MIDLANDS STATE UNIVERSITY

Developing a Real Time Taxi Monitoring and Passenger Inventory System in Zimbabwe.

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Abstract

The design and implementation of this real time taxi monitoring and Passenger inventory system is meant to unleash a new era of systematic taxi operation in Zimbabwe. It introduces a tight close monitoring environment for taxis so as to maximise on returns from the business. In the prevailing situation where there is a general lack of effective monitoring of taxis the employees run a parallel business of their own using the same taxis. This inherent inefficiency in the system adversely affect turn over. The new system uses GPS and GSM networks to locate and track these taxis and providing numerous selected parameters which the Owner might be interested to know at any given time. An opportunity which qualify this project comes from massive volumes of people who use the public transport system in many parts of the world. The project lends itself to a ready estimated market of more than 10000 taxis operating in Harare alone. The taxi monitoring and Passenger inventory system is empowered to indicate the instantaneous Passenger inventory at any moment so that collected revenue can be matched to the day's activities. This information will be availed by SMS on the Owner's cellphone. The system focuses on any public transport system where accountability on the business activities are of primary concern.

Declaration

I, **Emmanuel Kuri (R131020V)** hereby declare that I am the sole author of this dissertation. I authorize the Midlands State University to lend this dissertation to other institutions or individuals for the purpose of scholarly research.

Signature………………………………..

Date………………………………………

Approval

This dissertation entitled “Developing a real time taxi monitoring and Passenger inventory system in Zimbabwe” by Emmanuel Kuri meets the regulations governing the award of the degree in Telecommunications at the Midlands State University, and is approved for its contribution to knowledge and literal presentation.

Supervisor ……………………………………………

Date ……………………………………………

Acknowledgements

First and foremost I would like to thank the Almighty God for the gift of life that I should partake of the joys of being a student taking a profound degree programme at such an advanced age. I am indebted to my wife for love, financial and moral support. I would also like to express my profound gratitude to my Supervisors, Mr. G. Manjengwa, A. Mudzingwa and department Chairperson, Dr. A. Nechibvute. Last but not least I acknowledge the support and direction from the Midlands State University lecturers.

Dedication

This dissertation is dedicated to my dear wife Patience Kuri together with our three children.

Table of Contents

List of acronyms

GPRS: General Packet Radio Service

GSM:	Global System for Mobile Communications
GPS:	Global Positioning System
PUK code:	Pin UnlocK code
SMD:	Surface Mounted Device
SMS:	Short Message Service
SRAM:	Static Random Access Memory
EEPROM:	Electrically Erasable Programmable Read-only memory
DIP:	Dual In Line
UART:	Universal Asynchronous Receiver Transmitter
PCB:	Printed Circuit Board
USB:	Universal Serial Bus
LCD:	Liquid Crystal Display
DC:	Direct Current
MSB:	Main Significant Bit
LSB:	Least Significant Bit

List of tables

List of figures

Dissertation outline

Chapter 1 Presents an introduction to the dissertation, defines the problem, outlines **o**bjectives, justifies the project as well an outline of the entire dissertation.

Chapter 2 This chapter focuses on literature review. It does so by exploring related systems in the industry, marries the project to theoretical concepts, lists hardware requirements, highlights on working principles of the GSM and GPS networks, outlines the dissertation work plan and benefits of the real-time taxi monitoring and Passenger inventory system.

Chapter 3 The methods used in the implementation of the project are outlined. This is coupled with a detailed explanation of all the hardware elements used in the project showing how the units are interconnected and integrated to produce the final product.

Chapter 4 Presents the results and analysis as well as highlighting challenges encountered in the implementation of the project.

Chapter 5 Presents the conclusions and recommendations for further research.

Chapter 1 Introduction

1.1 Introduction

The use of satellite aided navigation is well established worldwide. Land, sea and air transport rely heavily on this technique which obtains reliable and accurate position information from satellites. The taxi monitoring and Passenger inventory system in this project undoubtedly relies on this method as well. Since the majority of Zimbabweans do not own private cars they depend on public taxis to traverse both short and relatively long distances. At present the informal and formal minibus-taxi industry is, for the most part, unsafe, overcrowded, unreliable and expensive. It is on this background that the project aims to develop a device that will use a satellite navigation system coupled with a GSM network to locate and track taxis commonly known as kombis in Zimbabwe. Completion of the project will demonstrate the feasibility of the theory, and in such a broadening market, it will be possible to develop the system further into a commercial product extending its application to long distance high capacity busses. The taxi monitoring part of the system will help to closely observe Passenger traits as well as volumes with respect to times of the day thus building a Passenger inventory system which a crucial planning tool for an all-round efficient taxi transport system.

1.2 Problem definition

The taxi business is very lucrative in Zimbabwe, however it is badly infested with numerous loopholes which results in ‘organized’ abuse of the business processes by the Crew members. To date there is no known way of accounting for all the activities of the vehicles let alone knowing exactly where the vehicles spend most of the day as well as actual cash collected. This results in a poor scheme where the Owners just stipulate the money which they want at the end of each day. The taxi Crews i.e. Driver and Conductor then resort to unscrupulous means to collect more than the target so that they can pocket the “surplus loot” every day. This is achieved by over-speeding, over charging, using undesignated routes, flouting road regulations and massive bribery with the traffic Police so that they remain on the road even when their vehicles are off-route, not worthy to be on the road or when their driving documentation are not in order. These taxis usually park at undesignated areas, colloquially known as “mushikashika.” This greatly compromises the safety of the Passengers and the health of the fleet.

The real time control monitoring system will allow the owner to be able to locate his/her vehicles and to track them and even know how many Passengers are aboard the vehicle at all times. This is an area of research which no known researchers have attempted to solve. The Operators will now realize more profits due to control of the usage of the vehicles and account for every dollar. The vehicles will have extended life on the road since all movements and driving patterns can be monitored by the Owner. The overheads can also be reduced by removing the conductor from the taxi such that the Driver can be in charge of the vehicle alone. A modification has to be done for automatic door opening at the Drivers’ command as well as a smart card swipe payment system. Over and above these positive developments this transport system will become organized thereby reducing accidents and decongesting the cities. This is an important area of study since it contributes to ZIM ASSET, a Zimbabwean blue print for sustainable development spanning from 2014 to 2018 [1]. This will totally transform the taxi industry in Zimbabwe by assisting the Government to enhance peace and safety of the populace thereby encouraging development. It enhances poverty eradication by providing much cheaper taxi fares for the majority of the commuting people.

1.3 Aim and objectives

1.3.1 Aim

The aim of this study is to design a cost effective real time taxi monitoring and Passenger inventory system in Zimbabwe. This involves the setup of a real time taxi monitoring system which shows the physical location of the fleet at any given time as well as numerous selected parameters which the Owner might be interested to know at any given time. A related Passenger inventory system will be built from the Passenger loading patterns collected on this system over time.

