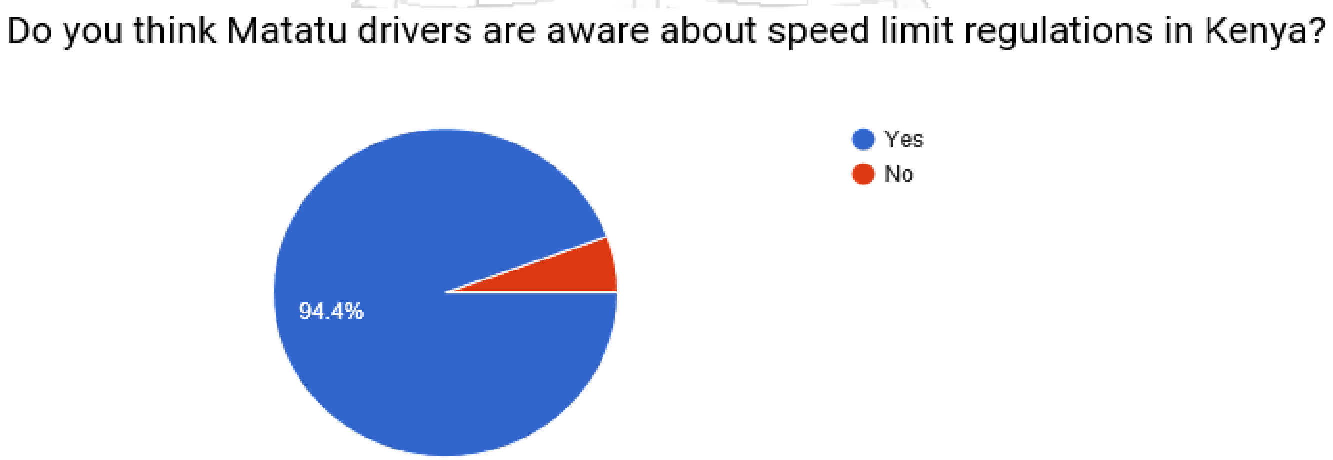

Figure 4.3: Speed Limit Awareness

4.3.4 Validity of Proposed System

A validity test sought to find out if the proposed system would help curb speeding. 77.8 % thought that an alert system to inform drivers about speed would be effective while 22.2% of the sample population gave a negative response. Majority thought that the system will be effective and effective compared to the current system.

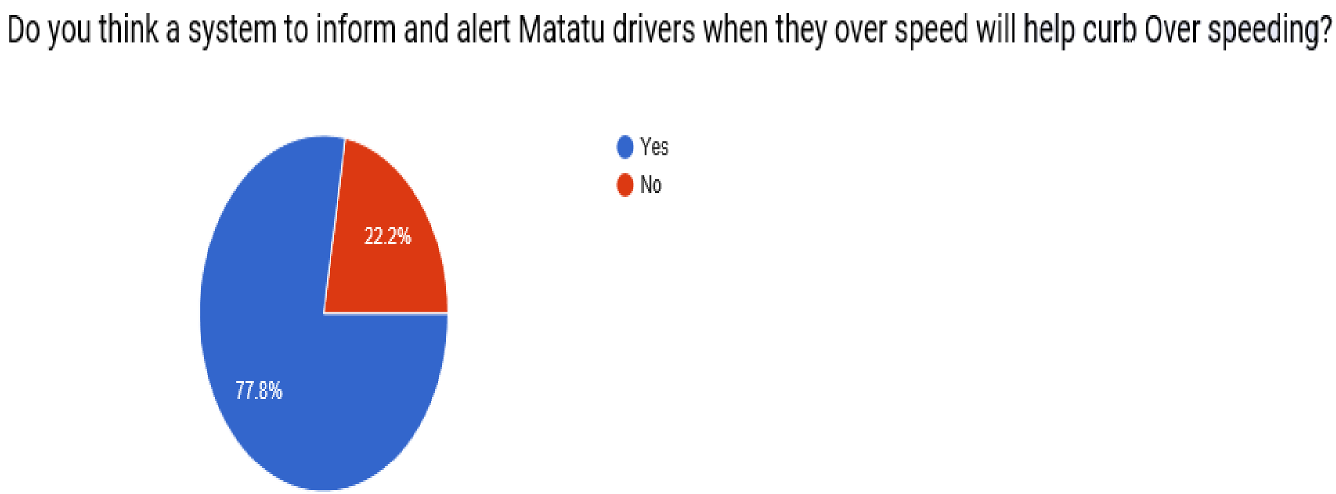

Figure 4.4: Validity of proposed system.

4.3.5 Computer Literacy and Internet Connectivity

With the above in mind, the researcher needed to find out if the Supervisors/administrators in the transport agencies are computer literate and if they have access to internet connectivity at work. Research showed that computer literacy was among the requirements for a supervisory/administrative position in the agencies. Figure 4.5 shows that 94.7% of the population sampled was computer literate and that 80% had access to internet at work.

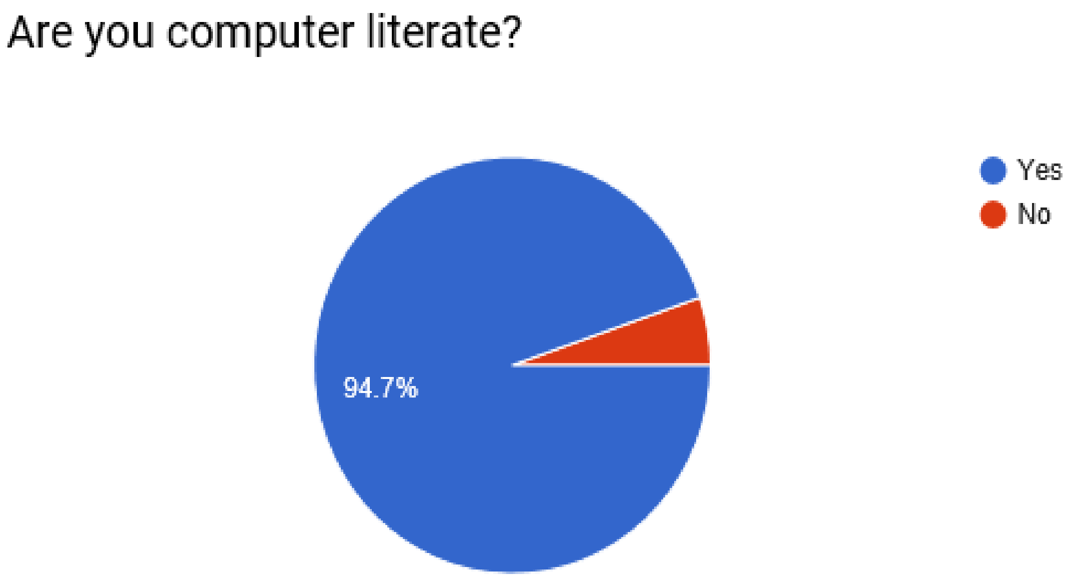

Figure 4.5: Computer Literacy statistics

4.3.6 Mobile Phones

The researcher inquired as to which mobile phones were commonly used by the target population. It was determined that 100% of the population had mobile phones and that 84.2 % of the population used android phones. This helped the researcher to determine the platform on which the mobile application should be built.

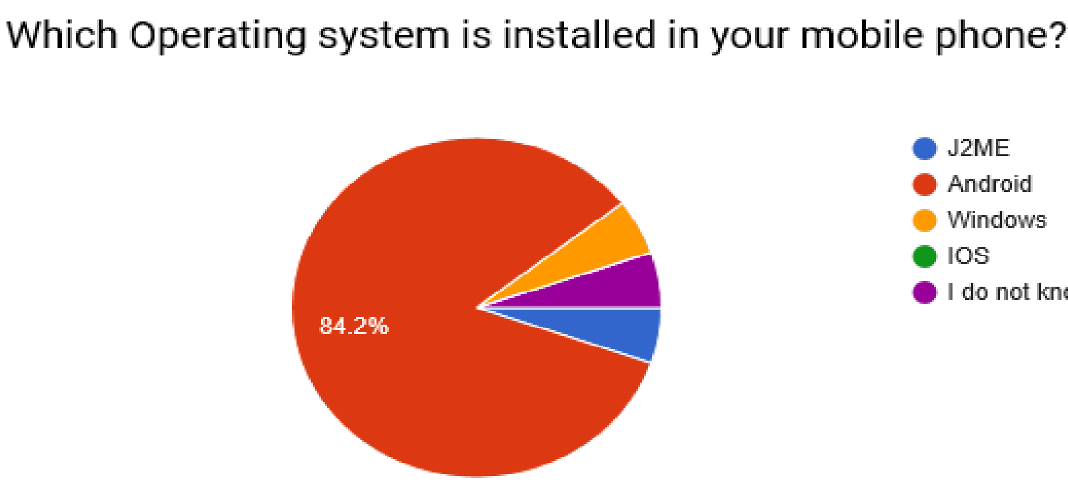

Figure 4.6: Operating system statistics

4.3.7 Willingness for system Testing

Finally, a research on whether the transport agencies would be willing to test functionalities of the completed system was carried out. It was noted that 93.8% of the target population are willing to test the system while the 6.2% provided a negative response. Figure 4.7 shows response by the agencies.

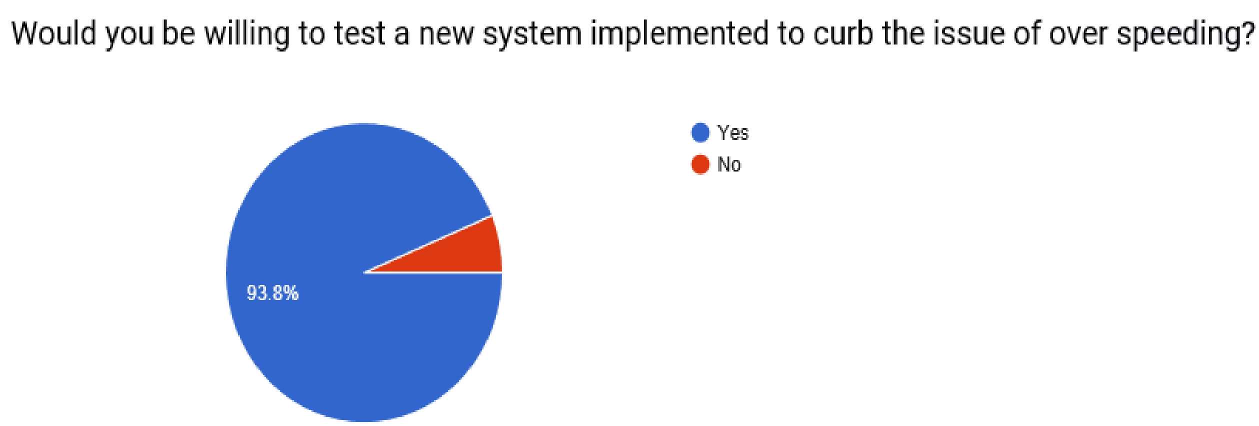

Figure 4.7: willingness for system adoption

4.4 Data Analysis Summary

The response received helped the researcher in deciding whether or not to implement the system. The researcher was able to decide on some of the functionalities to include in the system which had not been considered earlier. The conclusions according to the responses were:

Most potential users of the mobile application and web based system had the required technologies for access to the proposed system. Most users had smart phones and were capable of using the mobile application while the transport agencies had access to internet at their stations, hence able to use the web application. It was clear that the mobile application was to be built on android platform as it was the most commonly used operating system among the target population. The research also showed that most drivers are aware about the various speed limit regulations set on roads though a mapping and alert system would assist in alerting them about the speed limit zones while navigating. The sample population agreed that the system would be highly efficient and effective if implemented especially for the Public Service Transport Industry.

4.5 System Design

System design involves modelling elements to help in visualization of the intended system. Unified Modelling Language (UML) diagrams such as use cases, data flow diagrams, flow charts among others, were used in various stages of the design process to visualize, specify, construct and document the system.

4.5.1 System Architecture

For this system, the modelling was done based on the desired functionality. It is composed of an embedded system which interconnects with an android mobile application to ensure functionality is achieved. The figure below shows the High level interaction between the main components.

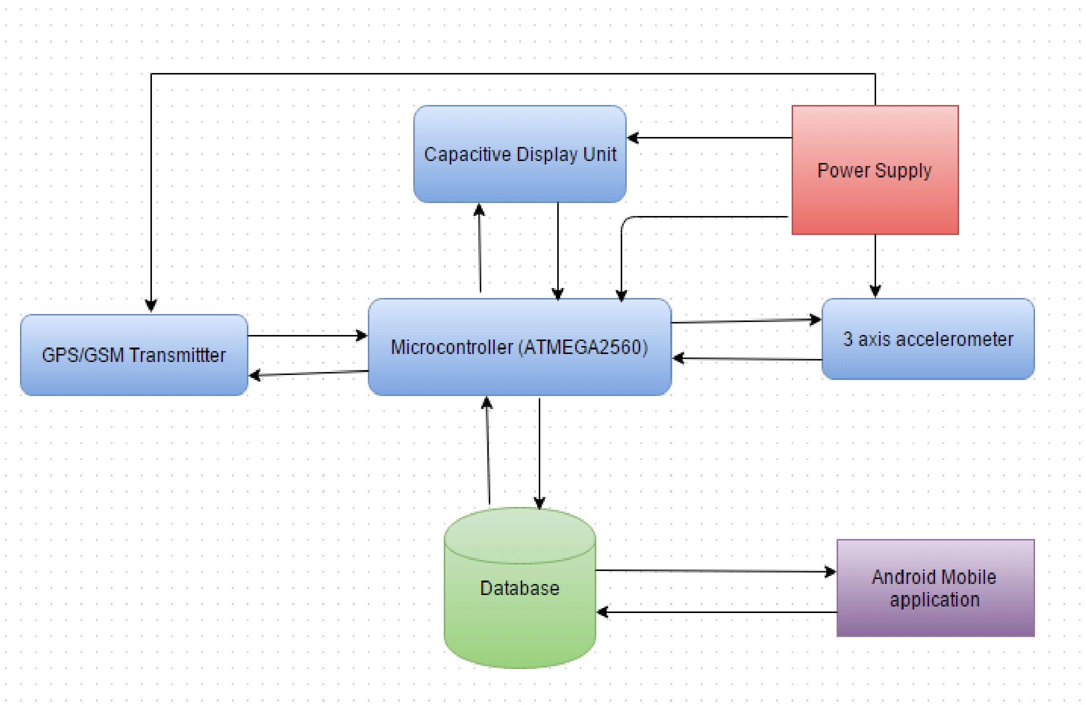

Figure 4.8: System architecture

The microcontroller provides supervisory control of the entire system. The display unit holds the map interface and shows the speed limit zones in various parts of the streets. The accelerometer will be used to detect speed in a particular direction and this will be used against the set speed limits in the area to gauge whether the driver is speeding or not. In case of speeding, an SMS with details of the exceeded speed, location and vehicle details is triggered from the GSM/GPS module to the central processing server. The motorists receive an audio alert from the device (buzzer on board).

The GPS module is used to get the exact coordinate location of the motorist in relation with the specified speed zones. This data is correlated to database which can be queried by the traffic police trough an android mobile application.

The system is consisted of two main parts

- Client Side
- Server side

i. Client Side

This consists of the android mobile application and speed violation embedded system deployed in the vehicle. The mobile application is used as a tool to provide information about speed violations to the legal vehicle owners who have signed up their vehicles in the PSV agencies. The embedded system consists of a display unit to be used by the motorists to view various speed limit zones in relation to their coordinate locations in an effort to notify in the event of speeding.

ii. Server Side

This consists of the server where speed violation information is sent. The embedded system contains a GSM/GPS module responsible for sending an SMS notification with details about location of speed violation, vehicle registration number and the exceeded speed to a database which is queried by mobile application users and the supervisors. It is used to receive, analyze and act on data as well as provide information to the Client side.

4.5.2 Data Flow Diagram (DFD)

A data flow diagram shows interactions between external entities and the system. A DFD also shows the various transformative processes that act on the data, as well as data stores where data resides after some form of action by the processes.

i. Context Diagram

A context diagram is high level data flow diagram showing the movement of data in the system. It shows the entire system as a single entity interacting with external entities and the processes that take place between the system components. In the system, there are three main external entities whose interactions with the systems have been clearly shown.

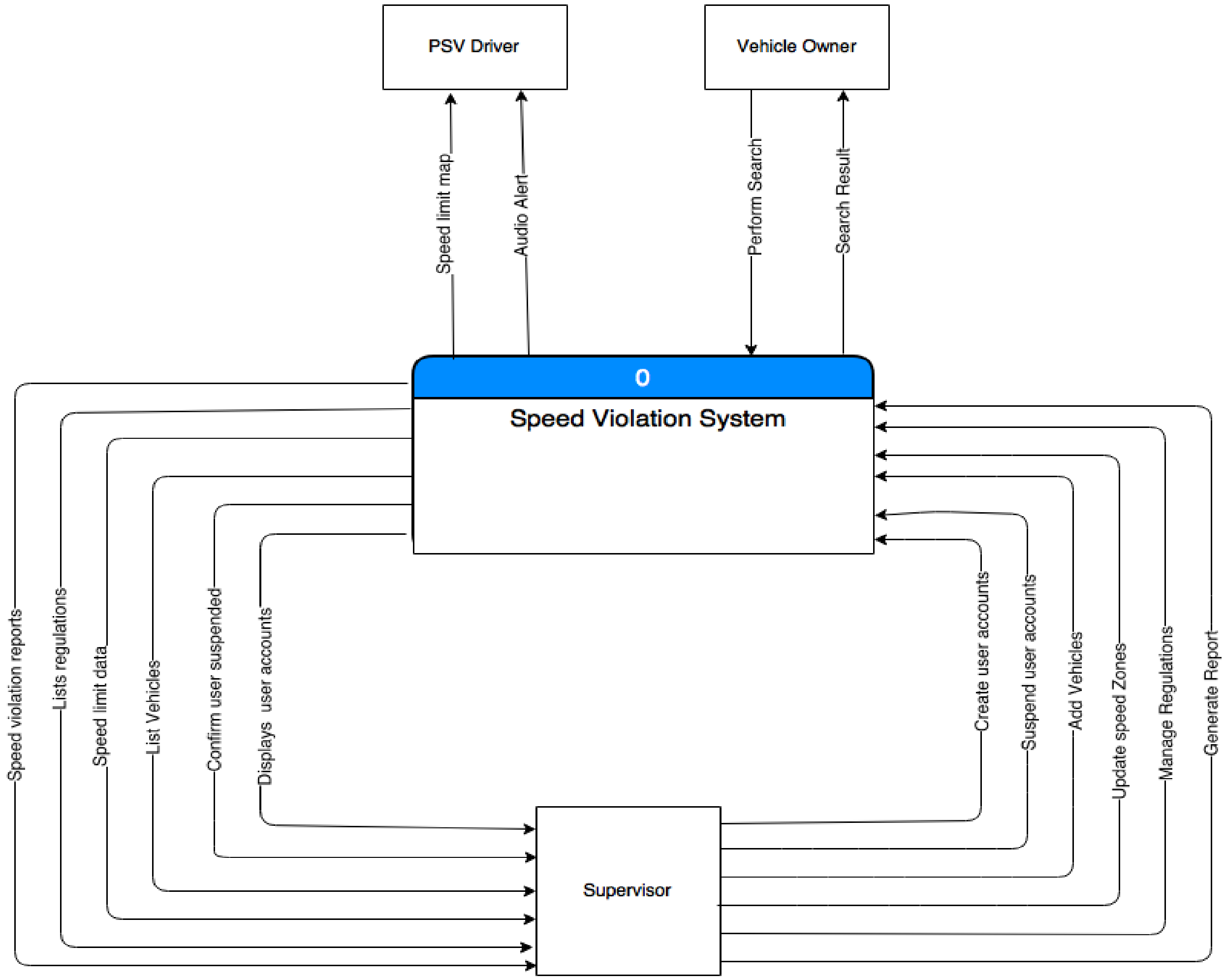

Figure 4.9: Context Diagram

ii. DFD Level 0

Figure shows the flow of data between the various users and the processes in the system. The Level 0 DFD diagram is a more elaborate design of the system as compared to context diagram finally, it shows the data stores available.