1.3.2 Objectives

The objectives of this study are:

1. To design a taxi Passenger inventory system.
2. To design a taxi tracking system.
3. To design a vehicle status monitoring system.
4. To design a database and user interface to capture and display information from the first three objectives in real-time.

1.4 Justification

Project implementation promotes reduction of the taxi crew team by half. The facility helps to eliminate taxi Passenger overloading by raising a flag when anyone sits on non-designated sitting positions like “Kadoma”. Reduction in taxi, fuel and cash abuse enhances the taxi business. Computations of approximate daily cash collections before cashing in gives peace of mind to the taxi Operators in this volatile business environment. Passenger inventory at any given time as well as the ability to monitor specific vehicle parameters like engine temperature, fuel level, speed, direction of travel and date of next service helps optimize the taxi business by relieving the Driver and sending the vehicles for preventative maintenance service at times which the system will show to be least busy. The system can be modeled to aid the Government revenue collection since taxes related to actual incomes can now be collected.

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2 Chapter 2. Literature review and theoretical concepts

2.1 Introduction

This chapter explores the related works in the same field, brings to light theoretical concepts involved and explains all the items used in this project. Similar systems have been identified in major cities of the first world countries and the applicability of a tailor made solution is being developed for implementation in this project. In Zimbabwe there is no known record of use for a similar system, at least for the majority of this type of kombi taxi. This is the current work under development.

2.2 Existing systems related to the project

2.2.1 Tramigo solutions

The Tramigo is a tracking system which works with any cellphone handset without any need of software or internet connection. This solution has three variants namely the T23 M1 Move, the T23 Fleet and the T23 Magnum. It has global and local support in many countries with no license requirements from users.

It is used for asset tracking and fleet management. This solution targets security, small and large fleet tracking as well as Personnel tracking. The T23 M1 Move is for private asset, vehicle tracking and small fleet tracking. It has an ultra-sensitive GPS receiver with no external antennae and minimized wiring which makes it easy to hide. It is also used by corporate, insurance, Finance and vehicle leasing companies. Professional tracking & security for private vehicle owners, fleet owners, fleet service providers and government vehicle users. M1 Fleet Enterprise is for large fleet management. Most appropriate for fleet of busses, trucks and for vehicle leasing companies with large fleets. This brand has a long lasting independent back up battery. Vehicle security and tracking solution is ideal for car leasing/rental companies and insurance companies. It is water-proofed, rugged design for container and other long-term outdoor asset tracking. Up to six weeks battery life with one charge. Professional fleet management and monitoring solution. The T23 Magnum is very flexible with internal and external GPS for flexible interfacing. It has numerous features which include driver identification, door sensors and temperature sensors in real time. It is also water resistant. These Tramigo tracking systems have flexible user interface software. The M1 Move and the M1 Fleet can be used on Android tablets and smart phones. M1 Fleet Enterprise is used with multi-client server software, it can have full time control of internal conditions on any of the vehicles. All these software use Land mark Directory Data (TLD) for easy of identifying of locations. The system has a directory of all known landmarks all over the world such that a typical location can be defined by both GPS coordinates and something like "*vehicle is parked at 13m from Karigamombe building in Samora Machel Avenue, Harare.*"

2.2.2 Econet connected car

This is a vehicle tracking system recently developed by Econet Wireless. It is optimized for mobile phones. Users can log in, track, manage and generate reports. It gives notifications and reports on driving behaviour events such as harsh braking and acceleration. The Econet connected car is equipped with the ability to set up geographical driving zones and sends alerts when in or out of the set zones. A panic button is used to alert vehicle owner of any event or threat by simply pressing a panic button helping them to react promptly. The system also allows tracking one's vehicle location even when it is outside Zimbabwe. It has customised reports as part of management tools to suit individual entity's reporting needs - historical trip summary and time reports, total km travelled, stops, etc. The Econet Connected Car web portal is optimised for easy viewing and navigation on mobile devices.

2.2.3 Taximeters

National meter manufacturing company represents numerous companies who are in the business of manufacturing taxi meters all over the world. The company, established in 2002 is a prominent manufacturer and exporter of wide range of electronic Taxi meters and rickshaw fare meters. The products are customised to provide GPS, GPRS and printers as per client's requirements. They claim that their array meets the highest international standards. Their products are designed in accordance with latest technology in digital electronics. Besides catering to the domestic market in India, they export their products to numerous clients based in Sri Lanka, Africa, Middle East, Nepal and Bangladesh.

FIGURE: 2.1 An Android™ simulation of modern taximeters

While National meter manufacturing company provides industry leading hardware that has integrated printers, GPS and GPRS, Techno Alliance comes with some seriously good software in the form of web and mobile applications. The mobile and web applications were developed by Redbytes and Probytes respectively, both of which are subsidiaries of Techno Alliance. The Company boasts of producing quality products with high precision, compactness, accurate results, efficiency, user-friendliness, and long operational life. They also offer one year warranty for their products against manufacturing defects.

2.2.4 Uber

Uber is a smartphone application which provides on-demand service to users. It connects willing Passengers to taxi cab drivers. Taxi drivers use their own cars when providing taxi service and Uber gets 20% of the fare. The total process is very simple, registered Uber users asks for a taxi using the Uber app, a Uber driver is then dispatched to the Passenger's location and assist the Passengers to reach his destination. The Passenger's credit card is used as the sole payment method. Currently, this service is said to be available in 200 cities across 55 countries. Uber connects the taxi driver and the Passenger and then receives a percentage of the fare.

Figure: 2.2 The Uber Business Model in a Nutshell

The Taxi Driver can be anyone with a driving license and a car. After screening, the driver is enlisted in the Uber system and is given a Uber iPhone. This provides a steady income to anyone with a car without additional hazard or investment. The Passengers are registered Uber users who download the Uber app to their phones and if they need a taxi, they call a taxi via the Uber app. They can also track the taxi on their phone as it approaches. This service is convenient for the Passengers, provides them relatively low cost comfortable service.

Uber sets the taxi fares. Premium fare during peak hours and flat rate for off peak hours. Passengers pay through their credit cards and don't have to pay any cash to the drivers. The fare is based on car type, distance and peak hour. Payment is secure because Passengers pay only via credit card using Uber app. At present, Uber doesn't own any taxi and because of that Uber can show a higher amount of its earnings as profits. Uber already reported to cover 200 cities in 55 countries and is expected to progress to dozens of new cities in the near future.

2.2.4.1 The strengths of the Uber Model

- Keep Passengers updated automatically by notifying through SMS
- Proper organization and management of vehicles and drivers to maximize efficiency
- Retention of customers through timely and well organized services.
- Comprehensive data through reports and statistics.
- Easy for drivers to process orders and give receipts using taximeter's vehicle tracking system.
- Passengers enjoy the safety of recognized drivers.
- The system is convenient with significant savings in terms of time and money.
- The biggest gain would be customer satisfaction which is the main ingredient in the success of the taxi business.

All the solutions provided for in the above review use the same basic GPS core units identical to the one in this project however their emphasis is on tracking. They all monitor and track vehicles without giving the crucial Passenger inventory at any given time. This project attempts to address this additional dimension for taxis so that the taxi Owner can relate the movement of the taxi with the collected revenues.

2.3 Theoretical concepts

2.3.1 Business value

The elimination of money leakages from the taxi business system means that the business becomes more viable and the general health status of the fleet is improved thus translating in a better economy with less accidents. This creates room for chances of slightly reducing the taxi fares thus benefiting the generality of the commuters and improving their way of living since they can now save some of the money for other necessities in life.

2.3.2 Feasibility Study

This feasibility study assesses the economic, technical, operational and social merits of the taxi monitoring and Passenger inventory system.

2.3.2.1 Technical Feasibility

The proposed technology is available and is practical in that the necessary technical expertise is available however there is need to train more technical teams on the product and to establish a research and development centre so as to continually customise the product to the current market dictates. The technology is mature enough to handle the solution. A mature technology is characterised by a larger customer base for obtaining advice concerning problems and improvements [2]. The active components of the system are integral units of a myriad of systems the world over. This technical feasibility study seeks to clearly prove that the project is technically possible to be undertaken. The fields of the technical study can be determined as follows: Method of production, Production technique, Project requirements and Project location.

2.3.2.1.1 Method of production

Inputs are readily available on the Chinese market. An online distributor known as Maspaka is able to deliver the electronic components required within five working days after paying, RS components in neighbouring South Africa stocks all the components that are necessary for the implementation of this project. Expected high demand of the product on the market will warrant mass production to cut on unit costs.

2.3.2.1.2 Production Technique

The optimal production technique would be to patent the product and get into a contractual agreement where the units are manufactured by another company, hopefully a Chinese one where cheaper labour rates are harnessed for mass production pursued. The use of Surface Mounted Devices technology so that the units are minute, use less power and are easy to mount on the most inaccessible parts of the taxis.

2.3.2.1.3 Project Requirements

Once the method of production and its technique are determined, technical people then determine the projects' requirements during the investment and operating periods. These include:-

- Determination of tools and equipment needed for the project such as screw drivers, connectors, cables, soldering kits, GSM modules, GPS modules, LCDs, batteries, housings, GPS and GSM antennae etc.
- Provision of skilled and unskilled labour, managerial and financial labour.
- Installation and mounting period for the units in a single 18 seater taxi.
- Costs of designs, software changes and consultations and the costs of mechanical works associated with the project.
- Minimum storage of inputs for say a fortnight's work requirements, cash to cope with operating and contingency costs.

2.3.2.1.4 Project Location

The project location will depend on approvals on the environment and concerned institutions for licencing. The first proposal for the location is in any of the industrial areas of Harare where rentals are not as expensive as in the CBD and where there is ample parking space for customers. The location has been chosen as Harare because the bulk of the customers are expected in this town and raw materials are cleared from the airport Customs department in the same town. Costs of transporting inputs and outputs to the project's location are therefore minimised.

2.3.3 Economic feasibility study

The purpose of the economic feasibility study is to demonstrate the net benefit of a proposed taxi monitoring and Passenger inventory project taking into consideration the benefits and costs to implement the project. The business case is very strong since it will be enforced by the owners of the business who know for certain that they did not have full control of their business empire. The expected customers are all kombi taxi Operators, long distance Passenger mini busses. At present they work with their crew members on a mutual trust basis without any way of strict monitoring of the operations and revenue collection. It is reported that there are over 60,000 minibuses and kombi taxis in Zimbabwe [3]. These initial volumes warrant the economic feasibility of the project. The economic impact on other state agencies and the general public is that of savings on transport fares so that other critical aspects of the daily lives can be attended to, thus improving the standard of lives of the commuters.

2.3.4 Environmental and Social feasibility study

This addresses the environmental and social aspects of the project. It requires a plan of environmental mitigation, as well as monitoring in order to identify future possible negative impacts. The vehicle is wired with numerous sensors and signal wires which must be of a nature that does not compromise Passenger safety even in the event of an accident. This task is best handled by a specialist and covers both the work plan and final operations.

Effect of operation in areas of influence, specifically near places like hospitals, schools, markets also need special assessment over a long time say six months. Evaluation of the direct environmental impacts caused in the radio frequency energy must also be done since this will continually be in the vehicle. The driver would have the maximum dosage and therefore affected much more than the Passengers*.
A social impact that results from this project is the loss of employment of taxi conductors. A mutually agreed compensation need to be put in place in view of the prevailing labour laws since the loss of employment is caused at the discretion of the Employer.

By the same token the "Hwindi" (informal workers as well) would gradually lose their touting jobs. Efforts would also be put in place to have the taxis operate in full compliance of their operational requirements, this would cut down on both bribery with the Police and accidents due to un-roadworthy taxis.

2.3.5 Operational feasibility

This defines the urgency of the problem and the acceptability of the solution. When the system is fully developed it will be most welcome to the taxi Owners since it has positive financial returns and assures them of direct control and monitoring of their business empire.

**The GSM transmitter is a class two unit which may reach a maximum radiation power of 2Watts*
It is also bound to have acceptance from the commuters and the society at large since it attempts

to tame the behaviour of the taxi drivers which possess a risk on the roads through autonomy and outright arrogance. The project is feasible within the limits of current technology and is also within the available resource constraints. The implementing budget will be availed from the savings which will be generated. The timing is most appropriate at this time when the economy is still in turbulent times hence the need to survive the business.

The feasibility of implementaing the taxi and Passenger inventory system is highly possible in Zimbabwe because of the favourable results from the various elements of the feasibility study discussed above.

2.4 Hardware requirements

2.4.1 Parts list

- Sim908 GSM/GPS/GPRS modem with antennae
- Arduino Uno
- LCD
- Auxiliary DC Power Supply
- Resistors
- Digital multiplexer circuit
- Seat sensors (Push to make switches)
- Cell phone handset
- A laptop (For uploading sketches and monitoring)
- Taxi (On which project is implemented)

2.4.1.1 Sim 908/Sim5320 GPS / GSM GPRS Shield

WCDMA shield for Arduino which quad band GPS technology for satellite navigation: operating at 850/900/18001900MHz with 42-channel, GPS L1 C/A code. It uses 6 -12V DC power supply. In this project it sits on top of the Arduino shield there by extending the power connections to the top.