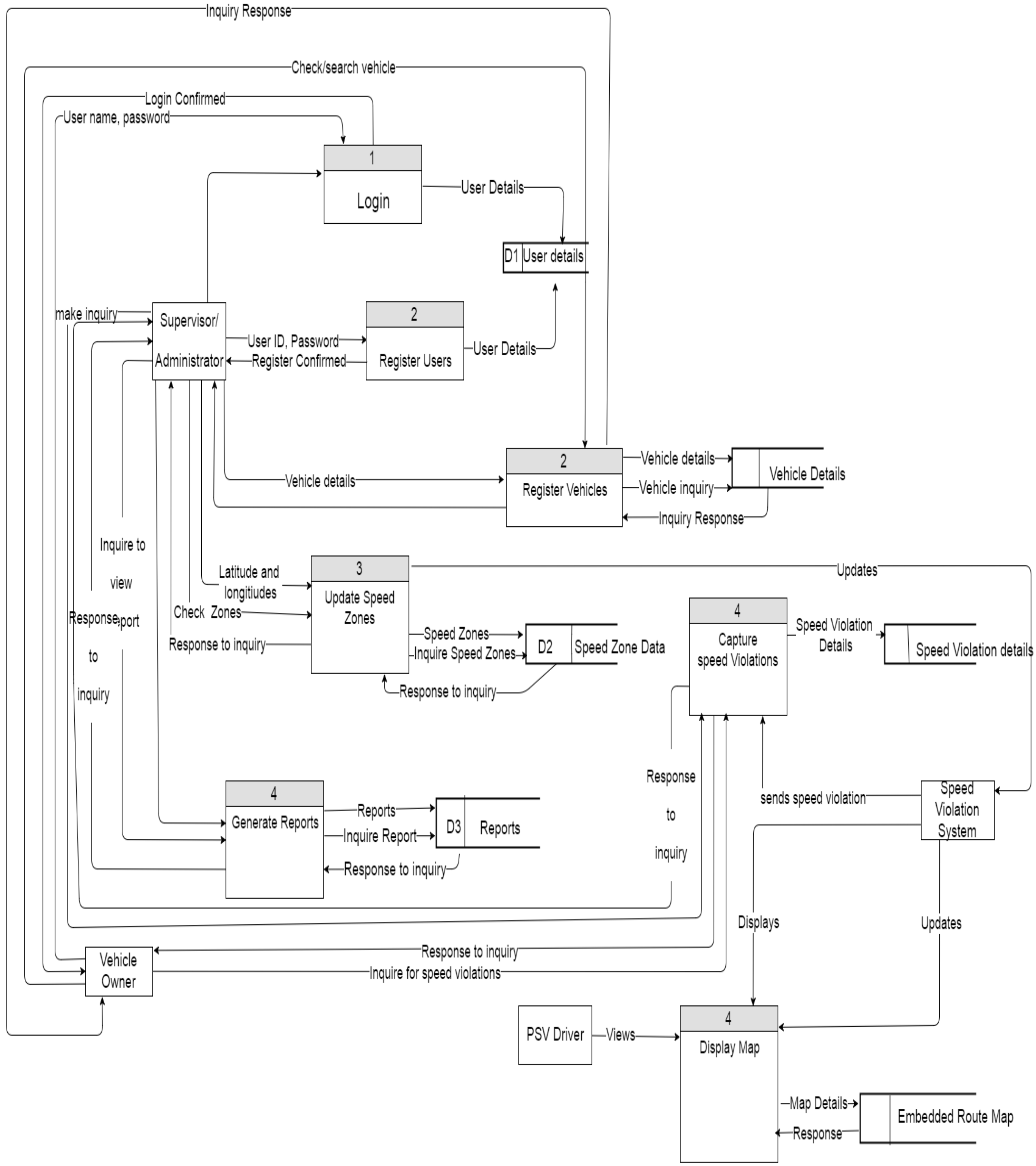

Figure 4.10: DFD Level 0

Figure shows a breakdown of the update speed zones use case. This is a main functionality since most processes are dependent on it. The supervisor is responsible for updating the speed limit zones which can be viewed by the driver through the display unit. The processor in the speed violation system compares the captured speed with the updated speed zone data to determine if a speed violation has been committed or not.

iii. DFD Level 1

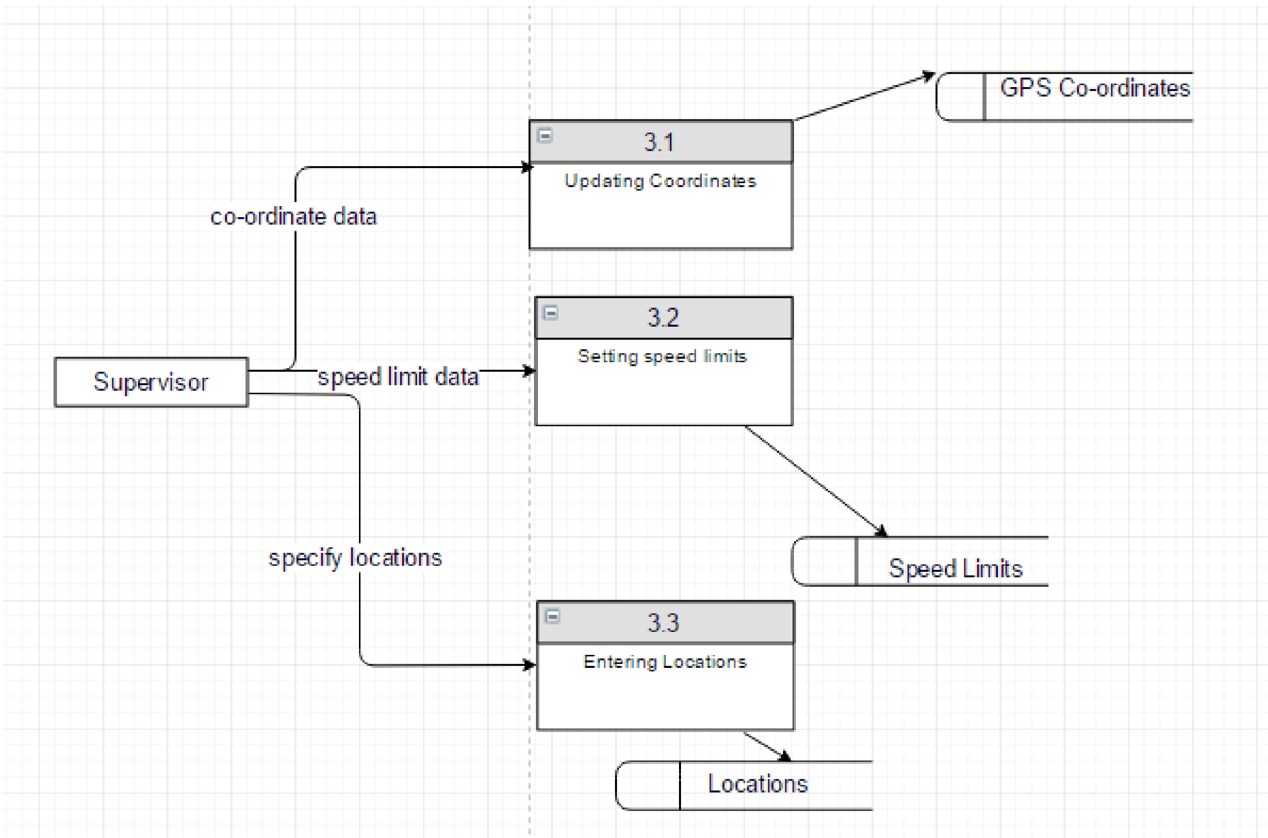

Figure 4.11: DFD Level 1

4.5.3 Use Case Diagram

A use case is a text based method used to describe complex processes through development of data models. Use case diagrams partition the system into set of actors and use cases. The use cases represent the behavior of the system to an event triggered by the actor while actors represent the roles of the identified users of the system. The main actors of the system are Traffic Speed police, motorists on the roads as well as the system administrator where the server side resides. Below is the use case diagram showing the relation between actors and events.

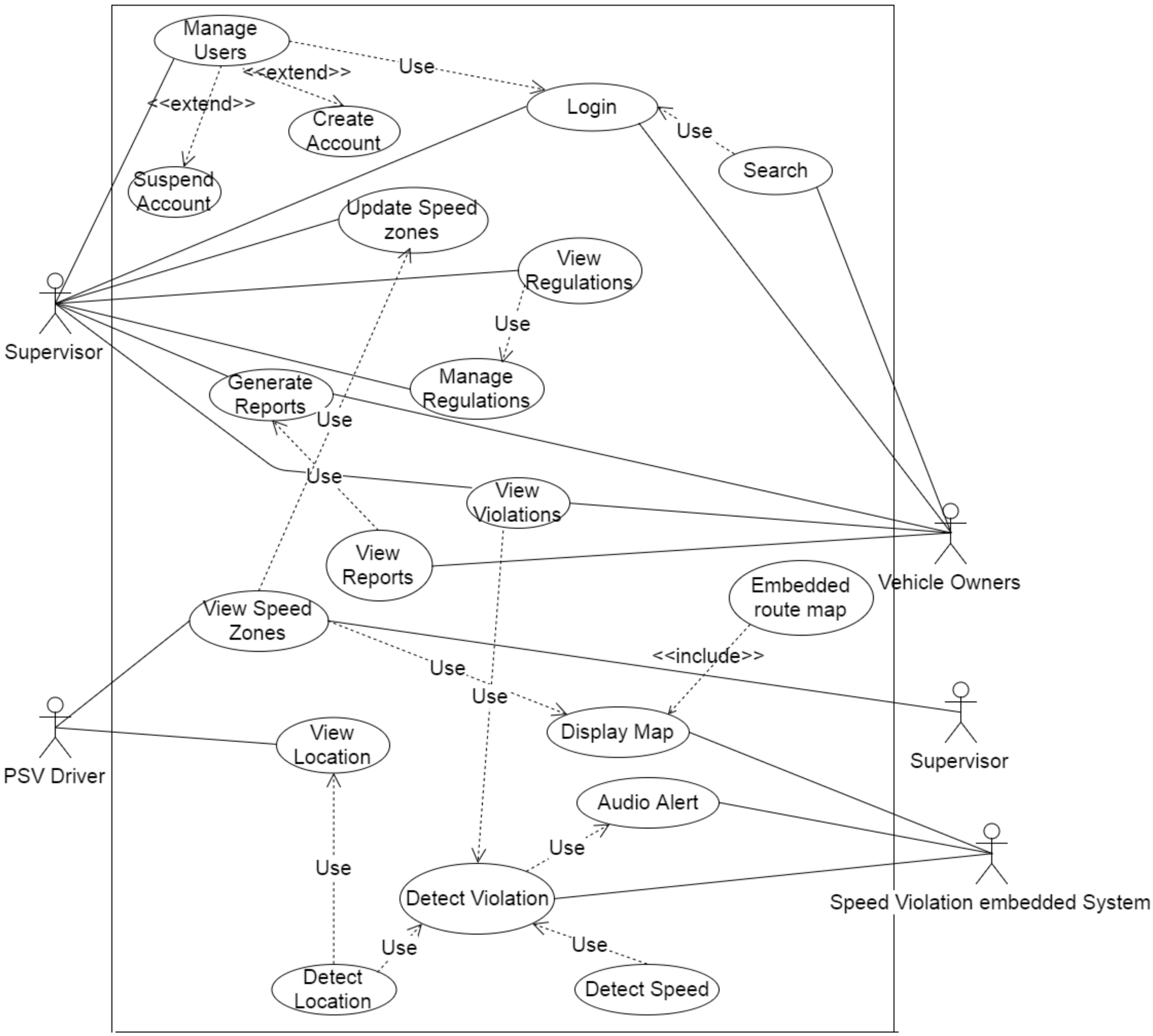

Figure 4.12: Use case Diagram

4.5.4 Use Case Descriptions

i. Manage Users

The Supervisor is responsible for creating user accounts to be used by the vehicle owners who are the primary users of the mobile application. These accounts are created in the web application by specifying the User ID and password. Vehicle owners are prompted to change password on first logon to be able to view speed violations of their vehicles on the roads. The supervisor can also suspend the user accounts in the event that user withdraws contract with the PSV agency. The table below shows the step by step process followed by the supervisor in managing users in the system.

Table 4.1: Manage Users

Use case Name	Manage Users
Brief Description	Supervisor creates and suspends account for the vehicle owners
Source	Supervisor
Major Inputs	User ID, password
Preconditions	The supervisor is authenticated and logged in the system.
Post Conditions	
Flow of Events	
Basic Flow	
	This use case starts when the supervisor needs to create or suspend user accounts 1 The supervisor clicks on “Manage Users” in the homepage. 2 Supervisor can either create or suspend an account
Case 1	Create Account
	1 Supervisor selects Create Account Option. 2 Supervisor provides User ID and password. 3 System verifies that data provided meets requirements specified. 4 User account is created in the system.
Case 2	Suspend Account

	1 System displays a list of active accounts in the system. 2 Supervisor selects user account to be suspended. 3 Supervisor clicks on Suspend account option in the window 4 Confirmation of account suspension.
Alternate Flow	
Title	**Description**
Incorrect Information during create Account	This alternate flow occurs when the supervisor supplies incorrect information during account creation 1 The system displays an error message after supervisor submits invalid information. 2 Supervisor re-enters information and clicks Create.

ii. Update Speed Limit Zones

This is a use case detailing the process of updating speed limit zones by the supervisor. Speed limit data is stored in the server and upon updating, sent via SMS to the embedded system. This information is then relayed to the motorist display unit. The step by step scenario of updating speed zone locations is given below.

Table 4.2: Update speed limits

Use case Name	Update Speed Zones.
Brief Description	The supervisor can add, delete or edit speed limit zone by specifying GPS coordinates of a particular speed zone.
Actor	Supervisor.
Major Inputs	GPS location Coordinates, Location names.
Preconditions	Identify the GPS locations to be updated in the system.
Post Conditions	Speed limit zones are updated in the display unit.
Flow of Events	
Basic Flow	

	This use case starts when a supervisor accesses the "Speed Zone" feature of the system. 1 The system prompts supervisor to enter information required to update speed zones (Latitude and longitude location coordinates ,speed limit requirements and location) *2* Supervisor enters required information and clicks on the Update tab in the window. 3 System validates the information entered by Supervisor 4 System displays map showing the updated speed zones.
Alternate Flow	
In correct information entered	1 The system displays an error message after supervisor submits the information and requests the supervisor to re-enter the information. 2 Supervisor re-enters information and clicks submit.
Cancel Update	1 Supervisor clicks cancel after selecting the feature. 2 System returns Supervisor to the administration panel.

iii. Generate Reports

Reports can be generated by either the vehicle owners or the supervisor. The reports generated contain details of the speed violations of a particular vehicle. The details of this use case have been specified in the table below

Table 4.3: Generate Reports

Use case Name	Generate Reports
Brief Description	The Supervisor and vehicle owners can generate reports with details about speed violations.
Actors	Supervisor and vehicle owners.
Preconditions	Speed Violations must be available.
Post Conditions	A report is generated.

Flow of Events	
Basic Flow	
	This use case starts when the supervisor selects Reports Option in the web application. 1 The supervisor enters search criteria in the search text box *2* Supervisor selects generate option in the web application 3 System generates report.
Alternate Flow	
Search item not found	The system displays an error message.
Cancel Report Generation	The administrator or supervisor can choose to cancel the process

iv. Detect Violation

This use case is dependent on the functionalities of the accelerometer sensor and the GSM/GPS module. The accelerometer records the current speed of the vehicle while the GPS sensor pin points the location. The processor compares the recorded data with the stored speed limit zone information. In the event that the speed recorded exceeds the speed limit, an audio alert buzzer is activated to notify driver about the speed. This data is herein sent to the server and can be accessed by supervisor or the vehicle owners.

Table 4.4: Detect Violation

Use case Name	Detect Violation
Brief Description	The speed violation embedded system detects and transmits speed violation data which specifies the location, speed details and vehicle registration data.
Actor	Speed Violation Embedded System.
Preconditions	Embedded system must detect location of vehicle and the speed of travel and determine if the speed has exceeded the speed limit requirements.
Post Conditions	
Flow of Events	
Basic Flow	

	This use case starts when the vehicle is in motion. 1 The GPS module captures the location of the PSV 2 The microcontroller compares with speed zone data to determine speed limit in the location. 3 Accelerometer captures the speed of the vehicle. 4 This speed captured is compared to the speed limit. 5 In the event that the speed is exceeded an audio alert is generated. 6 Speed violation information is sent to the processing server.

v. Display Map

The embedded speed violation system consists of a capacitive display unit which displays map showing the various speed limits set on a particular route. This map is updated remotely through sending SMS from the server to the speed violation embedded system.