2.4.1.2 Overview of the Sim 908/Sim5320 GPS / GSM GPRS Shield

FIGURE: 2.3 Sim 908/Sim5320 GPS / GSM GPRS Shield

Key:

SIM100: Sim Test point card socket

TP102: Test point SIM908VDD -EXT

U102: SIM908 Module

J104: GSM antenna connector

TP105: Test point SIM908 VBATT

J105: GPS antenna connector

SW101: GSM on/ off switch

J101: UART Connector jumper pins

CN100: Over design for GSM/GPS port

U3: 5110 LCD Connector

J100: Arduino Uno connector

J102: RJ12 Transmit /receive telephone connector

D102: Power indicator LED

D100: GSM Network Status LED

D101: SIM908 ON indicator LED

2.4.1.3 The Arduino Uno module

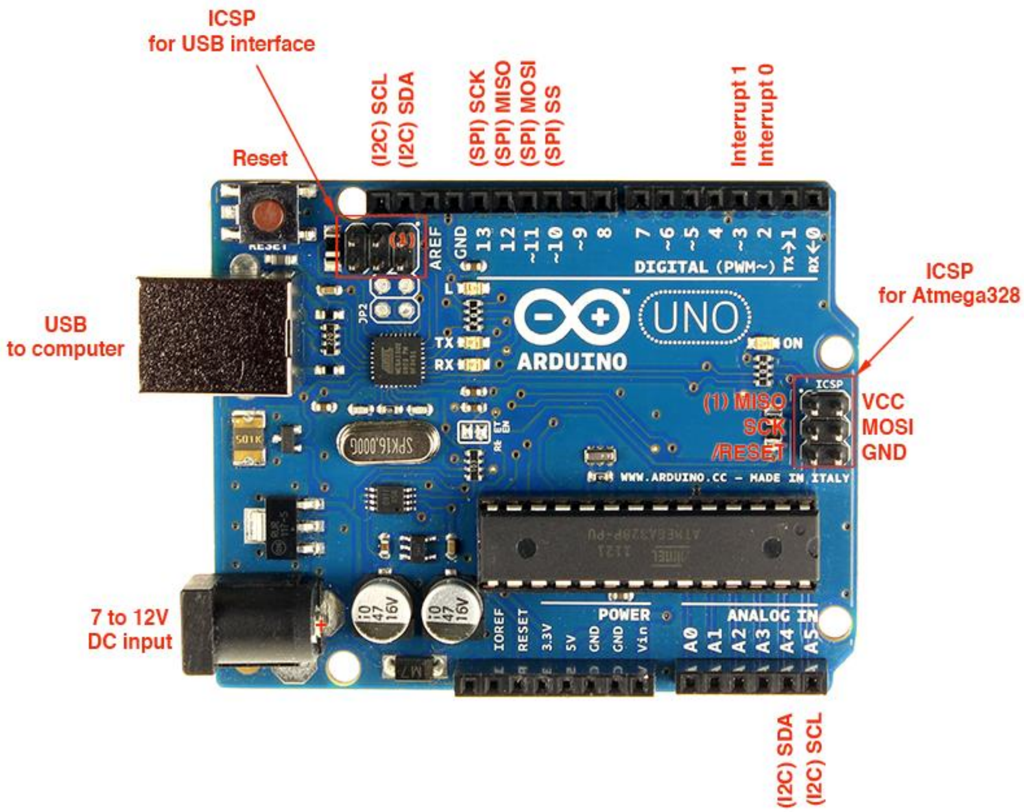

FIGURE: 2.4 The Arduino Uno module

The Arduino Uno is the heart of the project. It is an input output board with an electronic printed circuit board (PCB) and electronic parts featuring the ATmega8 processor from Atmel. It has 14 Digital pins which can be used as an inputs or outputs, using pin Mode(), digital Write, and digital Read() functions. The pins operate at 5 volts. Each pin can provide or receive a maximum of 40 mA and has an internal pull-up resistor (disconnected by default) of 20-50 Kilo Ohms. In addition, some pins have specialized functions, pin 13 is connected to a built-in LED. When the pin is HIGH value, the LED is on, when the pin is LOW, it's off.

The Arduino Uno has 6 analogue inputs, labelled A0 through A5, each of which provide 10 bits of resolution (i.e. 1024 different values. The Arduino GSM shield allows an Arduino board to connect to the internet, send and receive SMS, and make voice calls using the GSM library.

2.4.1.3.1 Specifications of the ATmega328 processor unit in the Arduino Uno

Microcontroller	ATmega328
Operating Voltage	5V
Input Voltage (recommended)	7-12V
Input Voltage (limits)	6-20V
Digital I/O Pins	14 (of which 6 provide PWM output)
Analog Input Pins	6
DC Current per I/O Pin	40 mA
DC Current for 3.3V Pin	50 mA
Flash Memory	32 KB (ATmega328) of which 0.5 KB used by bootloader
SRAM	2 KB (ATmega328)
EEPROM	1 KB (ATmega328)
Clock Speed	16 MHz

2.4.2 Liquid crystal display

The LCD is optional on the project because by nature the unit is hidden in the most inaccessible parts of the vehicle so that no one really uses it. If required use is made of LCD displays which were once used on Nokia 5110 / 3110. These are 84 by 48 pixel black and white LCDs whose pin configurations are shown below. It requires two different supply voltages, one for the LCD backlight and the other for the electronic circuitry on the LCD unit.

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TABLE: 2.1 Pinout for 5110 LCD

Pin Number	Pin Label	Pin Function	Input/Output?	Notes
1	**VCC**	Positive power supply	Input	Supply range is between 2.7V and 3.3V
2	**GND**	Ground	Input	
3	**SCE**	Chip select	Input	Active low
4	**RST**	Reset	Input	Active low
5	**D/C**	Mode select	Input	Select between command mode (low) and data mode (high).
6	**DN(MOSI)**	Serial data in	Input	
7	**SCLK**	Serial clock	Input	
8	**LED**	LED backlight supply	Input	Maximum voltage supply is 3.3V.

The LCD is controlled by a Philips PCD8544 chip through a synchronous serial interface. It has a clock (SCLK) and a data line (DN) as well as an active low chip select (SCE) input. With a maximum input voltage of 3.6 V DC. Voltage level conversion is done to use the Arduino which works on 5V to be interfaced with the LCD which requires 3.3V.

TABLE: 2.2 Interconnection of Arduino and the Nokia 5110 LCD

LCD Pin	Arduino Pin	Notes
1 - VCC	3.3V (VCC)	3.3V only (not 5V!)
2 - GND	GND	
3 - SCE	7	Can be any digital pin.
4 - RST	6	Can be any digital pin.
5 - D/C	5	Can be any digital pin.
6 - DN(MOSI)	11	Can't be moved.
SCLK	13	Can't be moved.
LED	9	Can be any PWM pin. 330Ω resistor in between the pins.

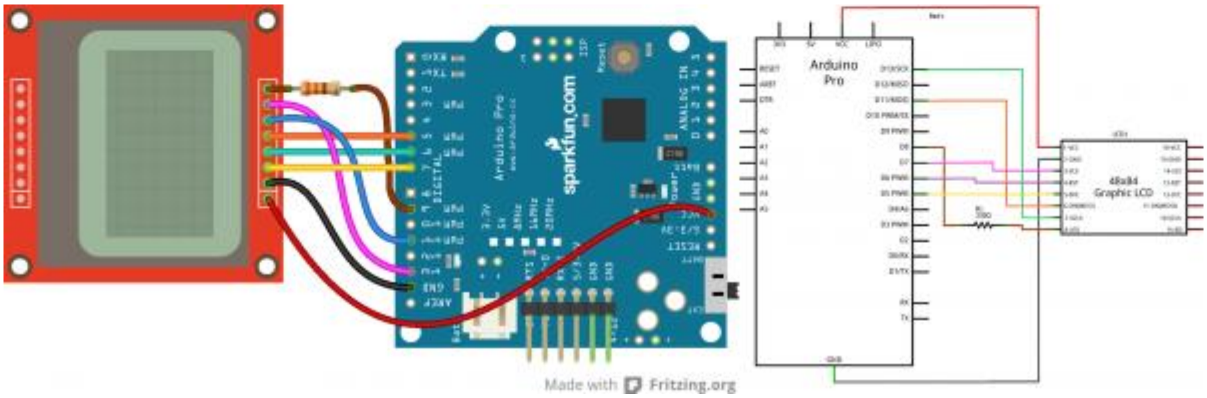

FIGURE: 2.5 Interconnection of Arduino Uno and the Nokia 5110 LCD

An Arduino Uno has digital output pins which switch between 5V and 0 Volts. These are connected via 10k ohm resistors to the inputs of a voltage level shifter which in turn is connected to the LCD inputs. Since the LCD has five 3.3V signal inputs and the level shifters only have four channels. To minimize on circuitry, one shifter can be used if we decide to forego the remote control facility by permanently tying the RST pin high through a 10kΩ resistor. The remaining four signals then go through the shifter.

2.4.3 Auxiliary 12 V supply

Whilst the Arduino Uno is usually powered by the computer USB port, however the associated GSM/GPS/GPRS requires an auxiliary power supply of 12V DC with the ability to drive a current of 1.5 Amps. (For some Arduino Uno's a maximum of 20 V DC is permissible) Use was made of a low internal resistance transformer with associated rectifier and regulation circuitry to avail the required power.

2.4.4 Resistors

Resistors are components which resist the flow of electric current through them when a potential difference is placed across their terminals. They come in different types, sizes and wattage and range from carbon film resistors which handle less power to wire wound resisters which dissipate more power. They may be Ohmic or non Ohmic. Ohmic resistors have a linear relationship between the voltage across them and the current which flows through them. Carbon resistors approximate these at constant temperatures. The resistance, R of an Ohmic resistor is defined by Ohms law which states that the Voltage ,V across the resistor is directly proportional to the current, I which flows through that resistor i.e. if the constant of proportionality is taken as R then V=IR. Power dissipated in that resistor is given in Watts, W by I squared multiplied by R or V squared divided by R.

2.4.5 Digital multiplexing circuit

The Arduino has limited inputs, both digital and analogue i.e. a total of 19. Multiplexing becomes necessary so that for this project where up to 32 digital inputs might be required only three pins can be used by using the CD 4021 Static Shift Register in cascade as elaborated in Chapter 3.3.2 of this dissertation. Inputs can range from Passenger sets to taxi door closed / open status, amount of fuel, temperature of engine etc.

2.4.6 Seat sensors

These are push to make switches which are activated to provide continuity when a Passenger occupies a seat. The 5V DC on the free end of the switch then replaces the 10k ohms resistive ground which is normally tied to the digital inputs when the seat is unoccupied. On the simulation board DIP switches are used to distinguish occupied and unoccupied seats. In the final product these will be blended in the upholstery of the seats.

2.4.7 Cell phone

Any cellphone can be used to receive the message of both the coordinates of the vehicle, the number of seats occupied in addition to any other information that may be required at any given time.

2.4.8 Sim card

A separate sim card is required to reside in other GSM unit stationed in the taxi. This sim card should preferably be on a contract line arrangement so that the much required SMS s are always available.

2.4.9 Lap top

A laptop is necessary for uploading and making changes to the program sketches on the micro controller. A serial interface is provided by the Arduino software so that it becomes unnecessary to have the LCD on this remote terminal unit since all the inputs and outputs can be viewed on this serial monitor.

2.4.10 Taxi

This is the vehicle whose parameters are being monitored inclusive of the coordinates and Passenger inventory. The seats are to be modified to include some bulging conducting material which completes the electrical circuit when seat is occupied. This is done in close consultation with the upholsterer. Doors are to be fitted with micro switches which close electrical contacts when closed. These give some of the prerequisite conditions to do the Passenger counting a set time or distance when the taxi has moved. Micro switches can also be fitted on non-designated sitting positions so that the vehicle is not overloaded e.g. “Kadoma.”

2.5 Working principles of a GPS system

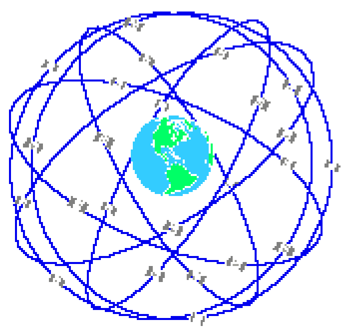

FIGURE: 2.6 Illustration of the network of the constellation of satellites above the globe

Global Positioning System defines and provide specific locations anywhere on the globe. These are defined by longitude, latitude and altitude with real time and date stamp. The system uses Global navigation satellite system. And requires uninterrupted line of site between the receiver and at least four satellites, It is maintained and owned by the United states and anyone with a GPS receiver is allowed to use it. It is made up of three sub-systems. These are the satellites which transit the position information, the ground stations which are used to control the satellites and update the information as well as is the receiver. The receiver collects data from the satellites and computes its location anywhere in the world based on information it gets from these satellites. The GPS receiver merely receives data from the satellite and does not send any information back to the satellite. The GPS receiver used in the project computes the current location using at least 4 satellites [4] and sends the data to the Arduino Uno.