Table 4.5: Display Map

Use case Name	Display Map
Brief Description	PSV driver views the map of speed limit zones along their route as well as their location with respect to the speed zones.
Preconditions	Speed limits along the routes have to be configured.
Post Conditions	
Flow of Events	
Basic Flow	
	This use case starts when the supervisor sends speed limit information to the speed violation embedded system deployed in the vehicle. 1 The supervisor updates speed zones through the web application. 2 An SMS is triggered from the web application to the embedded system. 3 The speed limit information for a particular route is displayed on the map.
Alternate Flow	

Title	Description
Cancel	

vi. Search

The search option is used by the mobile application user to query database for speeding violations. The vehicle owner is required to provide the registration details of the vehicle to the system before results are displayed.

Table 4.6: Search

Use case Name	Search	
Brief Description	User of mobile application can perform search using vehicle registration details	
Type	External	
Major Inputs Vehicle registration	Source Database	Major Result Speeding details
Preconditions	The speed police has to be active in the system	
Post Conditions	Vehicle Speeding information is displayed	
Flow of Events		
Basic Flow		
	This use case starts when a user accesses the "Search" feature of the mobile application. 1. The search submission box is displayed in the mobile application 2. User inputs search criteria and submits. 3. System displays results 4. Use case ends	
Alternate Flow		
Title	Description	

Cancel	1 User selects the "Cancel" option in the mobile application 2 System returns user to Home page.

4.5.5 Sequence Diagram

The diagram (Figure 4.13) displays the sequential flow of information in the system.

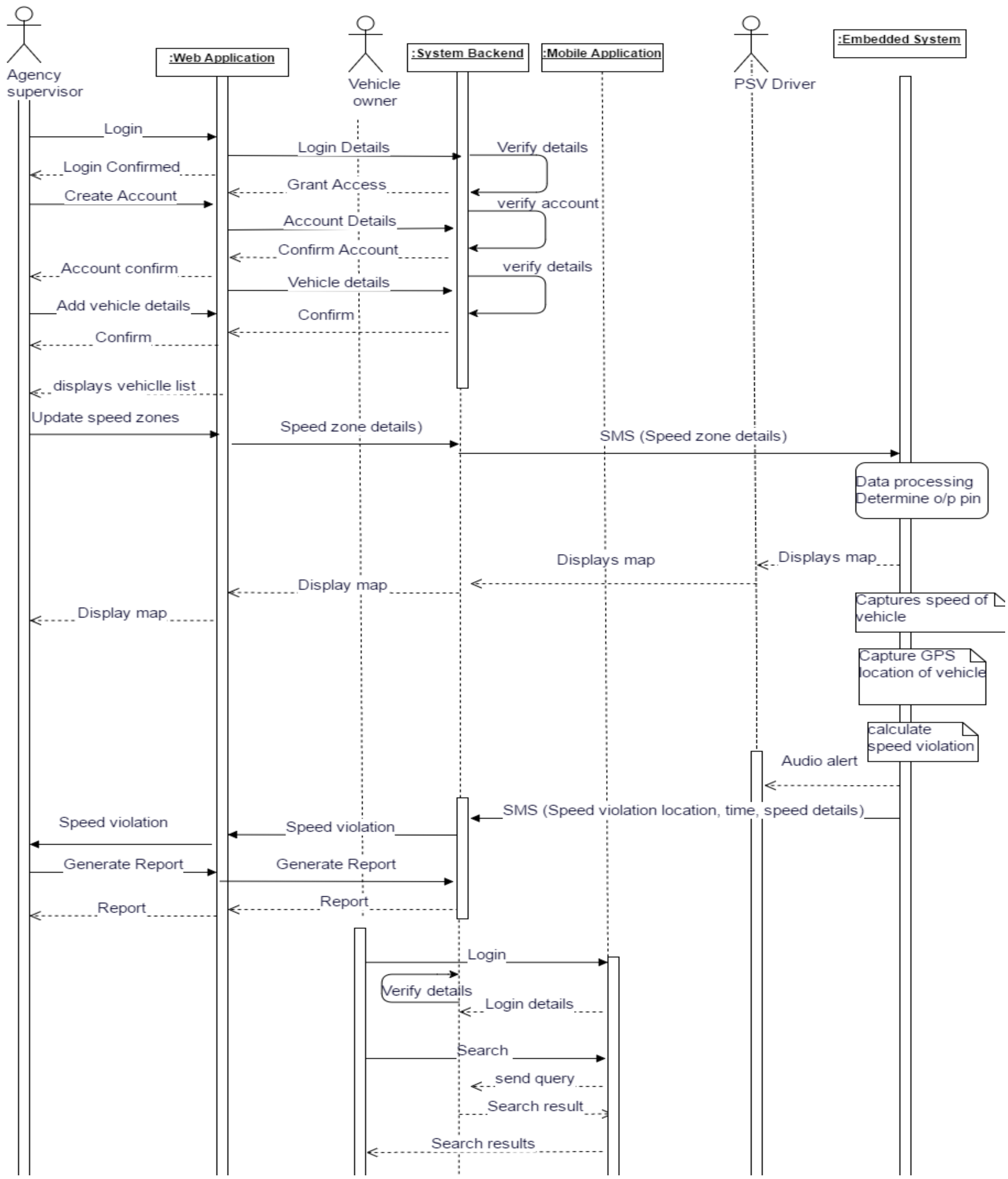

Figure 4.13: Sequence Diagram

4.5.6 Entity Relationship Diagram

The entity relationship diagram is used to show the relationships between the database entities. Figure 4.14 shows the ERD for the proposed system.

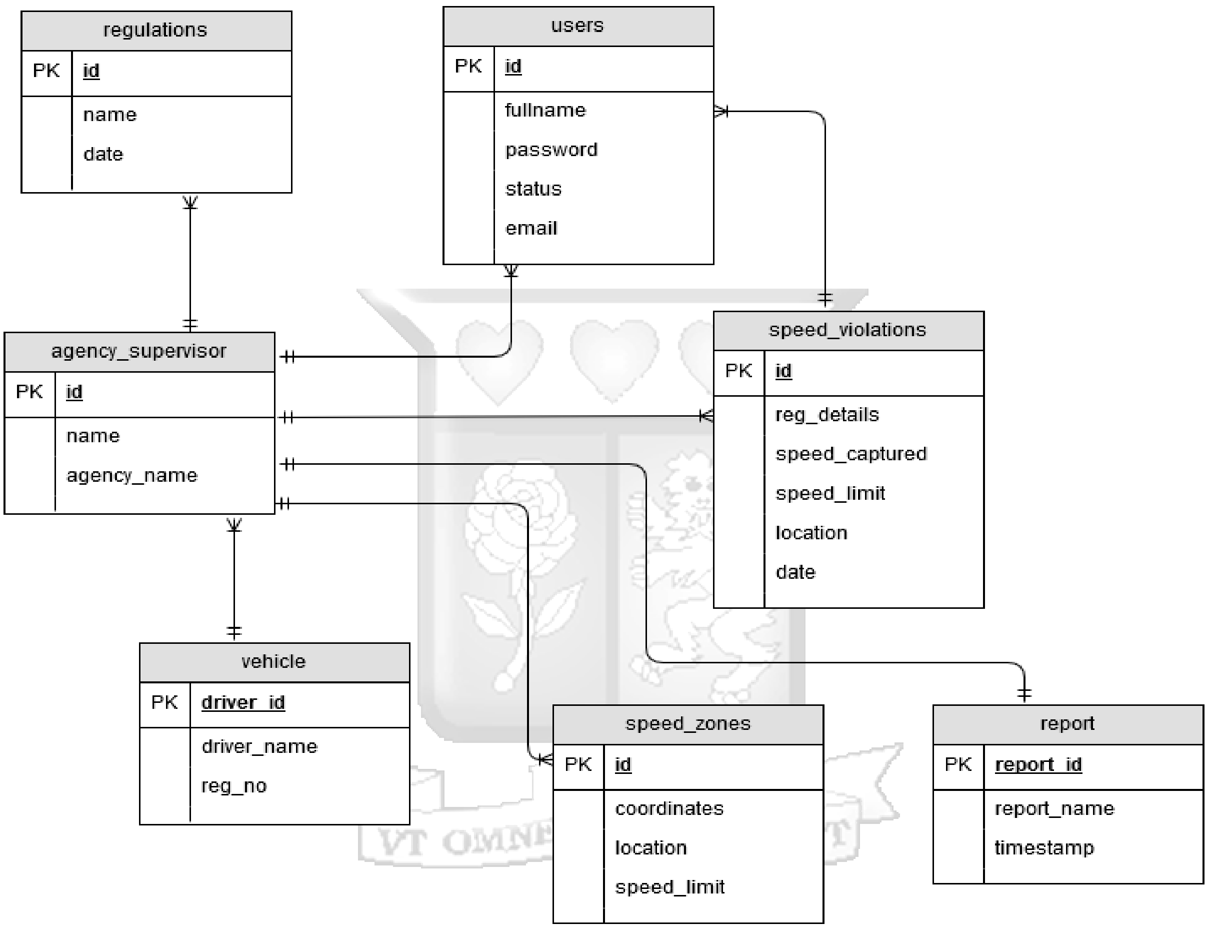

Figure 4.14: ERD diagram

4.5.7 Embedded System Collaboration Diagrams

A collaboration diagram represents objects that collaborate to ensure functionality of a system. They use the aspect of message passing for realization of a particular behavior.
(Dorf, 2006).

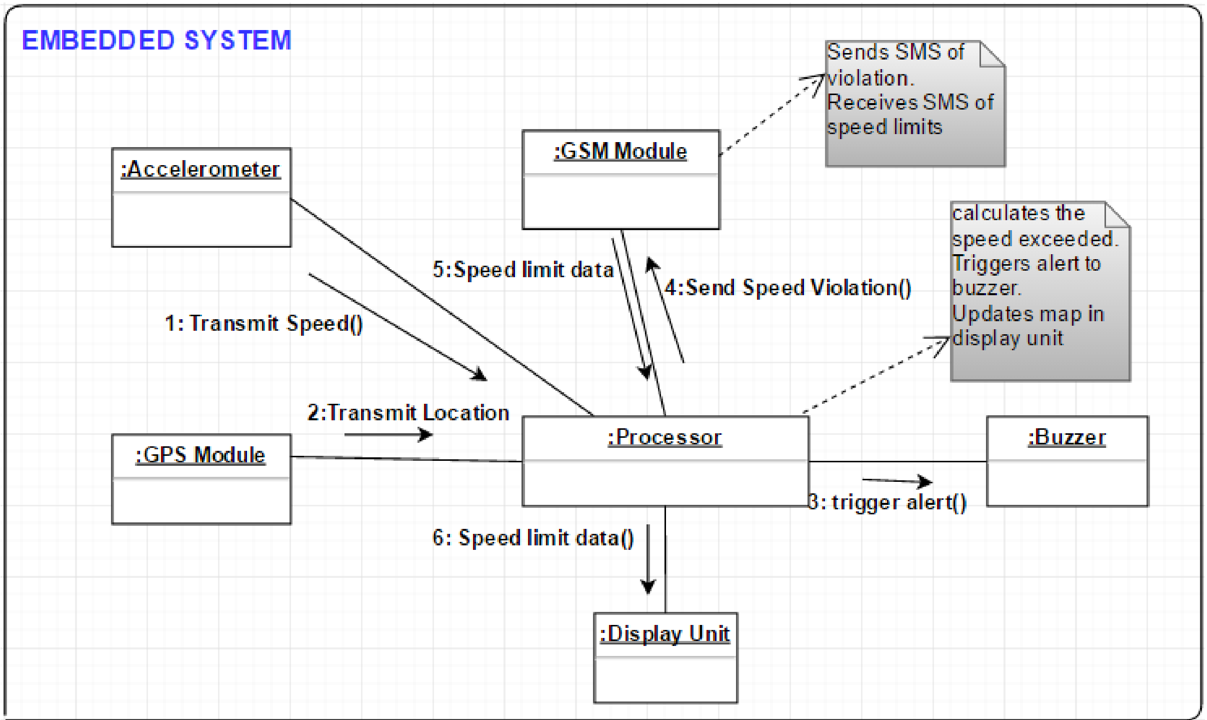

Figure 4.15: Embedded system collaboration diagram

4.5.8 Mobile Application Design

i. Login and Password Change

Figure C.1 in appendix shows the login and password change wireframes to be used in developing the Mobile application. The users are required to change password after first logon. The first logon password is provided by the supervisor and has to be changed before user can access the data. After the users login in they then can view speed violations reported over a period of time.

ii. Home Screen

Figure C.2 shows the details of speed violations as recorded by the embedded system. It specifies the vehicle registration details, location of speed violation, speed exceeded and the time. It further shows the previous records in relation to speed violations for a particular motorist.

4.5.9 Web Application Design

The web application provides the following functionalities to the system.

i. Manage Vehicles

This window allows the supervisor to add details of the various vehicles registered in the agency with details about the driver assigned to them. This helps them in keeping track of the fleet and management of the vehicles. The supervisor c.an additionally delete and edit vehicle details. Figure C.3 in appendix C shows the manage vehicles mockup design.

ii. Speed Zones

Through this window, the supervisor can update speed zone information through provision of GPS latitude and longitude details. This details are sent to the processor unit in the embedded system through the SMS to web gateway. The display unit is updated by the processor with new speed limit and speed zone data as configured by the supervisor. It enables user to view the specific speed zones set along a particular road/route. Figure C.4 in appendix C shows the manage vehicles mockup design.

iii. Generate Reports

This allows the supervisor to generate and view reports. These reports contain details of speed violations as captured and transmitted by the embedded system. Through generation of reports, the behaviour of the driver can be analysed by the agency for decision making purposes. Figure C.5 in appendix C shows the manage vehicles mockup design.

4.5.10 Embedded System Development process

According to Petru Eles, design of embedded systems can be modelled through task graphs (Eles). The figure below shows the development process of the embedded system. The researcher selected the required hardware components to be used in the embedded system. Assembly of this components was done before testing. Source code deployed in the microcontroller has to be perfected by carrying out tests before deployment to the hardware system. In the event of an error in both software and hardware, the developers reassembled and redesigned the components.

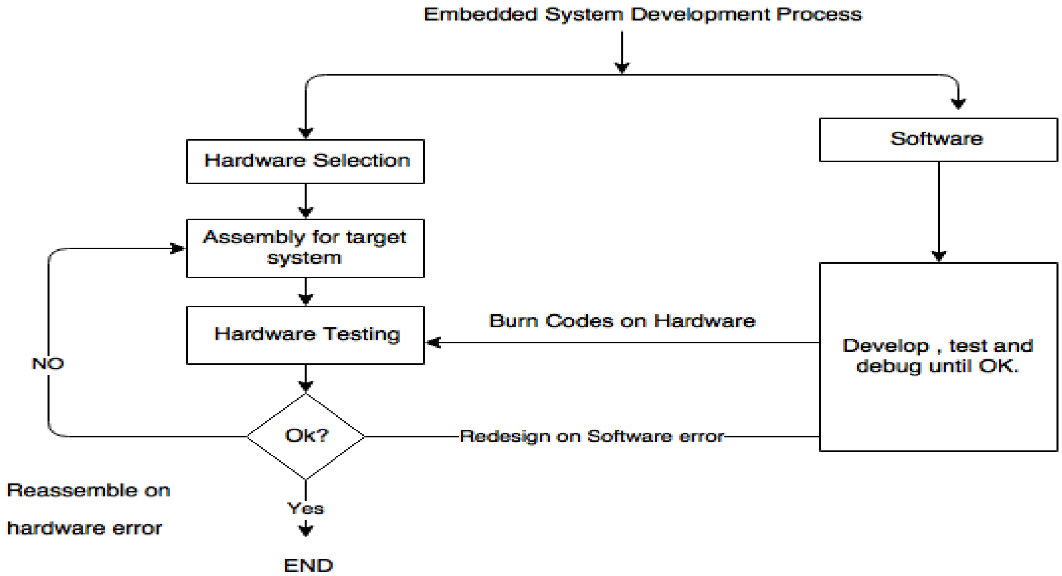

Figure 4.16: Embedded system development process

4.5.10.1 Microcontroller

The researcher selected Atmega 2560 microcontroller to use as the core processing unit. Atmega 2560 was selected due to its advantages over the other microcontrollers. The advantages and specifications of this microcontroller are specified below.

Figure 4.17: Microcontroller unit

<u>Advantages of Atmega 2560</u>

- The microcontroller achieves high performance through execution of instructions in a single clock cycle hence achieving a high throughput hence power optimization.
- Low power consumption

- Atmega 2560 has Four Universal Synchronous/Asynchronous Receiver/Transmitter (USARTs) used to establish a communication channel to the computer using RS-232 serial interface.
- It Serial Interface for communication. A serial interface
- Advanced RISC Architecture

The table shows specifications and features of the Atmega 2560.

Table 4.7: Microcontroller Specifications

Specifications	features
RAM	8KB
Flash Memory	256KB
General Purpose I/O pins	86 PINS
PWM Channels	12
Serial USARTs	4
ADC Channels	16

4.5.10.2 Accelerometer

The researcher selected the ADXL345 3axis accelerometer to be embedded in the system. The function of the accelerometer is to measure acceleration of the vehicle in 3 dimensions; X, Y and Z. This sensor is very sensitive to changes in velocity and has the capability of sensing if the acceleration exceeds a particular user set level. This feature makes this sensor the most suitable to the system being developed. The figure below shows the accelerometer

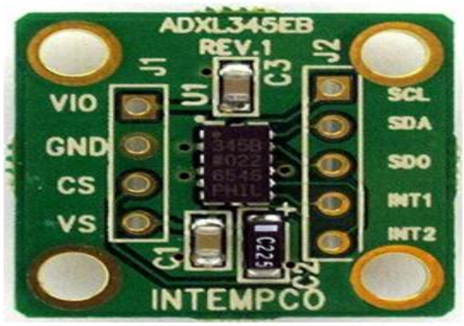

Figure 4.18:3 axis accelerometer

Features of the ADXL345

- Two interrupt output pins
- First In, First Out buffer system used to store data hence minimizing interactions with the main processor.
- The accelerometer consumes and dissipates low power.