2.6 Work plan

Table: 2.3 Planned project schedule

Month (2015)	**Jul**				**Aug**				**Sept**				**Oct**				**Nov**				**Dec**	
Task /Week Number	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2
Writing the Proposal	■																					
Research	■	■	■	■	■	■																
Sourcing GPS, GSM Modules & Controller		■	■	■	■	■																
Interconnecting modules						■	■	■	■													
Writing Software									■	■	■	■										
Wring and testing the code												■	■	■	■							
Testing Entire system and final report															■	■	■	■	■	■		
Project Presentation																					■	■
Documentation	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■

2.7 Benefits

The benefits of the Taxi real time monitoring and Passenger inventory project include operational cost reductions, accident reductions, increased flexibility of operation, better and more accurate timely information which can be used in optimization of the business.

2.8 Conclusion

The taxi monitoring system and Passenger inventory system developed in this dissertation differs from all kwon units because it seeks to focus and specialize taxis like “kombis” in Zimbabwe. The project is unique because the majority of people in states like Zimbabwe do not own cars and therefore depend on commuter taxis for most of their journeys. In addition to the strengths in the similar units all over the world this system seeks to have an instantaneous inventory of the Passengers in the vehicle so that all collected revenue can be accounted for.

3 Chapter 3.0. Methods and resources

3.1 Introduction

This section provides the relationship and interconnection between the hardware components that are listed in section 2.4,1 of this document and the aim of the dissertation.

3.2 System overview

As mentioned earlier, the Arduino is the heart of the project. It has a microcontroller which manages all the attached units. The programme is uploaded in this Arduino Uno and depending on the signal inputs, the unit continually collects GPS coordinates and sends them as a string to the Arduino Uno which forwards them to the LCD (If installed) and the GSM shield SIM908/SIM5320. This information is basically latitude, longitude and altitude with a time and date stamp. GPS uses at least 4 satellites for tracking the location. The Arduino also hands over any information that is required for transmission together with the GPS coordinates, The GSM shield then transmits the SMS signal to the directed mobile number at the instruction from the Arduino. The signal can be transmitted after fulfilling set conditions or on demand from a remote recognised cell phone number. The mobile phone receives the information collected in the taxi thereby concluding the task at hand.

3.3 Diagram for proposed system

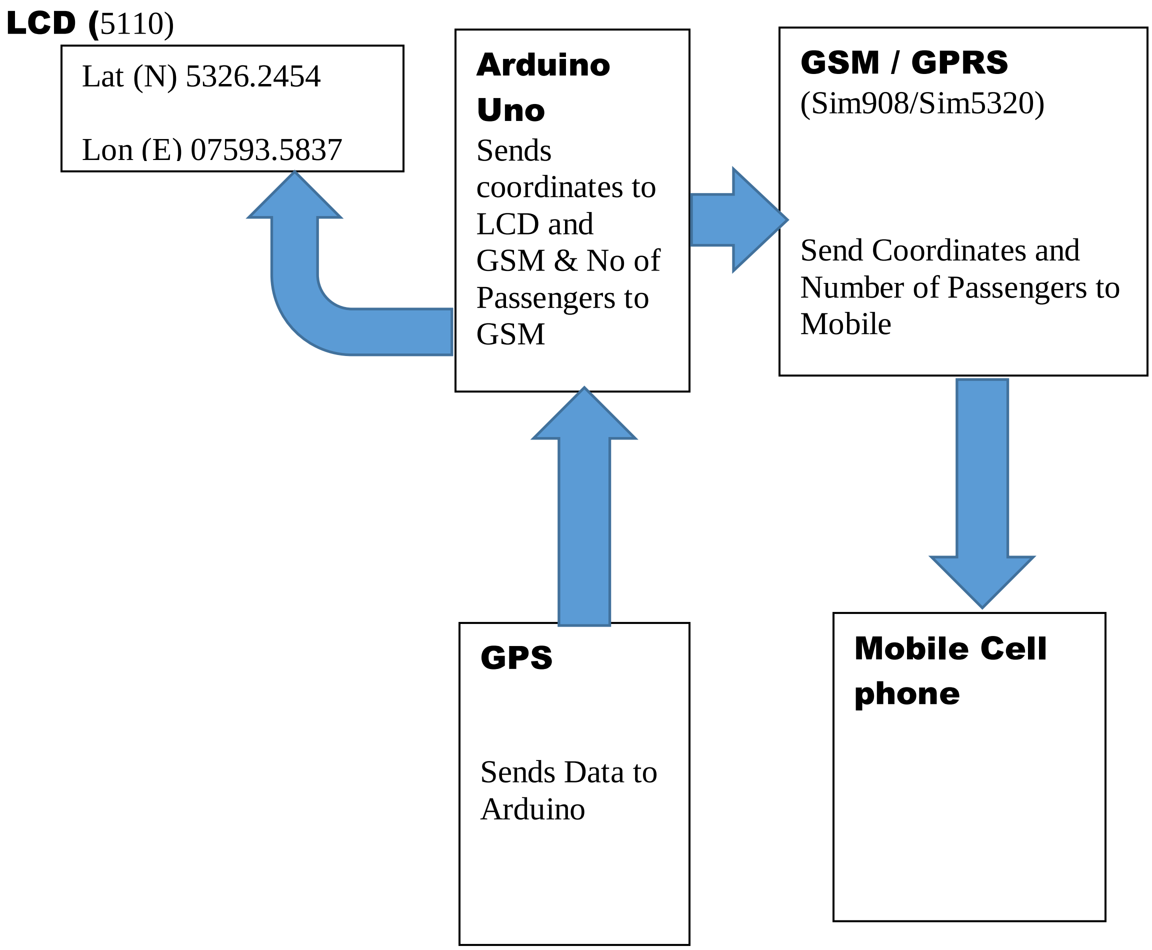

FIGURE: 3.1 Block Diagram of a Real Time Taxi Monitoring and Passenger Inventory System.

3.3.1 Resistors

These are used to limit current and act as additional protection on the ports of the Arduino in the event of a fault or short circuit. Quarter watt carbon film resisters have been used.

3.3.2 Digital multiplexing circuit

Multiplexing is a very efficient technique for controlling many components wired together in a matrix/array. In this project, exclusive multiplexing of an array of digital inputs from sensors like doors, seats and a host of other engine parameters are all being transferred from the Arduino using just three digital pins Clock, Latch and Data. The multiplexing units can be cascaded if more input /outputs are required.