4.5.10.3 Display Unit

The researcher selected a capacitive 7 inch display unit for map display.Capacitive touchscreens are very accurate and respond instantly when lightly touched by a human touch.

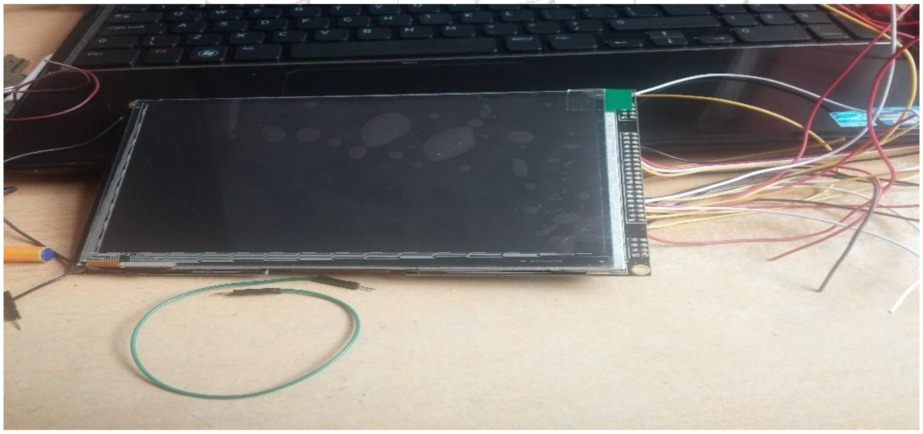

Figure 4.19: Display unit

4.5.10.4 GSM and GPS module

The researcher selected SIM 808 which is a high performance integrated GSM andGPS module to be used in the embedded system. Its core functionalities are transmitting and receiving SMS notifications as well as locating position of the vehicle with respect to the specified speed zones. These features are in line with the requirements of the system proposed. The figure below shows the SIM808 module. Figure in appendices shows the structure of the SIM808 module

Figure 4.20:SIM808

The key features considered by the researcher during selection of this module are

i. The module is compliant to GSM 850/900MHz and 1800/1900MHz
ii. The module consumes low power.
iii. It offers point to point mobile originating and mobile terminating point
iv. Can broadcast SMS to multiple destinations
v. The GPS receiver is sensitive hence captures accurate data
vi. Supports both serial and USB interface

4.5.11 Summary

System analysis and design helps in understanding the system requirements and specifications. UML notation was used to construct the various diagrams and show the flow of data and messages within the system. These diagrams include; use case diagrams, Data flow diagram, sequence diagram, collaboration diagram, class diagram, ERD diagram and the database schema. This chapter has also discussed the various elements of the embedded system and pointed out their main characteristics which makes them efficient for use in the system.

Chapter 5: System Implementation and Testing

5.1 Introduction

After the system was designed as discussed in Chapter 4, these designs were converted into a real operational system and tested to ensure that all functionalities were captured. As per the design, the system was made up of two parts consisting of the client side and the server side. The client consisted of the android mobile application and an embedded system to be deployed in the vehicle. The server side is the component management system that resided at the public service vehicle agency servers and was responsible for receiving speed violations as well as providing information to the client side. The output of the system is shown and described in this chapter.

5.2 Client Side

5.2.1 Embedded System Implementation

The hardware system is comprised of the following components; Microcontroller, GSM/GPS module, accelerometer, display unit and Alarm buzzer. The main function of the embedded system is to collect data about the speed and location of the vehicle in relation to the speed zone and transmit this to the server for processing. The display unit provide the Graphical User Interface (GUI) through which the motorist/driver can view the various speed limits configured.

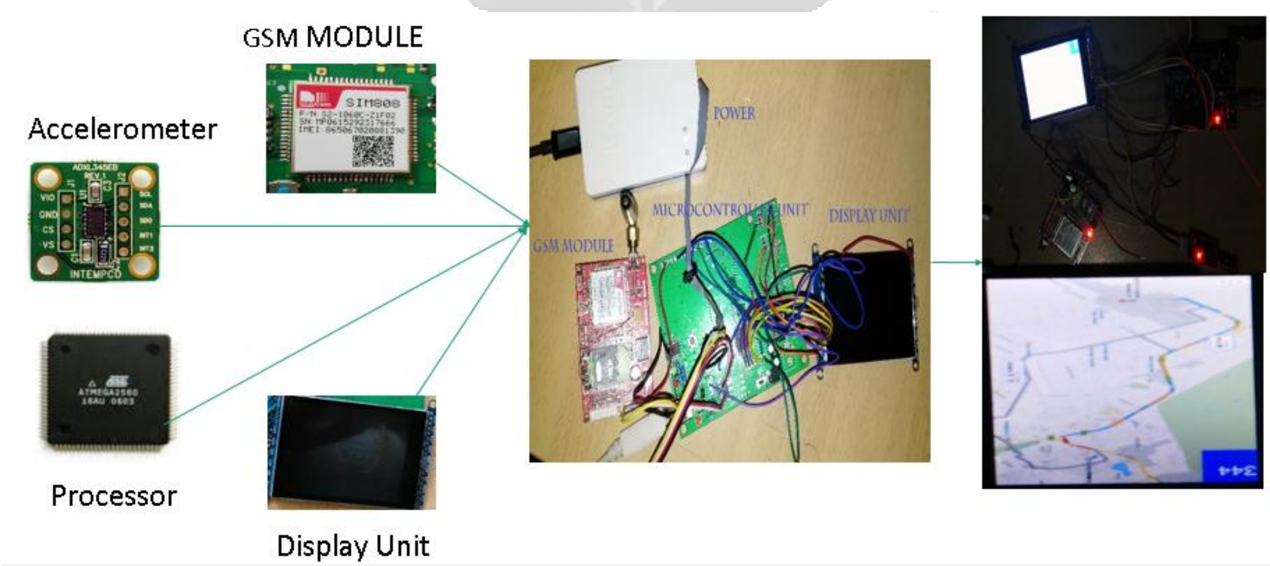

Figure 5.1: Embedded System Implementation diagram

5.2.2 Mobile Application Implementation

The mobile application was built to run on the Android platform, this is based on the research done which showed that the target population uses Android phones. The application was built for the vehicle owners whose vehicles are registered in the Public Service Vehicle transport agencies. Below are screen shots of the application and their functionalities:

i. Login

The mobile application users click on the icon on their android devices to launch the application. The mobile application requests for the User ID and password for authentication purposes. The users are required to change password on first log on before granted access to the homepage. Screen shots below shows the log in and password change screens in the mobile application.

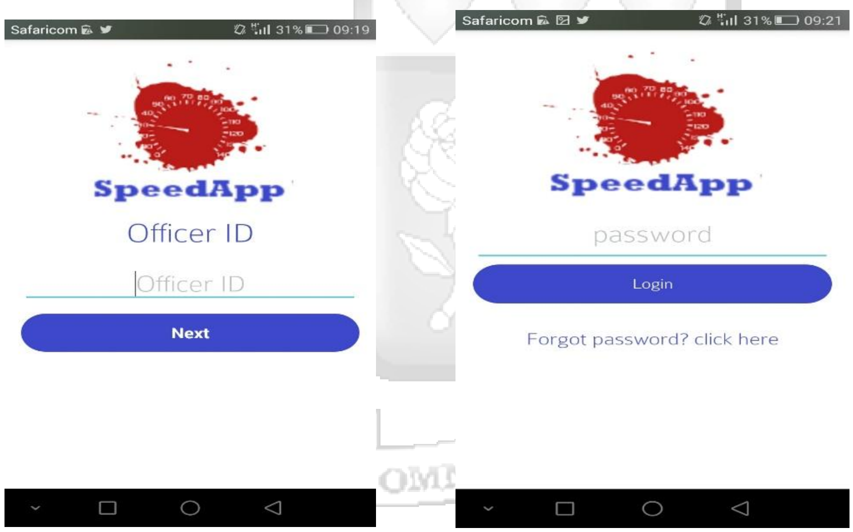

Figure 5.2: Login Screens

ii. Home Page

Upon authentication of the user details, the user is authorized to access the home page of the mobile application. The details of speed violations including vehicle registration number, speed exceeded, location and time are listed in this window. To view more details, the administrator selects an item in the list from where they are directed to a details page. The home page also provides a search option through which users can query the database by vehicle registration number. All speed violations relating to the search query is displayed in Figure 5.2 below.

Figure 5.3: Mobile application Home Page

iii. Details Page

This window provides more detail about the vehicle speed violation to the mobile application user. It enables the user to view previous cases reported about the vehicle in regards to speed violation. The screen shot below shows the details page in the mobile application.

5.3 Server side

5.3.1 Web Application Implementation

The supervisor's main role is to manage users, manage speed zones, manage vehicles and generate reports. To perform these functions, they access the system through the web application where they are required to provide authentication data i.e. used ID and password. The Figures below shows a screenshots of the main functions performed by the supervisor in the system.

i. Managing Users

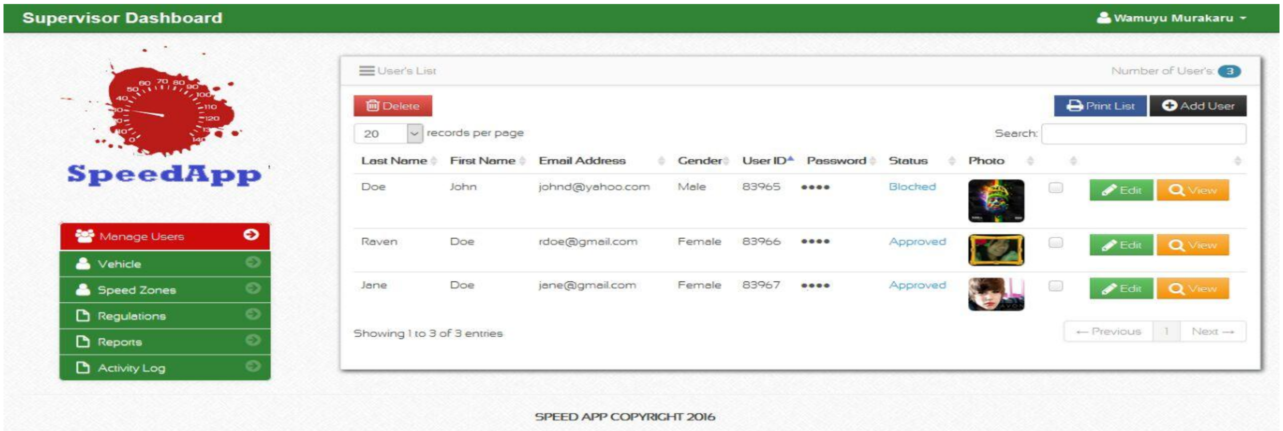

Figure 5.4: Manage users in web application

ii. Managing Speed Zones

The supervisor/administrator is also responsible for updating the speed zone information which is sent from web application to the embedded system. The screen shot shots the interface for updating the speed zones.

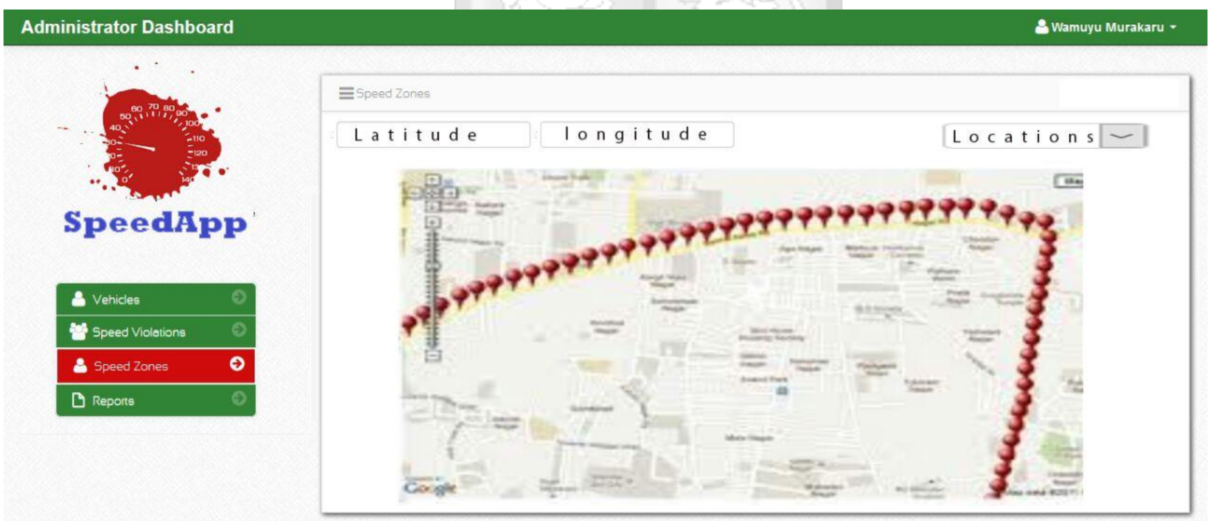

Figure 5.5: Speed zones

5.4 System Testing

This Section covers testing of the system to ensure that it works well. The testing was divided into two sections, developer testing and user Assessment testing. The first tests done by the developer were to ensure that the various functionalities were working well, the tests included: unit testing, integration testing, compatibility testing, functionality testing and user testing.

5.4.1 Unit and Integration Testing

In unit testing, the individual units were scrutinized to test for operation. The isolated hardware components were separately to ensure that each component performs required function. The input/output ports for the units were tested using hardware testing IDE. It was also performed to test the source code before deployment to the processor unit. Integration testing was performed after system integration where two or more of the components were integrated and tested for functionality. During this test, multiple errors were deduced and corrected.

5.4.2 Compatibility Testing

Compatibility test was done to ensure that the mobile and web applications are compatible with the available platforms. The mobile application was tested against the available Android versions while the web application was tested against the available web browsers that are commonly used.

5.4.2.1 Software Compatibility

Compatibility testing was done to ensure that the mobile application and the web application are compatible with the available platforms. It ensures that the mobile application runs on all device versions and that users with different Android API level phones would use the application with ease. The mobile application was tested using the available android versions while the web application was tested against the web browsers used.

i. Android Platform Compatibility Testing

Table 5.1 shows the results of compatibility test conducted for each of the available Android platforms

Table 5.1: Android Compatibility

Android versions	Version Name	Compatible
Android 5.1	Lollipop	YES

Android 4.4	KitKat	YES
Android 4.2	Jellybean	YES
Android 4.0	Ice cream sandwich	YES
Android 3.2.1	Honeycomb	YES
Android 2.3.6	Gingerbread	YES

ii. Web Browser Testing

This test was carried out to determine if the web application developed is compatible with the browser types specified in Table 5.2 below.

Table 5.2: Web Browser testing

Browser types	**Compatibility**
Internet Explorer (versions 4 and above)	Yes
Firefox (version 8.0 and above)	Yes
Chrome (All versions)	Yes

5.4.3 Functionality Testing

Functional tests were carried out to test the features of the system implemented. It based on use cases to determine the success of the implemented system. This section tested both the hardware and software to determine whether all functionalities were achieved. For each use case testing measures were set with results being considered successful or unsuccessful. Below are tables showing some of the major use cases and their test results.

i. Manage User Accounts Testing

This test was done to ensure that supervisors and administrator accounts were created before access was granted to the system.

Table 5.3: User Account creation testing

Test Name	Creating user account		
Date of test	3/03/2016		
Description of Test	Supervisor creates the administrator and supervisor accounts in the system.		
Utilized Use Case	Create Account		
Steps	User Actions	System Response	Pass/Fail
1	Supervisor accesses the web app URL through the browser.	Launches the login and registration web page	Pass
2	Supervisor clicks on Register and fills out their details	Confirms that valid data is provided and directs user to home page	Pass
3	Supervisor clicks on admin tab and adds details of the administrator	Confirms that the ID and password are valid	Pass
Comment	Successful account creation for the administrators and supervisor		
Test Pass/Fail	Pass		

ii. Login Testing

Table 5.4: Login Testing

Test Name	Administrator Login
Date of test	3/03/2016
Description of Test	Administrator logs into the mobile application

Utilized Use Case	Login		
Steps	User Actions	System Response	Pass/Fail
1	The administrator clicks on the mobile application icon in the android device	The mobile application launces and displays login requirements (ID and password)	Pass
2	Administrator enters ID and password provided by the supervisor	Authenticated data provided and directs user to password change window	Pass
3	Administrator provides password details and clicks login button	Confirms that the password provided meets password requirements before directing user to Home page	Pass
Comment	Successful account creation for the administrators and supervisor		
Test Pass/Fail	Pass		

iii. Search Testing

This test was done to ensure that administrators of this system can perform a search in mobile application. The table 5.5 below shows the test results as at 3/03/2016

Table 5.5: Perform testing

Test Name	Search		
Date of test	3/03/2016		
Description of Test	The administrator performs a search query using vehicle registration details		
Utilized Use Case	Search		
Steps	User Actions	System Response	Pass/Fail

1	Administrator	Launches the login and registration web page	Pass
2	Supervisor clicks on Register and fills out their details	Confirms that valid data is provided and directs user to home page	Pass
3	Supervisor clicks on admin tab and adds details of the administrator	Confirms that the ID and password are valid	Pass

Precondition	The vehicle registration details must exist in the database.
Comment	Successful search performed and details displayed.
Test Pass/Fail	Pass

iv. Update speed Zones Testing

This test was done to ensure that supervisors and administrator are able to update the speed zone data by entering GPS coordinates of a location. They can also speed limit data previously updated.

Table 5.6: Update speed zones testing

Test Name	Update Speed Zones		
Date of test	3/03/2016		
Description of Test	The supervisor or administrator is responsible for adding, deleting and editing the various speed zones in the system.		
Utilized Use Case	Update Speed Zone		
Steps	User Actions	System Response	Pass/Fail
1	Supervisor or administrator clicks the update button tab in the web application	Navigation to the update zone window where the user can add, edit or delete speed zones	Pass

2	Supervisor selects add option		Pass
3			Pass
Comment	Successful update of speed zones.		
Test Pass/Fail	Pass		

v. Generate Reports Testing

This test was done to ensure that administrators and supervisors have capability of generating reports based on a vehicle registration number.

Table 5.7: Generate report testing

Test Name	Generate Report		
Date of test	3/03/2016		
Description of Test	Testing whether the administrator and supervisor can generate reports from the system		
Utilized Use Case	Generate Reports		
Steps	User Actions	System Response	Pass/Fail
1	Supervisor or administrator clicks on the reports tab in the web application.	System displays a search window	Pass
2	Supervisor or administrator performs a search through entering date or vehicle registration number.	System displays records according to search criteria	Pass
3	Supervisor or administrator selects print option from the Reports window	System prints the report	Pass
Comment	Successful generation of reports		
Test Pass/Fail	Pass		

5.4.4 User Testing

User testing is performed to seek reaction of the target population to the system. The researcher formulated post questionnaires which were distributed among the sample population to get feedback on the application. Out of the 115 respondents involved in the research, 65 carried out user testing and provided feedback which was used to refine the prototype .The reason as to why only 65 respondents were involved in the testing process is; they were the only ones who were available in the agencies during the testing phase. An instruction kit on how to use the application was provided to the users to provide guidance on download. Credentials to the active test accounts were provided to the sample for testing purposes**.** User testing was done to achieve the following objectives: User Interface Aesthetics, Ease of use, Functionality, Acceptability

i. User Interface Aesthetics

The objective of this test was to obtain feedback about the look and feel of the application. User Interface testing was done for the mobile application and the display unit. For the mobile application, 78.6% of the target population indicated that it was attractive while 21.4% indicated that the application was average.

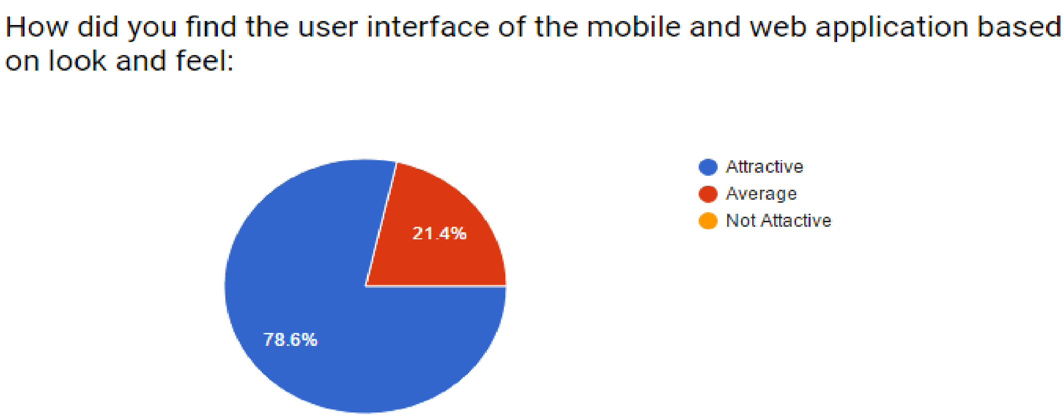

Figure 5.6: User Interface testing

For the display unit interface, 76.5% indicated that it was attractive, 11.8% indicated it was average while 11.8 % indicated it application was not attractive. A summary of the results is shown in figure below

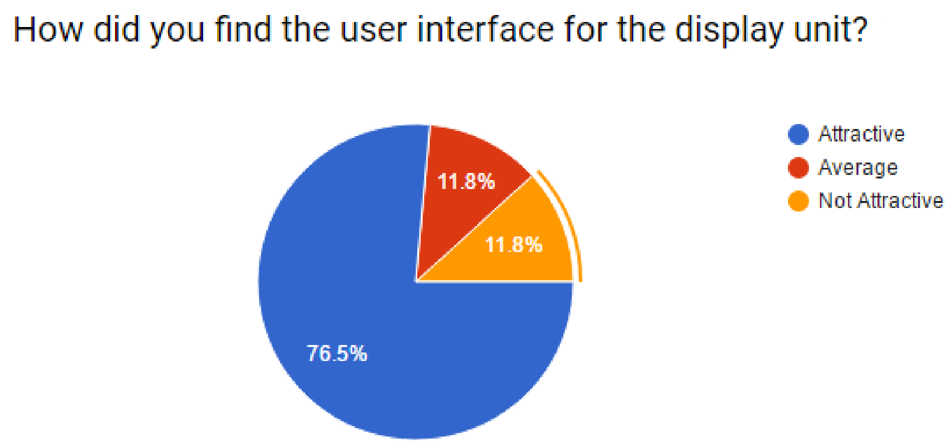

Figure 5.7: User Interface Testing- display

ii. Ease of use

The ease of use which includes learning and using the mobile application was tested by the potential users. The results obtained were as follows; 78.6% of the population indicated that the application was easy to use while 21.4% indicated that the application was average.

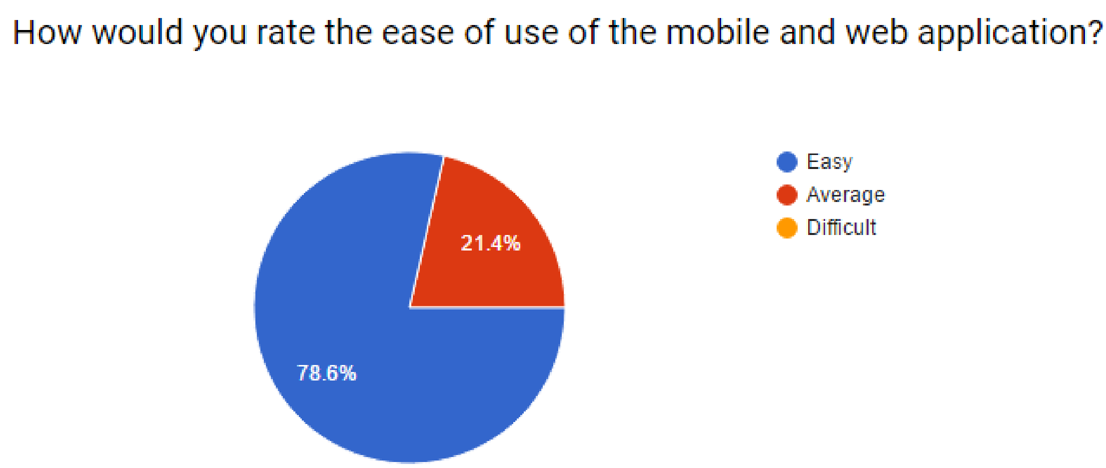

Figure 5.8: Ease of use testing- applications

For the display unit, 84.6% of the population indicated that the system was easy to use, 20% indicated that it was average while 15.4% indicated that it was difficult to use. Figure below shows a summary of the results.

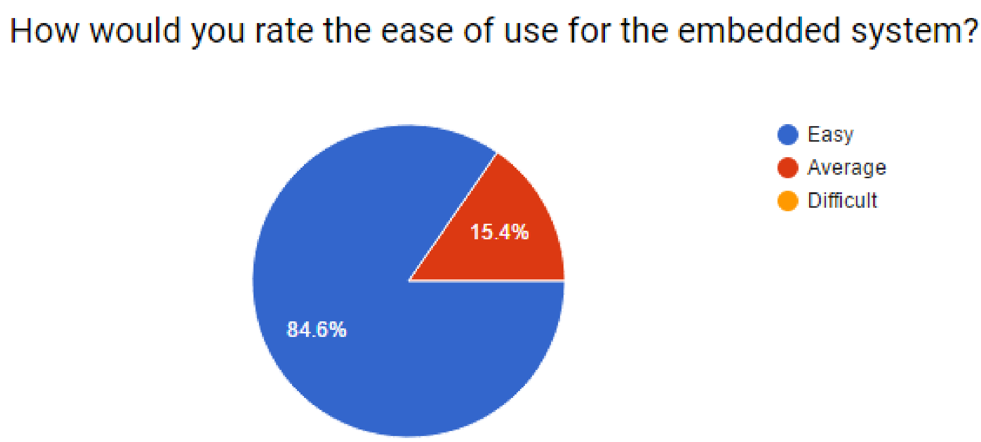

Figure 5.9: Ease of use testing- embedded system

iii. Functionality

Potential users of the system tested the system against the user specifications to test whether the desired functionalities have been achieved. 84.6% of them indicated that the specified functionalities had been achieved by the developer.15.4% Indicated that the functionality achieved was fair meaning that some of the specifications had not been met. This feedback was used to refine that prototype in an attempt to meet all specifications. The figure below shows the summary of results

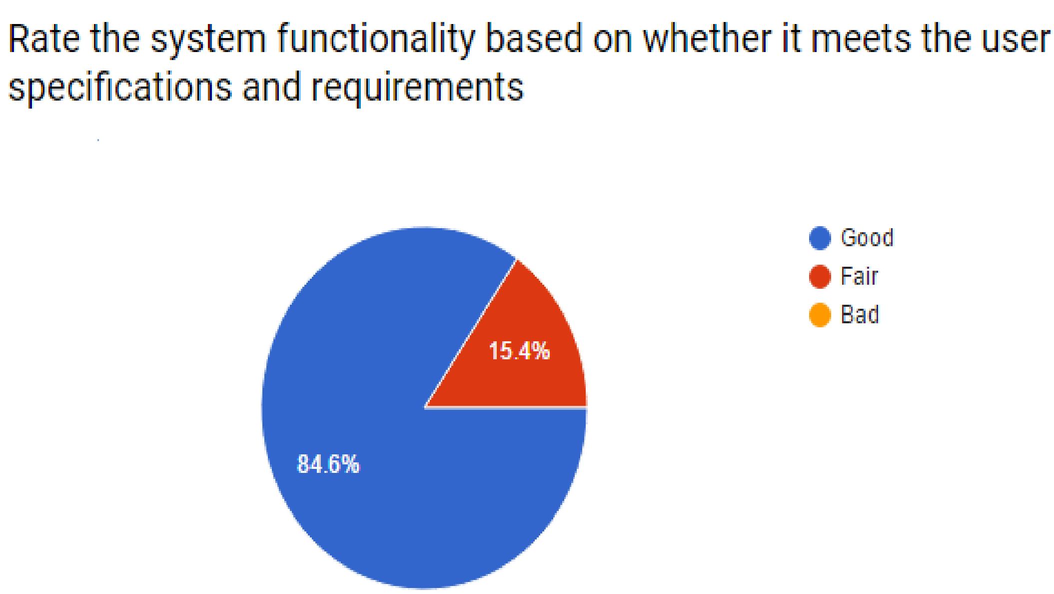

Figure 5.10: Functionality testing

iv. Acceptability

User acceptability testing was done to determine whether the application was a success. 78.6% of the population accepted the application for use in managing and reporting speed violations while 14.3 % rejected the application. Since majority of the target population accepted the application, this test proved to be successful. Figure below shows the summary of results

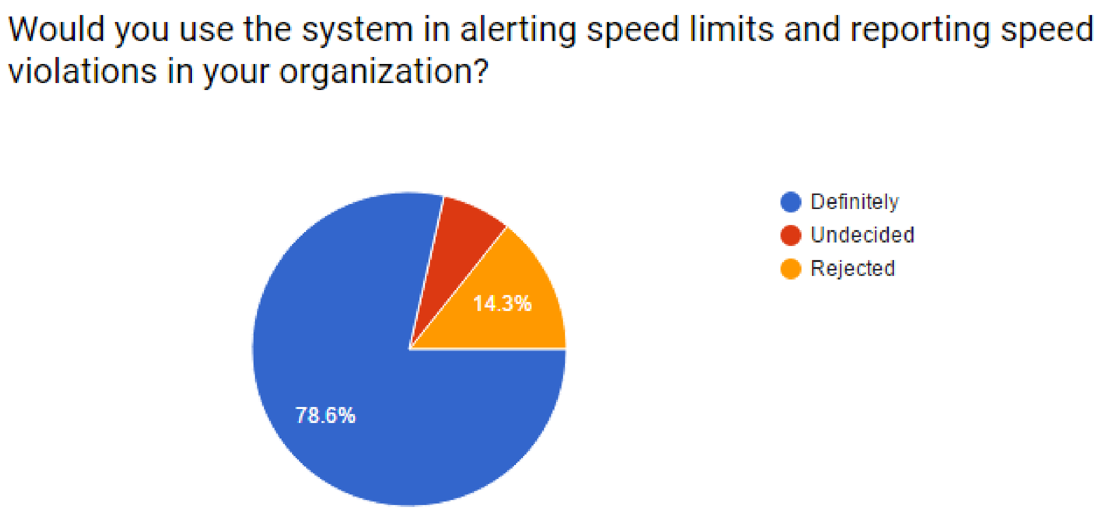

Figure 5.11: Acceptability Testing

5.5 Summary

This chapter describes the process of system implementation and testing. The system design in the previous chapter together with the research objectives and research questions were put into consideration to ensure that the system was developed to achieve the set goals.

Agile software development and testing was adopted at all stages of implementation. This allowed for the developer to involve the target population by taking note of their inputs at the different stages of development. It also enabled the researcher to change aspects of the system to suit needs of the target population.

The mobile application was developed on the Android platform using android studio. The main functionality is to give users ability to view speed violations on the roads. The web application was implemented for administrator management, speed zones updates, report generation and tracking of speed violations. System testing was conducted by mainly testing functionality to ensure that all requirements were met. Installation testing for both hardware and software was carried out to ensure that a communication channel is established between the two components. Compatibility testing was carried out to determine if the mobile application is compatible with all android versions and the web application is compatible with the web browsers. Finally, user testing was carried out to ensure that the system is user friendly and easy to understand.

Chapter 6: Discussion, Conclusion and Future Work

6.1 Introduction

The purpose of the research was to investigate the approaches taken to curb speeding on roads and the limitations of the systems in order to identify a system that will help solve the challenges identified. This research aims to develop a system that can be easily adopted in the transport industry in alerting drivers of the speed limit zones and reporting to the authorities and stakeholders in the event of speed violation. This chapter of the research focuses on the various findings and achievements, how the research objectives were achieved and provides a review of the system in relation to the current systems. It also discusses the advantages and future works of the developed system.

6.2 Findings and Achievements

A comprehensive review of previous literature indicated that there are various techniques adopted to curb speeding on roads. Speed bumps, speed guns, speed limit signs and imposing hefty fines are among the techniques adopted in Kenya. In the public transport Industry, the government has passed a regulation requiring all vehicles to have a speed governor which limits the speed to 80 Kilometers per Hour. The National Transport and Safety Authority periodically passes speed limit regulations lower than 80Kph along specific roads. With this, the application of the speed governors is impractical since it does not limit vehicles to the specified NTSA requirements. Transport Agencies such as Taxi Companies, long distance buses and carriage vehicles do not have a mechanism to influence and monitor speed of drivers on the roads. Further research shows that a speed zone mapping system displaying speed limits would be efficient in notifying drivers about speed limit regulations in relation to their GPS location. An audio alert system was also implemented to alert driver when speed is exceeded. In the event of a speed violation, the GSM module in the embedded system deployed in the vehicles sends the details of the violation to the server for review by the agency stake holders.

6.3 Review of Research Objectives in Relation to the Developed System.

A mobile, web application and embedded system was designed and developed in line with the research objectives. This section describes the various objectives of the research in relation to the findings or results.

The first objective was to investigate the approaches adopted in curbing speeding for Public Service vehicles in Kenya. This information helped to gain an understanding of the techniques in place as well as identify their strengths and weaknesses in order to select the best approach to be adopted by the researcher. This objective was achieved by reviewing literature, reports and documentation maintained on the current systems used globally. Available systems and technologies include: Speed guns, Speed Limiters, Speed bumps, speed zoning and Speed Cameras. In Kenya, Speed Guns, speed bumps, speed limiters and speed limit signs, Speed regulation are the most common approaches used to curb speeding. The system proposed by the researcher uses speed limit regulations set by NTSA to map speed limit zones along routes used by PSV vehicles.

The second objective was to identify how a mobile application and embedded system can be applied to help curb speeding of PSV on roads. This objective was achieved by reviewing literature and accustoming to various technologies which can be applied. From the feedback received during the data collection phase, the researcher identified that the best approach is to develop an embedded system to be deployed in the vehicle to monitor speed and location of the vehicle. This system consists of a display unit where the map showing speed limits on a particular road is displayed. The mobile application developed was to be used by the vehicle owners for speed violation reporting. A web application through which the supervisor can manage speed zones, view violations, add agency vehicle information and generate reports was also developed.

The third objective was to design and propose a system for mapping speed limit zones along roads. This objective was achieved through carrying out interviews with PSV agencies to determine the routes commonly used. The researcher mapped speed limits along sections of two major Highways in Nairobi; Mombasa Road and Thika road. The map was displayed on the capacitive display unit in the vehicle for the driver.

The fourth objective was to design and develop a mobile and web application for PSV Agencies and stakeholders to view speed violations. The applicability of the mobile application was evaluated in relation to the sample population. Research showed that PSV agencies depend on willing individuals to register their vehicles to the agency. It also showed that the owners of these vehicles would be interested in viewing reports about speed violations reported regarding their vehicles. Also, the supervisors/administrators in the agency would be able to view the speed violation details and generate reports.

The last objective of this research was to test the functionalities of the system developed. The following tests were conducted to prove the validity of the system; Compatibility testing, functionality testing, unit testing, integration testing and user testing. Testing of the embedded system was also done during integration of the components. Testing to ensure a functional communication channel between the embedded system and the server was also done to ensure data transmission between the two sub systems. It was concluded that the system functioned as required.

6.4 Advantages of the System

Advantages of the system in relation to the current systems used to curb speeding include:

i. The display unit enables driver/motorist to view speed limit zones along their routes.

ii. The system generates an audio alert to inform driver once speed limit is exceeded.

iii. It provides real time transmission of speed violations by drivers to the transport agency and stakeholders.

iv. Reports generated provide details about speed violation on roads.

v. Speed Violations can be reported around the clock.

vi. Provides evidence of speed violations to vehicle owners and PSV Agencies.

vii. The system offers real time updates of speed limit zones and enables drivers to access data remotely.

viii. The system incorporates a web application that can be used for data manipulation and data presentation.