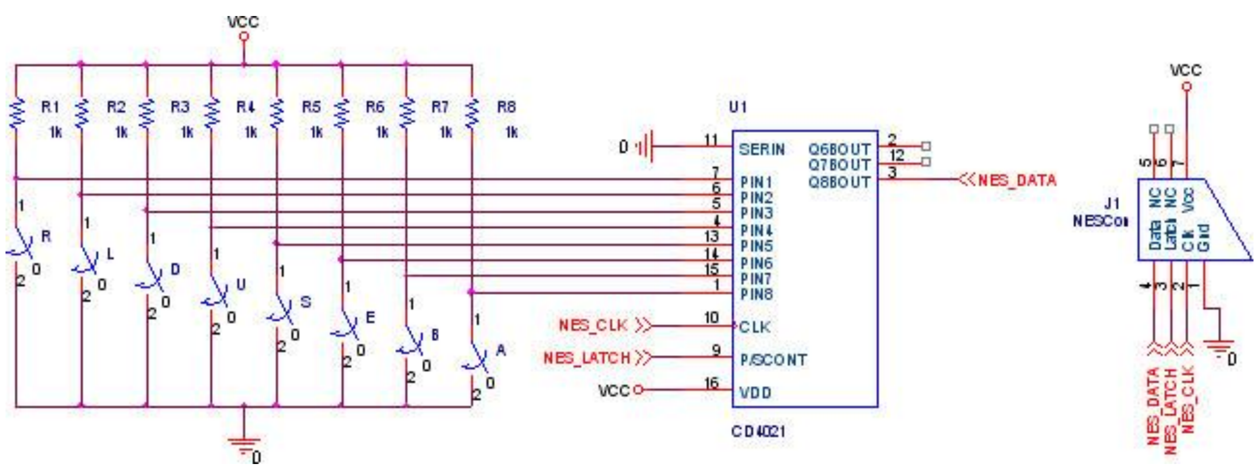

FIGURE: 3.2 Schematic Diagram for Multiplexing of inputs on an Arduino Uno.

From the diagram above it can be noticed that all the buttons are active low and the order of the data is from MSB to LSB i.e. switch A is polled first followed by B up to the left. The switches are simple push to make switches which are integrated under each Passenger seat so as to detect the presence of a Passenger. The required three digital pins are Data, Latch and Clock. VDD and VSS are power supply lines. In one latch state the clock pulse loads data from the digital switches to the shift register. This will be in an asynchronous way. When the data latch state toggles state the clock pulses now clock the data out of the shift register to the Arduino in a synchronous manner. These three control signals come from the Arduino. Thus the parallel inputs are loaded into the Arduino for processing before sending an SMS signal together with the GPS coordinates. The CD 4021 static shift register can de cascaded with similar ones to increase the number of digital inputs which can still be accommodated on the same three control digital pins used by the first CD 4021 chip. The diagram below shows the clock and data lines within a single latch state.

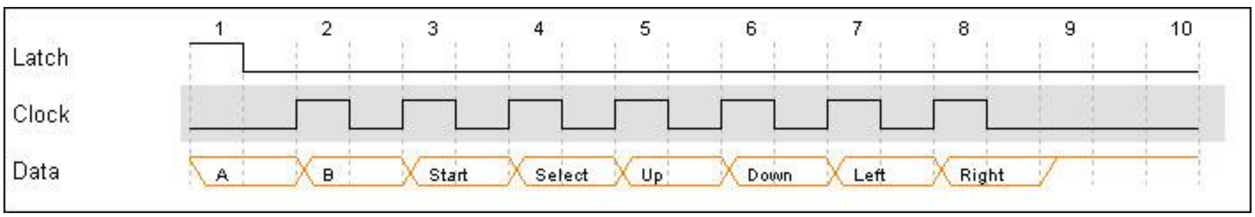

FIGURE: 3.3 Timing Diagram for a CD 4021 Static Shift Register

3.4 Functional requirements

The vehicle is wired with numerous pressure and door sensors coupled with signal wires which will be of a nature that does not compromise Passenger safety even in the event of an accident.

4 Chapter 4.0 Results and analysis

4.1 Introduction

This chapter presents the results and analysis as well as highlighting challenges encountered in the implementation of the project.

4.2 Testing and test strategies used

Because of the complications of actually working on a real taxi, which I do not own at the moment as well as the limited time, it was thought to be a good idea to do a simulation setup where the seat sensors are represented by on/ off DIP switches. A normal taxi would accommodate up to 16 Passengers however for the purposes of demonstrating on the principle of operation just three seats were used. To minimise on the volume of texts sent the system will only send a message when the Passenger bus is full i.e. 3 Passengers aboard.

FIGURE: 3.4 4 Way DIP Switch

4.3 Results

4.3.1 Sample of test results from the serial monitor

```
--------------------------------------------------------------------------------
First seat
                         0
Second seat
                        1
Third seat
                         1
Total number of Passengers
              2
--------------------------------------------------------------------------------

First seat
                         1
Second seat
                        1
Third seat
                         1
Total number of Passengers
              3
--------------------------------------------------------------------------------

AT+CMGF=1
AT+CMGS="+263772107542"
Passenger bus loaded with
      3
Passengers
First seat
                         1
Second seat
                        1
Third seat
                         1
Total number of Passengers
              3
--------------------------------------------------------------------------------

AT+CMGF=1
AT+CMGS="+263772107542"
Passenger bus loaded with
      3
Passengers
First seat
                         1
Second seat
                        1
Third seat
                         1
Total number of Passengers
              3
```

According to the specifics of the program whenever the Passenger bus was full a message i.e. 3 Passengers, an SMS was sent and received by the cell phone whose number has was input in the Arduino software. The SMS message is *"Passenger bus loaded with 3 Passengers"*

4.4 Constraints, limitations and assumptions

- The main constraint in the implementation of the project was the failure to debug on the malfunctioning of the GPS. Header library file on the GPS shield. The SoftwareSerial function could therefore not be called to set the virtual serial communications port with the Arduino. As a result the GPS coordinates are missing from the results.
- It is assumed that GSM network is readily available as and when required and that SMS system remains at least almost real-time.
- It is highly assumed that the project will receive Government support through appropriate regulations and legislation since the concept attempts to complement Government efforts on good governance. It is also assumed that no legal aspects will arise.
- It is assumed that the Passengers are from source to destination so as to simplify calculations at this stage. Excessive pick-up and drops on the same route require more rigorous computations and a learning of the behaviour of Passengers.
- It is assumed that the routes taken have enough Passengers to ensure that at least the vehicle is fully loaded on every trip taken.
- It is also assumed that the vehicle will always be used to ferry Passengers and not be hired for some other language
- The system undoubtedly faces serious objections from the drivers whose opportunity to fleece the taxi Owners is sealed off. These could indulge in acts of sabotage and coercing fellow drivers to fail the system.