6.5 Future Work

The following can be used to further enhance the system:

ii. The mobile application should be developed for other mobile platforms to allow users with phones other than Android to access the application's functionality.

iii. The display unit should include a map showing all speed limits along routes used by drivers on the road.

iv. The application should be integrated to the regulatory body Systems to automatically report speed violations and provide evidence of violations.

v. Integration of a payment system to enable fines payment upon speed violation by the drivers.

vi. This system can be redesigned to provide traffic information and data on different routes.

vii. The accelerometer in the system provides direction information along 3 axis(X, Y and Z), hence, the system can be advanced to reconstruct accident scenes on roads.

6.6 Conclusion

This research was carried out to improve the transport industry, where vehicles are registered under a particular agency, by designing and developing a system to help curb speeding. Prior to design and development, a comprehensive study was carried out to determine the existence of the problem and viability of the research. The data collected from sample population was analysed and helped in designing a relevant system to curb the challenge. This system not only reports speed violation, but maps speed limit zones on a specific route. This provides speed limit information to the drivers and speed violation data to supervisors/administrators in the transport agency. Additionally, drivers are alerted once they exceed a specific speed.

An android mobile application was developed to provide a platform through which speed violations can be monitored by the owners of the vehicles. A web application was designed and developed to enable supervisors to manage users, manage speed zones, manage regulations and generate reports. An embedded system was also designed and integrated to collect data about location and speed of the vehicle and transmit to the server through an SMS gateway.

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Appendices

Appendix A: Questionnaires

i. Travel Agency Questionnaire

This questionnaire is aimed at collecting relevant information about operations of public transport agencies. The information you give will be of benefit to the researcher in accomplishing academic goal. Kindly answer the questions to the best of your abilities, there is no right or wrong question, your response will be highly appreciated. There is no need to give your name anywhere on the form, the information collected is used for academic purposes only.

(Please try and answer all the questions to the best of your abilities)

Speed App Questionnaire: Travel Agency

1 Are you computer literate?

☐ Yes

☐ No

2 Do you own a mobile phone?

☐ Yes

☐ No

3 Which Operating system is installed in your mobile phone?

☐ J2ME

☐ Android

☐ Windows

☐ IOS

☐ I do not know

4 Do you have access to internet at work?

☐ Yes

☐ No

5 Kindly Specify the Public Service Vehicle agency name

6 What Role do you play in this agency?

7 Who legally owns the vehicles operating in the agency?

8 Are you willing to share your organizational structure?

☐ Yes

☐ No

9 Do you have access to a computer with internet connectivity at work?

☐ Yes

☐ No

10 Are you aware of the speed limits set on roads?

☐ Yes

☐ No

11 As an Agency, do you have regulations to govern speed of vehicles in the agency?

☐ Yes

☐ No

12 Would you set regulations to govern speed with respect to the speed limits set by the government regulatory body?

☐ Yes

☐ No

13 Do you have access to new regulations about speed limits as set by the Regulatory body?

☐ Yes

☐ No

14 Have any drivers in your agency been arrested due to speeding?

☐ Yes

☐ No

15 Do you have a system to receive reports about speeding by drivers on the roads?

☐ Yes

☐ No

16 Do you think that all the drivers in the agency have access to speed limit information?

☐ Yes

☐ No

17 Does your agency play any role in ensuring that the drivers are aware of speed limit information?

☐ Yes

☐ No

18 What techniques do you adopt to ensure that drivers in your agency maintain required speed?

19 Do you think that a map showing speed limit zones would help drivers maintain the required speed?

20 Do you think an alarm system to notify drivers when speed is exceeded would help them maintain the required speed?

☐ Yes

☐ No

21 Would you be willing to test a new system implemented to curb the issue of speeding?

☐ Yes

☐ No

ii. General Public Questionnaire

This questionnaire is aimed at collecting relevant information from individuals who use public transport. The information you give will be of benefit to the researcher in accomplishing academic goal. Kindly answer the questions to the best of your abilities, there is no right or wrong question, your response will be highly appreciated. There is no need to give your name anywhere on the form, the information collected is used for academic purposes only.

(Please try and answer all the questions to the best of your abilities)

Speed Monitoring System Questionnaire: General Public

Have you ever travelled by Public means of Transport (Matatu/taxis) in Kenya?

- ☐ Yes
- ☐ No

Do you think most accidents in Kenya are caused by speeding?

- ☐ Yes
- ☐ No

If your answer is No in the above question, Please provide details

____

____

Have you witnessed/been involved in an accident whose primary cause was speeding?

- ☐ Yes
- ☐ No

Do you think Matatu drivers are aware about speed limit regulations in Kenya?

- ☐ Yes
- ☐ No

Are you aware of any measures taken to curb speeding on Kenyan roads

- ☐ Yes
- ☐ No

If Yes, Kindly name one measure taken to curb speeding

Do you think the measures adopted to curb speeding in Public Transport industry have been efficient over the past years? *

☐ Yes

☐ No

Do you think speed limit signs along the roads are adequate in informing drivers about various speed limit Zones? *

☐ Yes

☐ No

Do you think a system for reporting speed violation by Matatu drivers would help reduce speeding in Public Transport Sector? *

☐ Yes

☐ No

Appendix B: Interviews

i. Public Service Vehicle Drivers

1. Are you aware of speed limits on the roads?
2. Have you ever committed a speeding offence?
3. What are the main reasons for speeding while driving?
4. Do you think a system to display speed limit zones and alert you while driving would help curb the problem?
5. Do you think a reporting system for speed violations would be relevant?

ii. Vehicle Owners

1. How many vehicles have you registered in various PSV agencies?
2. Do you select the specific drivers for your specific vehicles?

3. Do your drivers know about speed limits on roads?
4. How do you know if a speeding violation is committed by the driver of your vehicle?
5. Do you think a mobile application to inform you about speed violations would be relevant?
6. Do you think a system to alert drivers about speed limits would be relevant?
7. Do you think a system to report speed violations would be useful?
8. **What** features do you think the application should have?

Appendix C: System Design Screen shots

Mobile application wireframes

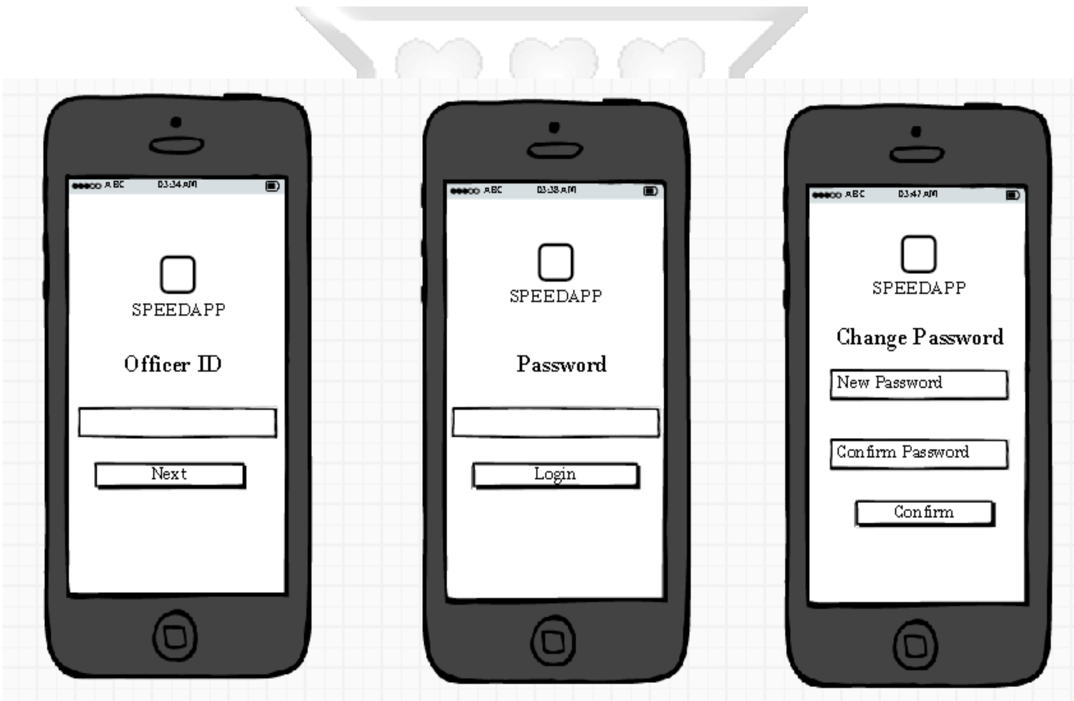


Figure C. 1: Mobile application wireframes

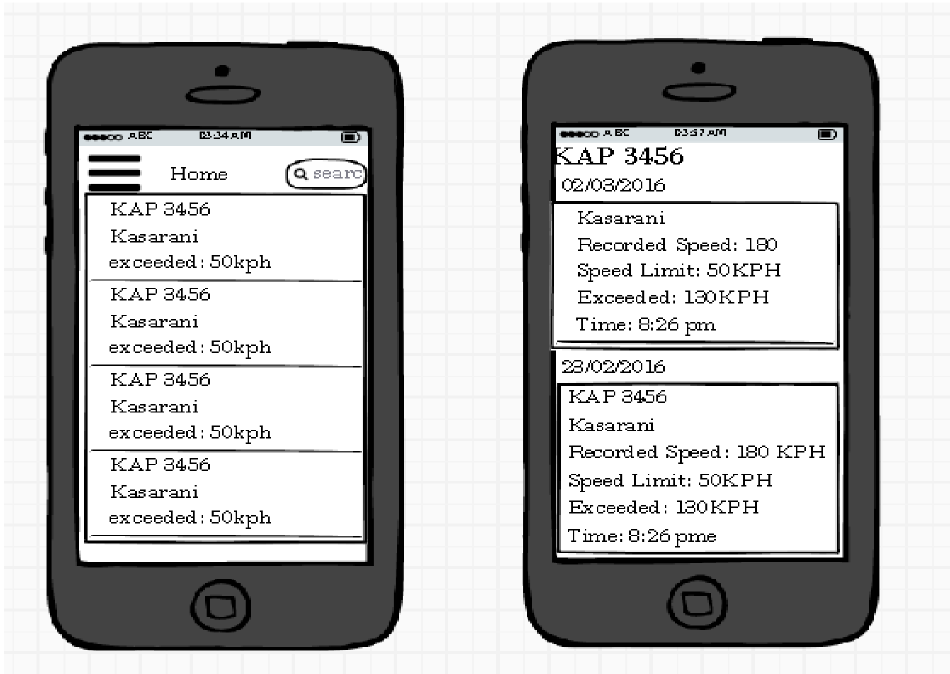


Figure C. 2: Mobile application wireframes

Web application wireframes

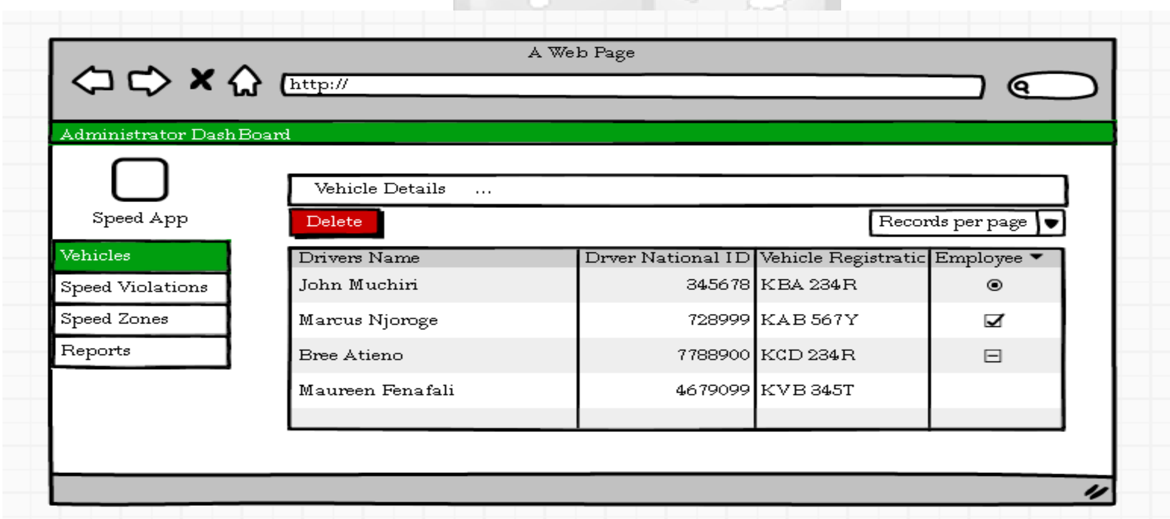


Figure C. 3 : Add vehicles

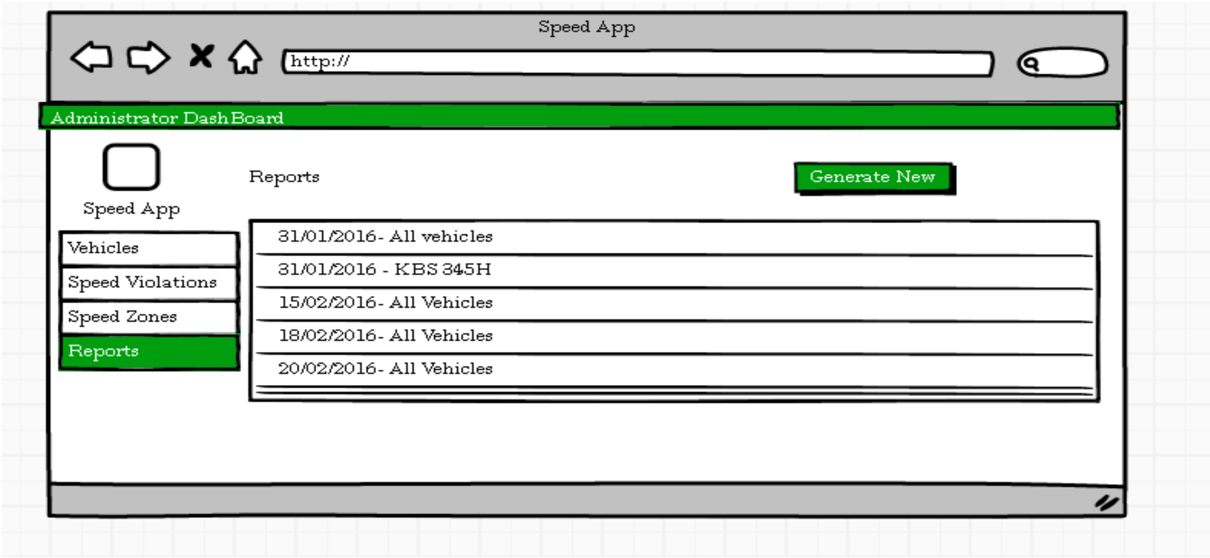


Figure C. 4: Generate Reports Wireframe

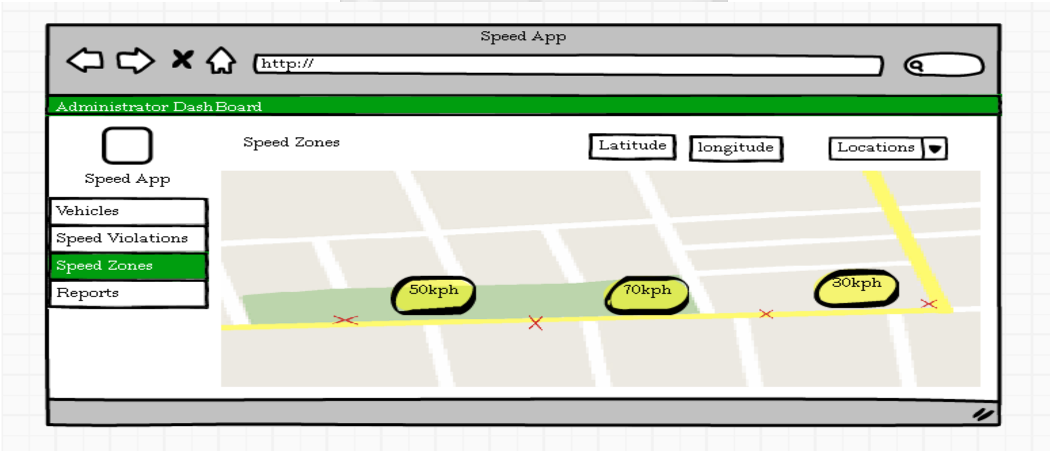


Figure C. 5: Speed Zone data wireframe

Appendix D: Implementation Screen shots

This section of the appendices shows that screen shots of the login and password change functionalities

i. Login for Mobile Application

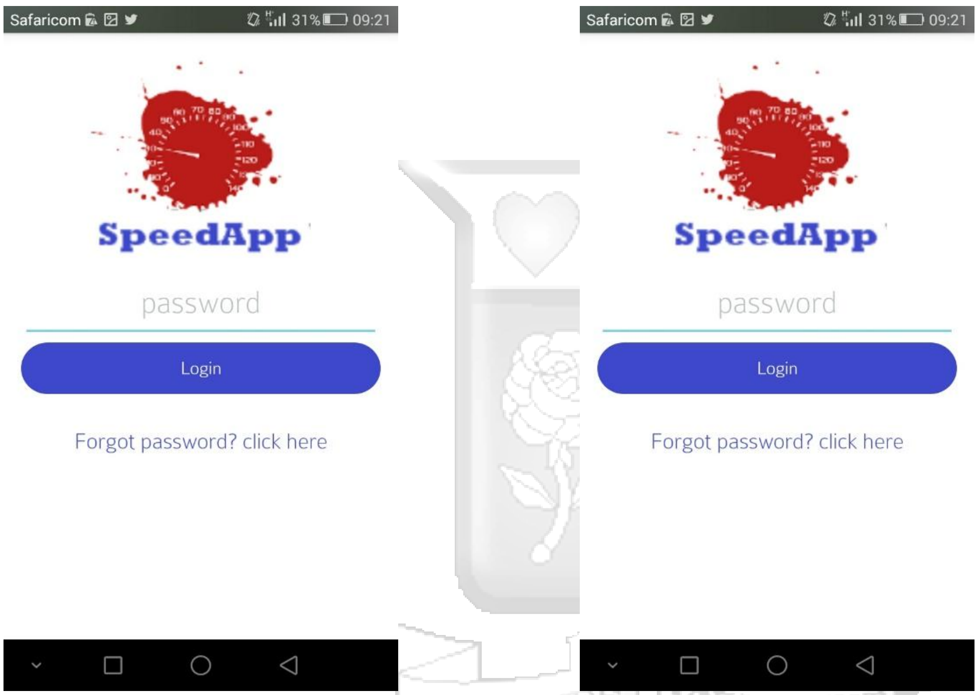


Figure D. 1: Login Screenshots

ii. Web Application Implementation Screens

- Vehicle Registration

The supervisor is responsible for adding data about PSV agency vehicles. This vehicle details are tied to a particular drivers details.

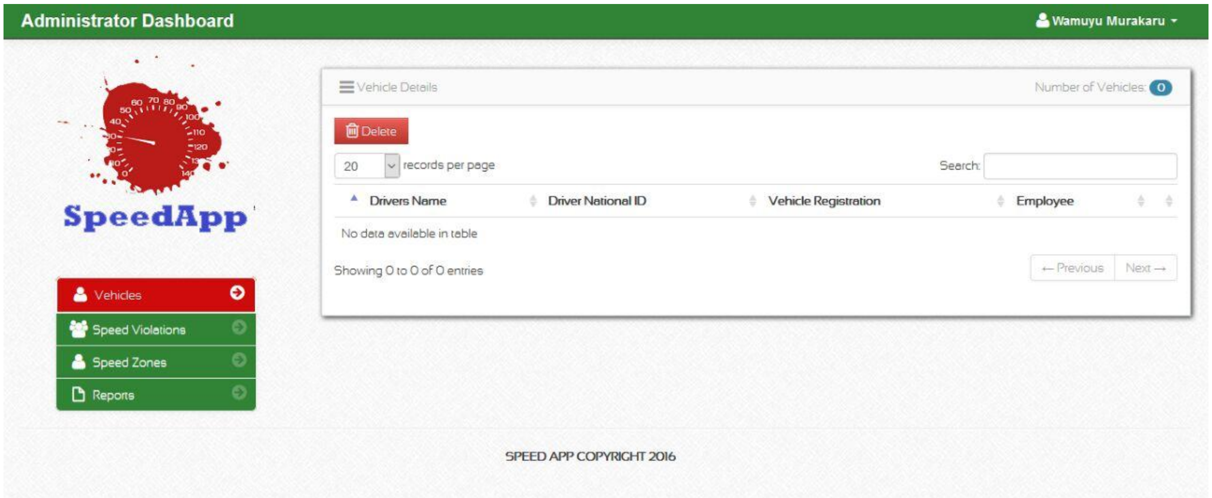


Figure D. 2: Vehicle data screenshots

- View Speed Violations

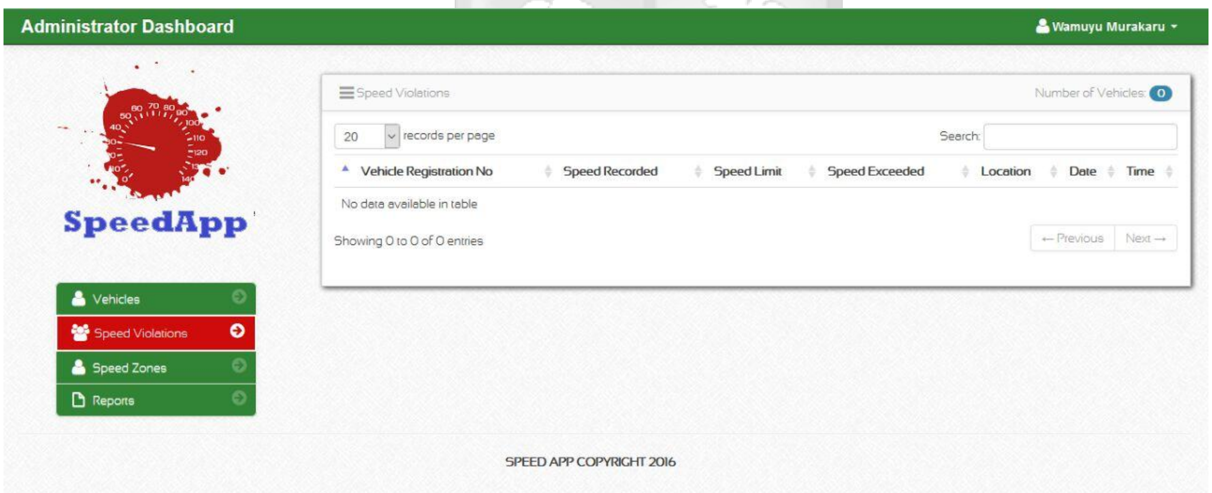


Figure D. 3: Speed Violation Screenshots

- Generate Reports

Reports containing data of speed violations can also be generated from the web application.

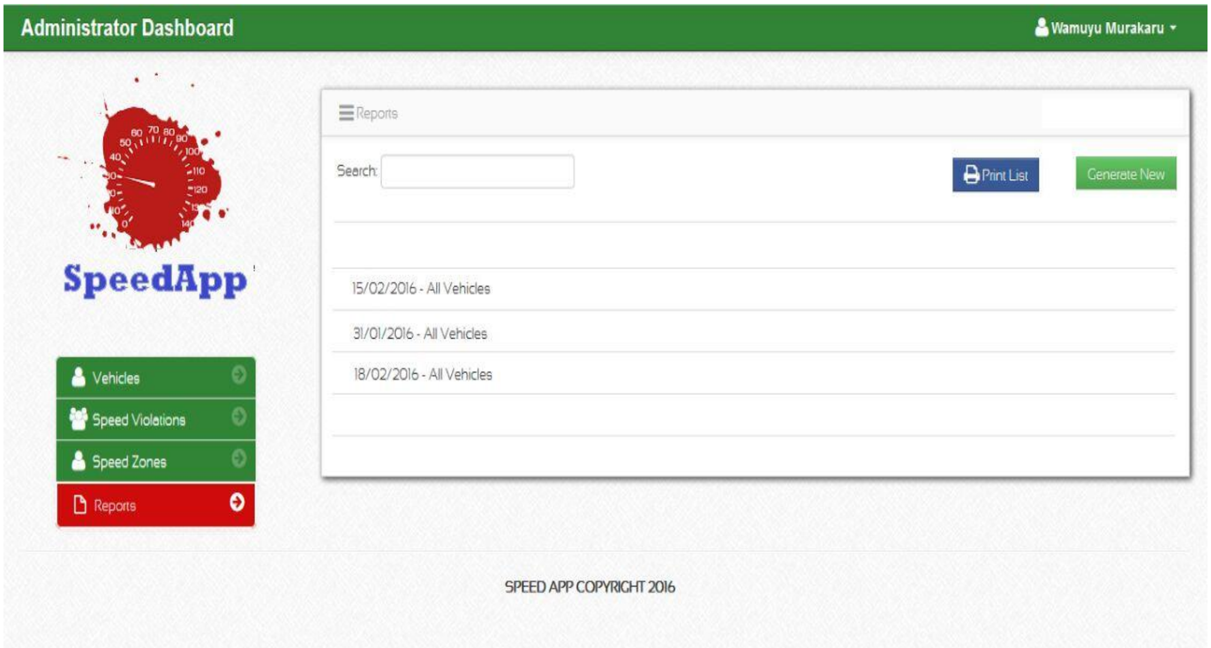


Figure D. 4: Generate Reports Screenshots

Appendix E: Design Diagrams

i. Class Diagrams

The figure below shows the classes that will be used in the application, their attributes and behaviors as well as the relationships between the various classes.

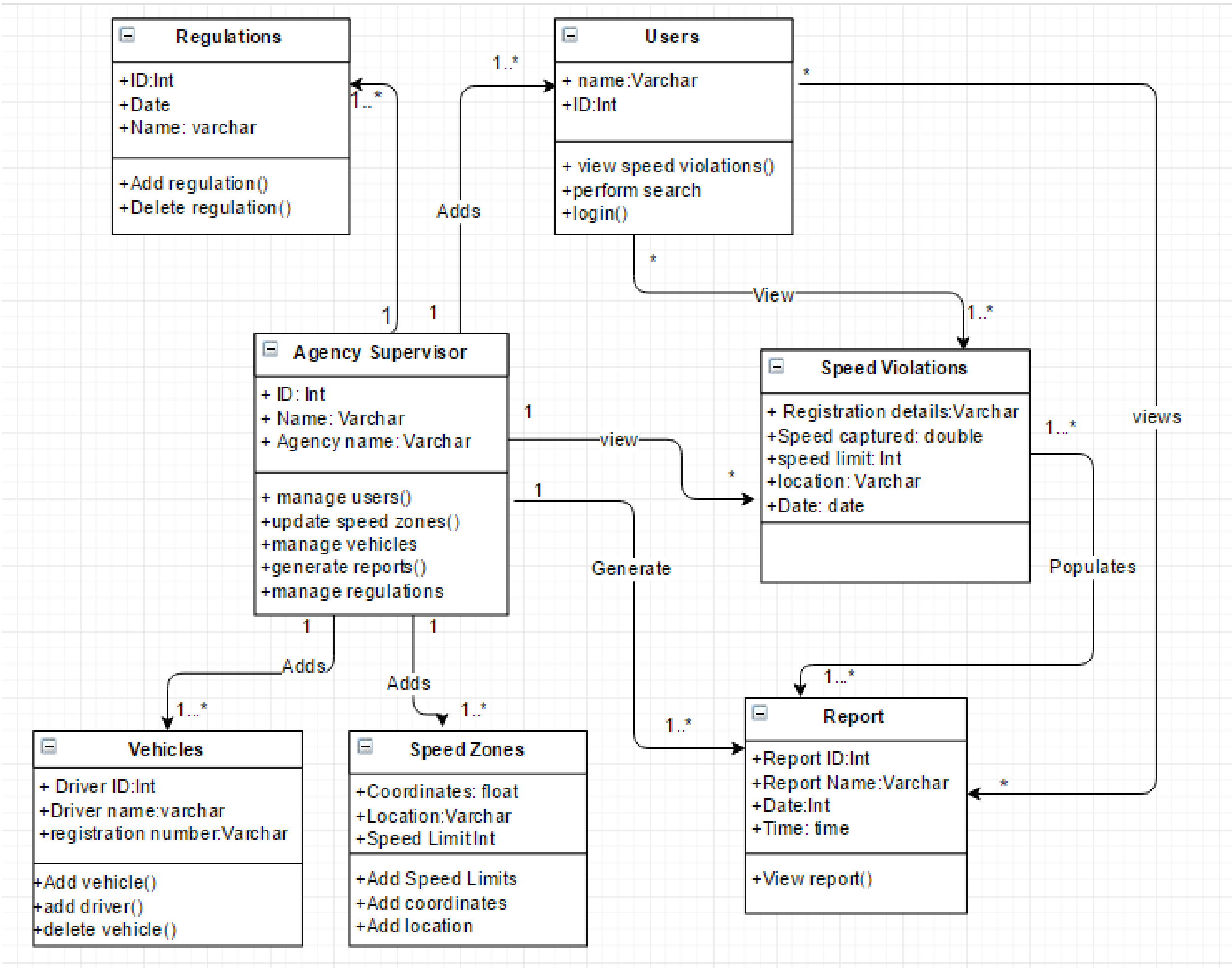


Figure E. 1: Class Diagram

ii. Database Schema

The database schema illustrate the table structure comprising of the fields, data types and the descriptions. The figure below show the database schema

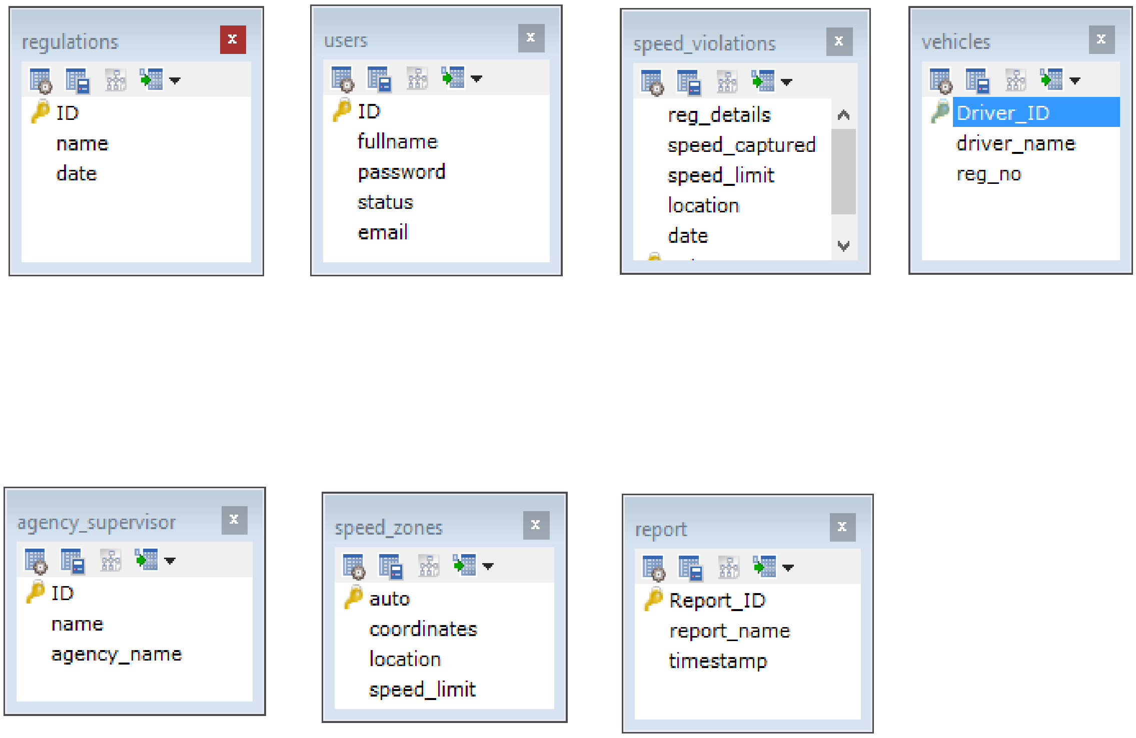
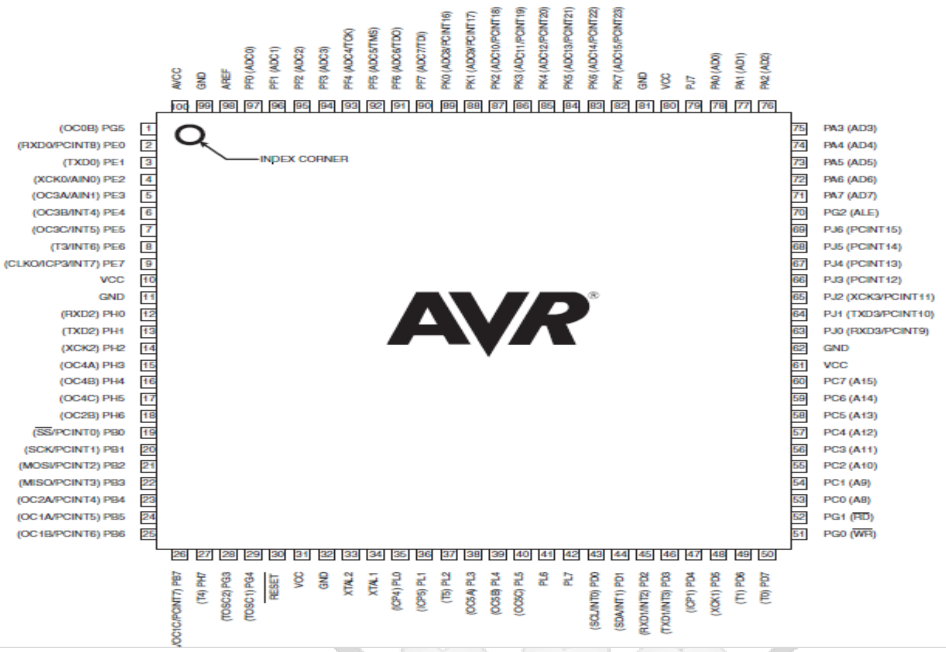


Figure E. 2: Database Schema

Appendix F: Embedded System

Each hardware component contains a data sheet which gives its technical description and can be used by the developer in system integration.

i. ATMEGA1280 Pin Configurations



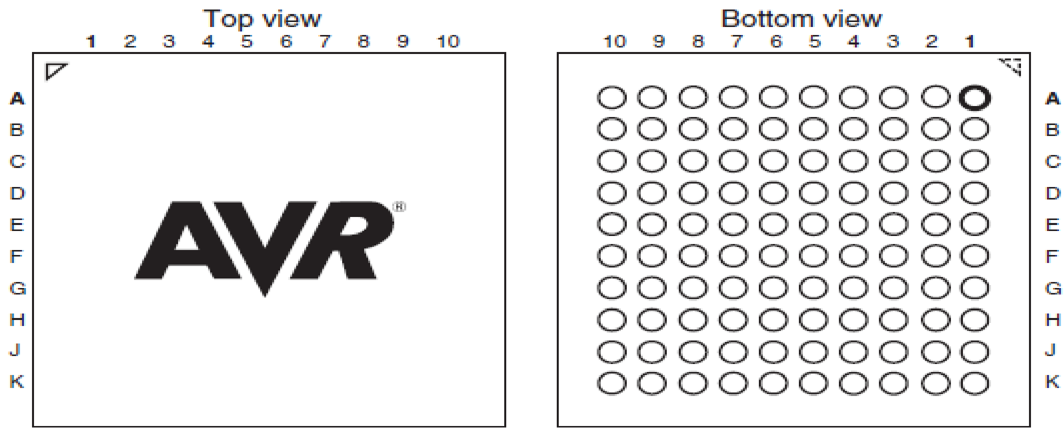


Table 1-1. CBGA-pinout ATmega640/1280/2560

	1	2	3	4	5	6	7	8	9	10
A	GND	AREF	PF0	PF2	PF5	PK0	PK3	PK6	GND	VCC
B	AVCC	PG5	PF1	PF3	PF6	PK1	PK4	PK7	PA0	PA2
C	PE2	PE0	PE1	PF4	PF7	PK2	PK5	PJ7	PA1	PA3
D	PE3	PE4	PE5	PE6	PH2	PA4	PA5	PA6	PA7	PG2
E	PE7	PH0	PH1	PH3	PH5	PJ6	PJ5	PJ4	PJ3	PJ2
F	VCC	PH4	PH6	PB0	PL4	PD1	PJ1	PJ0	PC7	GND
G	GND	PB1	PB2	PB5	PL2	PD0	PD5	PC5	PC6	VCC
H	PB3	PB4	RESET	PL1	PL3	PL7	PD4	PC4	PC3	PC2
J	PH7	PG3	PB6	PL0	XTAL2	PL6	PD3	PC1	PC0	PG1
K	PB7	PG4	VCC	GND	XTAL1	PL5	PD2	PD6	PD7	PG0

Figure F. 1: Atmega Specifications

ii. ADXL345 3 AXIS Accelerometer

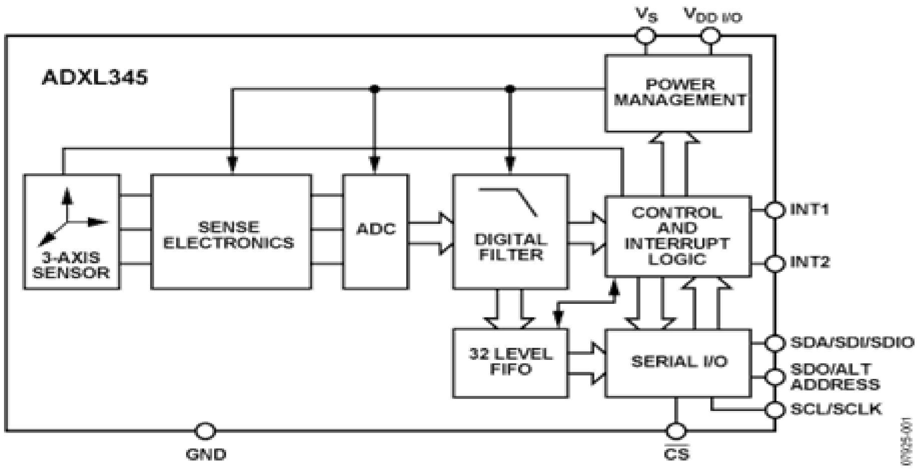


Figure F. 2: 3 Axis accelerometer

iii. SIM 808 Functional unit

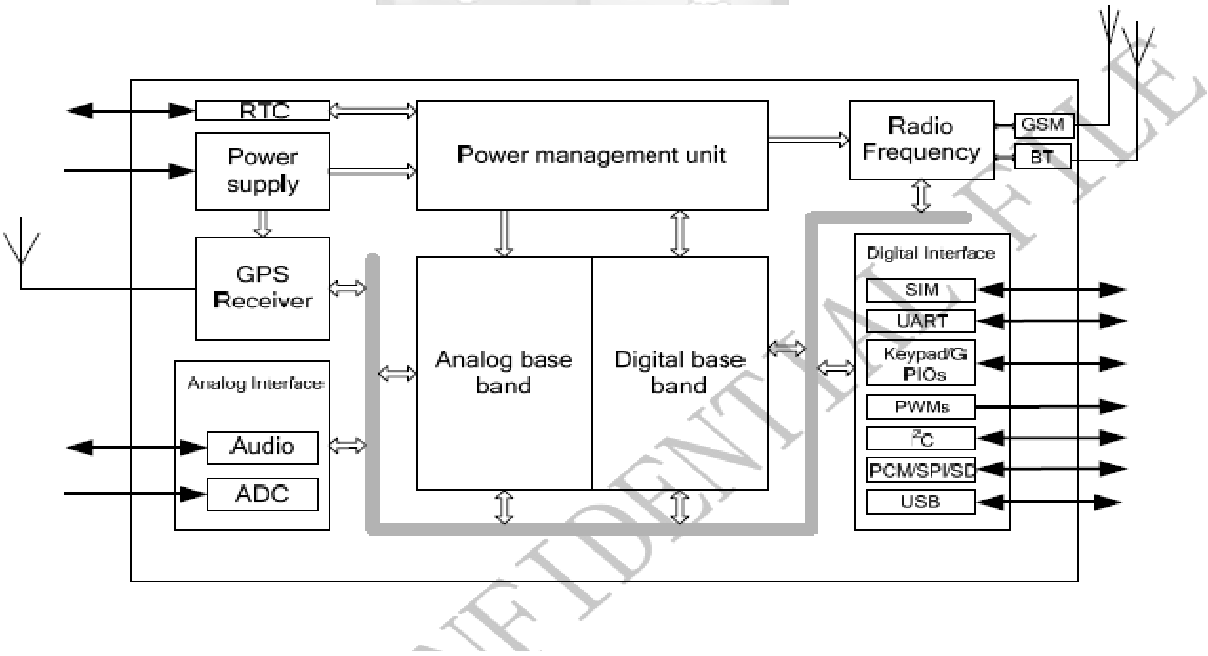


Figure F. 3:Sim808 Internal Components

iv. Embedded System Code Specifications

The code below is run in the microcontroller using the Arduino IDE to enable the embedded system to send and receive SMS, capture GPS data and speed of vehicle in real time.

```
#include <SoftwareSerial.h>

#include <Adafruit_GPS.h>

#include <SD.h>

#include <SPI.h>

#include <Adafruit_ILI9341.h>

#include <Adafruit_GFX.h>
#include <gfxfont.h>


// For the Adafruit shield, these are the default.
#define TFT_DC 9
#define TFT_CS 10

#define SD_CS 4

SoftwareSerial mySerial(3, 2);
SoftwareSerial gsmPort(7, 6);

Adafruit_GPS GPS(&mySerial);
```

```
// this keeps track of whether we're using the interrupt
// off by default!
boolean usingInterrupt = false;
void useInterrupt(boolean); // Func prototype keeps Arduino 0023 happy

//const char CTRL_CENTRE_NUMBER[] = "+254712630118";
const char CTRL_CENTRE_NUMBER[] = "+254723268653";

// Use hardware SPI (on Uno, #13, #12, #11) and the above for CS/DC
Adafruit_ILI9341 tft = Adafruit_ILI9341(TFT_CS, TFT_DC);
// If using the breakout, change pins as desired
//Adafruit_ILI9341 tft = Adafruit_ILI9341(TFT_CS, TFT_DC, TFT_MOSI, TFT_CLK,
TFT_RST, TFT_MISO);

int acceleration = 0;

void fillScreen()
{
  tft.fillScreen(ILI9341_BLACK);
}

void getVelocity()
{
  unsigned long start_val = micros();
  delay(1000);
  unsigned long read_value = analogRead(A0);       // read analog input pin A0

  unsigned long voltage = (read_value / 1023) * 3.3;

  unsigned long stop_val = micros() - start_val;  //elapsed seconds
```

```
  tft.fillRect(0, 0, 50, 50, ILI9341_BLUE);
  tft.setCursor(1, 10);
  tft.setTextColor(ILI9341_WHITE);  tft.setTextSize(2);
  tft.print(read_value);
  //Serial.print(read_value, DEC);

}

unsigned long testText() {
  tft.fillScreen(ILI9341_BLACK);
  unsigned long start = micros();
  tft.setCursor(0, 0);
  tft.setTextColor(ILI9341_WHITE);  tft.setTextSize(1);
  tft.println("Hello World!");

  tft.fillScreen(ILI9341_BLACK);

}



// This function opens a Windows Bitmap (BMP) file and
// displays it at the given coordinates.  It's sped up
// by reading many pixels worth of data at a time
// (rather than pixel by pixel).  Increasing the buffer
// size takes more of the Arduino's precious RAM but
// makes loading a little faster.  20 pixels seems a
// good balance.

#define BUFFPIXEL 20

void bmpDraw(char *filename, uint8_t x, uint16_t y) {
```

```
File     bmpFile;
int      bmpWidth, bmpHeight;   // W+H in pixels
uint8_t  bmpDepth;              // Bit depth (currently must be 24)
uint32_t bmpImageoffset;        // Start of image data in file
uint32_t rowSize;               // Not always = bmpWidth; may have padding
uint8_t  sdbuffer[3 * BUFFPIXEL]; // pixel buffer (R+G+B per pixel)
uint8_t  buffidx = sizeof(sdbuffer); // Current position in sdbuffer
boolean  goodBmp = false;       // Set to true on valid header parse
boolean  flip    = true;        // BMP is stored bottom-to-top
int      w, h, row, col;
uint8_t  r, g, b;
uint32_t pos = 0, startTime = millis();

if ((x >= tft.width()) || (y >= tft.height())) return;

/* Serial.println();
  Serial.print(F("Loading image '"));
  Serial.print(filename);
  Serial.println('\'');
*/

// Open requested file on SD card
if ((bmpFile = SD.open(filename)) == NULL) {
  // Serial.print(F("File not found"));
  tft.setCursor(0, 0);
  tft.fillRect(0, 0, 100, 50, ILI9341_BLUE);
  tft.setTextColor(ILI9341_YELLOW);  tft.setTextSize(2);
  tft.println("File not found!");
  delay(2000);
  tft.fillRect(0, 0, 230, 50,ILI9341_BLUE);
  return;
```

```
}

// Parse BMP header
if (read16(bmpFile) == 0x4D42) { // BMP signature
  // Serial.print(F("File size: ")); Serial.println(read32(bmpFile));
  (void)read32(bmpFile); // Read & ignore creator bytes
  bmpImageoffset = read32(bmpFile); // Start of image data
  //Serial.print(F("Image Offset: ")); Serial.println(bmpImageoffset, DEC);
  // Read DIB header
  //Serial.print(F("Header size: ")); Serial.println(read32(bmpFile));
  bmpWidth  = read32(bmpFile);
  bmpHeight = read32(bmpFile);
  if (read16(bmpFile) == 1) { // # planes -- must be '1'
    bmpDepth = read16(bmpFile); // bits per pixel
    //Serial.print(F("Bit Depth: ")); Serial.println(bmpDepth);
    if ((bmpDepth == 24) && (read32(bmpFile) == 0)) { // 0 = uncompressed

      goodBmp = true; // Supported BMP format -- proceed!
      // Serial.print(F("Image size: "));
      // Serial.print(bmpWidth);
      //Serial.print('x');
      // Serial.println(bmpHeight);

      // BMP rows are padded (if needed) to 4-byte boundary
      rowSize = (bmpWidth * 3 + 3) & ~3;

      // If bmpHeight is negative, image is in top-down order.
      // This is not canon but has been observed in the wild.
      if (bmpHeight < 0) {
        bmpHeight = -bmpHeight;
        flip      = false;
      }
```

```
// Crop area to be loaded
w = bmpWidth;
h = bmpHeight;
if ((x + w - 1) >= tft.width())  w = tft.width()  - x;
if ((y + h - 1) >= tft.height()) h = tft.height() - y;

// Set TFT address window to clipped image bounds
tft.setAddrWindow(x, y, x + w - 1, y + h - 1);

for (row = 0; row < h; row++) { // For each scanline...

  // Seek to start of scan line.  It might seem labor-
  // intensive to be doing this on every line, but this
  // method covers a lot of gritty details like cropping
  // and scanline padding.  Also, the seek only takes
  // place if the file position actually needs to change
  // (avoids a lot of cluster math in SD library).
  if (flip) // Bitmap is stored bottom-to-top order (normal BMP)
    pos = bmpImageoffset + (bmpHeight - 1 - row) * rowSize;
  else     // Bitmap is stored top-to-bottom
    pos = bmpImageoffset + row * rowSize;
  if (bmpFile.position() != pos) { // Need seek?
    bmpFile.seek(pos);
    buffidx = sizeof(sdbuffer); // Force buffer reload
  }

  for (col = 0; col < w; col++) { // For each pixel...
    // Time to read more pixel data?
    if (buffidx >= sizeof(sdbuffer)) { // Indeed
      bmpFile.read(sdbuffer, sizeof(sdbuffer));
      buffidx = 0; // Set index to beginning
```

```
          }

          // Convert pixel from BMP to TFT format, push to display
          b = sdbuffer[buffidx++];
          g = sdbuffer[buffidx++];
          r = sdbuffer[buffidx++];
          tft.pushColor(tft.color565(r, g, b));
        } // end pixel
      } // end scanline
      // Serial.print(F("Loaded in "));
      // Serial.print(millis() - startTime);
      // Serial.println(" ms");
    } // end goodBmp
  }
 }

 bmpFile.close();
 if (!goodBmp) Serial.println(F("BMP format not recognized."));
}

// These read 16- and 32-bit types from the SD card file.
// BMP data is stored little-endian, Arduino is little-endian too.
// May need to reverse subscript order if porting elsewhere.

uint16_t read16(File &f) {
 uint16_t result;
 ((uint8_t *)&result)[0] = f.read(); // LSB
 ((uint8_t *)&result)[1] = f.read(); // MSB
 return result;
}

uint32_t read32(File &f) {
```

```
  uint32_t result;
  ((uint8_t *)&result)[0] = f.read(); // LSB
  ((uint8_t *)&result)[1] = f.read();
  ((uint8_t *)&result)[2] = f.read();
  ((uint8_t *)&result)[3] = f.read(); // MSB
  return result;
}


void initGPS()
{

  // connect at 115200 so we can read the GPS fast enough and echo without dropping chars
  // also spit it out
  //Serial.begin(115200);
  //Serial.println("Adafruit GPS library basic test!");

  // 9600 NMEA is the default baud rate for Adafruit MTK GPS's- some use 4800
  GPS.begin(9600);

  // uncomment this line to turn on RMC (recommended minimum) and GGA (fix data)
including altitude
  GPS.sendCommand(PMTK_SET_NMEA_OUTPUT_RMCGGA);
  // uncomment this line to turn on only the "minimum recommended" data
  //GPS.sendCommand(PMTK_SET_NMEA_OUTPUT_RMCONLY);
  // For parsing data, we don't suggest using anything but either RMC only or RMC+GGA
since
  // the parser doesn't care about other sentences at this time

  // Set the update rate
  GPS.sendCommand(PMTK_SET_NMEA_UPDATE_1HZ);   // 1 Hz update rate
  // For the parsing code to work nicely and have time to sort thru the data, and
```

```
  // print it out we don't suggest using anything higher than 1 Hz

  // Request updates on antenna status, comment out to keep quiet
  GPS.sendCommand(PGCMD_ANTENNA);

  // the nice thing about this code is you can have a timer0 interrupt go off
  // every 1 millisecond, and read data from the GPS for you. that makes the
  // loop code a heck of a lot easier!
  useInterrupt(true);

  delay(1000);
  // Ask for firmware version
  mySerial.println(PMTK_Q_RELEASE);

}


// Interrupt is called once a millisecond, looks for any new GPS data, and stores it
SIGNAL(TIMER0_COMPA_vect) {
  char c = GPS.read();
  // if you want to debug, this is a good time to do it!

}


void useInterrupt(boolean v) {
  if (v) {
    // Timer0 is already used for millis() - we'll just interrupt somewhere
    // in the middle and call the "Compare A" function above
    OCR0A = 0xAF;
    TIMSK0 |= _BV(OCIE0A);
    usingInterrupt = true;
```

```
  } else {
    // do not call the interrupt function COMPA anymore
    TIMSK0 &= ~_BV(OCIE0A);
    usingInterrupt = false;
  }
}

uint32_t timer = millis();

void runGPS()
{
  // in case you are not using the interrupt above, you'll
  // need to 'hand query' the GPS, not suggested :(
  if (! usingInterrupt) {
    // read data from the GPS in the 'main loop'
    char c = GPS.read();

  }

  // if a sentence is received, we can check the checksum, parse it...
  if (GPS.newNMEAreceived()) {
    // a tricky thing here is if we print the NMEA sentence, or data
    // we end up not listening and catching other sentences!
    // so be very wary if using OUTPUT_ALLDATA and trytng to print out data
    //Serial.println(GPS.lastNMEA());   // this also sets the newNMEAreceived() flag to false

    if (!GPS.parse(GPS.lastNMEA()))   // this also sets the newNMEAreceived() flag to false
      return;  // we can fail to parse a sentence in which case we should just wait for another
  }

  // if millis() or timer wraps around, we'll just reset it
  if (timer > millis())  timer = millis();
```

```
  // approximately every 5 seconds or so, print out the current stats
  if (millis() - timer > 5000) {
    timer = millis(); // reset the timer


    if (GPS.fix) {

      /*Disable Echo*/
      Serial.println("ATE0\r");
      delay(1000);
      /*Delete all stored messages*/
      Serial.println("AT+CMGD=1,4\r");
      delay(1000);
      /*Set Message format to Text Mode*/
      Serial.println("AT+CMGF=1\r");
      delay(1000);
      /*Set New Message Indication format to Forward to SIM*/
      Serial.println("AT+CNMI=2,2,0,0,0\r");
      delay(1000);

      /*Set New Message Indication format to Forward to SIM*/
      Serial.println( "AT+CMGS=\"0726120256\"");
      delay(1000);

      Serial.print(GPS.longitude, 4);  Serial.println(GPS.lon); Serial.println(";");
      Serial.print(GPS.latitude, 4);  Serial.print(GPS.lat); Serial.println(";");
      Serial.print(GPS.day, DEC);  Serial.print(GPS.month, DEC); Serial.print("20");
Serial.println(GPS.year, DEC); Serial.println(";");
      Serial.println(GPS.speed);  Serial.println(";");
      Serial.println("KCF 121A;");
```

```
      delay(300);
      Serial.write(0x1A);
      delay(300);

    }
  }
}



void setup()
{
  Serial.begin(9600);
  pinMode(A0, INPUT);

  Serial.begin(9600);

  tft.begin();
  tft.setCursor(0, 0);
  tft.setTextColor(ILI9341_RED);  tft.setTextSize(2);
  tft.setRotation(2);

  if (!SD.begin(SD_CS))
  {
    //  Serial.println("failed!");
    //tft.setCursor(0, 0);
    // tft.setTextColor(ILI9341_RED);  tft.setTextSize(2);
    tft.println("SD Failed!");
    delay(2000);
  }
  else
  {
    tft.println("SD OK!");//Serial.println("OK!");
```

```
    delay(2000);
   }

  tft.fillScreen(ILI9341_BLUE);
  delay(2000);
 bmpDraw("strathjk.bmp", 0, 0);
 // bmpDraw("purple.bmp", 0, 0);
  //tft.drawCircle(10, 50, 10, ILI9341_BLACK);
  initGPS();

}

//unsigned long velocity = 0;

void loop(void)
{
  getVelocity();
  runGPS();
  delay(10000);

}
```

Appendix F: Turnitin Report

The screen shot below shows the turnitin report.