4.5 Conclusion

The timing of the project comes at a time when the Government is looking for every means to successfully implement ZIM ASSET, thus there is higher expectation for its support through supportive legislation. This project sought to identify the prevailing requirements and expectations from both the Passengers and taxi Operators and come up with an efficient way to improve service delivery in in taxi service delivery system in Zimbabwe and other countries. A solution is hereby proposed using support from the experimental results in this chapter. The developed system is an improvement on the known existing systems as it seeks to inherit all the strengths of these systems and enhance on the Passenger inventory. It attempts to fully equip the Owner of a taxi with the tools to monitor and find ways to optimise on the business due to availability of Passenger inventory in addition to all other parameters. The received SMS messages results have demonstrated that the concept is workable and worth investing in. Imlementing such a product keeps the country abreast of the rapidly changing technologies where the world is heading for the internet of things in all facets of life.

5 Chapter 5.0 Recommendations for further research

- Making the system web based with provision for onsite data logging facility into an SD card so that all the activities are logged for uploading via the internet or physical periodically.
- Making analogue inputs to work with pressure sensors so that the weights of Passengers can be categorised into say 5kg increments to cover all the 0 to 1023 resolvable input states. This can help counter Passenger sitting habits which lead to calculation errors. This works on the probability that not all the Passengers have the identical weight.
- Automation of door to effectively make the conductor redundant and leave just the driver to man the taxi.
- Prepayment with some discounts to encourage the take up of the system such that smart cards can be used to pay for fares. Swiping on boarding and un-boarding the vehicle will allow different fares to be charged relating to distance travelled and time of travel. This will simplify the Passenger inventory data collection.
- .The taxis for which the discussed systems were designed are mainly for small capacity vehicles which normally have point to point journeys for each trip. There is room to find the best way to account for multi-destination Passengers as these represent a multiplying effect on the revenues collected especially for busy relatively long routes. Certain routes lend themselves to the opportunity of embarking and disembarking the taxi before reaching the taxi destination.
- In the real world scenario all the inputs and outputs of the system will require electrical isolation because lightening, and frequent mistakes by the mechanics can send dangerous voltages to the unit by “mistake”. The best setup would be to use the normal 12V car battery and then optically couple to all the inputs and outputs to provide adequate isolation.
- The system can be made to become mandatory by the taxi licencing authourties so that they can easily police taxis which do not operate according to set regulations like overspeeding, off route etc. This would also assisit in the best way to licecnce routes depending on servive demand.

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List of appendices

Appendix A Source code

```
//* This is the final year project in BSc Telecommunications Engineering Degree 2015 by
Emmanuel Kuri Reg. Number R131020V.*//

#include <SoftwareSerial.h>
SoftwareSerial  mySerial(2, 3); // Code to create virtual serial port: Pin 2 is  Receive pin and Pin
3 is Transmit pin.
 void setup() {
  mySerial.begin(2400);   // Setting the baud rate of GSM Module
    Serial.begin(9600);// Setting the baud rate of Serial Monitor (Arduino)
  delay(1000);
}
// the loop routine runs over and over again forever:
void loop() {
  int Passenger1 = analogRead(A0);// read the input on analog pin 0:
  int Passenger2 = analogRead(A1);// read the input on analog pin 1:
  int Passenger3 = analogRead(A2);// read the input on analog pin 2:

 // Convert the analog reading (which goes from 0 - 1023) to a voltage (0 - 5V): representing 0
//and 1
  int voltage1 = Passenger1 * (5.0 / 1023.0)/5;
  int voltage2 = Passenger2 * (5.0 / 1023.0)/5;
  int voltage3 = Passenger3 * (5.0 / 1023.0)/3;
  int voltage4 = 0;
  // printing out the value read:
  delay (3000);
  Serial.print("First seat\r                                   ");
  Serial.println(voltage1);
  Serial.print("Second seat\r                                  ");
  Serial.println(voltage2);
  Serial.print("Third seat\r                                   ");
  Serial.println(voltage3);
  Serial.print("Total number of Passengers\r                      ");
  voltage4 = voltage1+voltage2+voltage3;
  Serial.println(voltage4);

  if (voltage4 == 3){
  Serial.print("\r");
  delay(1000);
  mySerial.println("AT+CMGF=1");   //Sets the GSM Module in Text Mode
  delay(1000);
  mySerial.println("AT+CMGS=\"+26372107542\"\r");    //Number to which message is sent as
//SMS
  delay(1000); // Delay of 1000 milli seconds or 1 second
```

```
  Serial.print("AT+CMGS=\"+263717586932\"\r");    //Number to which you want to send the
sms
  delay(1000);// Delay of 1000 milli seconds or 1 second

  Serial.print("Passenger bus loaded with \r ");   //The text of the message to be sent
   Serial.println(voltage4);
  Serial.print("passengers\n");
  mySerial.println("Passenger bus loaded with \r ");// The SMS text sent phone
   mySerial.println("passengers\n");
  delay(1000);// Delay of 1000 milli seconds or 1 second
  Serial.write(0x1A);
 Serial.print("--------------------------------------------------------------------------------------\n");
  delay(1000);  // Delay of 1000 milli seconds or 1 second
 }
}
```

Appendix B Reports attributed to absence of monitoring of taxis by Owners

Last week, a commuter omnibus operator Beauty Nyanhongo found herself at the receiving end after a police officer Sergeant Panganai Sylvester Maqata decided to do the unthinkable. Maqata, according to Nyanhongo, ordered a tout Trevor Musorosekwa to drag her driver out of her commuter omnibus along Fourth Street to give chase to an errant kombi driver. In April last year, an elderly woman died after being knocked down by a kombi whose driver was fleeing from police near the Copacabana bus terminus in central Harare. In December, a Tafara resident and war veteran Raphael Mbanje died at the corner of Chinhoyi and Bank Streets in downtown Harare and the accident saw Mbanje being killed instantly by the reversing kombi. [5]

Only last week in Bulawayo, 16 commuters were injured after an accident, when a kombi was fleeing from police. Inspector Mandlenkosi Moyo, the Bulawayo provincial police spokesperson, told our sister publication Southern Eye that the driver was under age and was speeding. Witnesses said the police threw spikes in front of the moving kombi leading to the accident. “After the kombi overturned, the police officers fled from the roadblock, but one of them was caught and beaten up by the public for endangering the lives of people just for a fine,” an eye witness said [6].

Appendix C AT Commands summary

ACommand	Response	Description
AT+CMGF=	OK	Specifies the input and output format of the short messages. 0 for PDU mode and 1 for text mode.
AT+CMGS		Sends a message.
AT+CMGR=*		Reads a message. * is the number of the message.
AT+SAPBR	OK	Configures GPRS profile.
AT+FTPCID=1	OK	Selects profile 1 for FTP.
AT+FTPSERV=”****”	OK	Sets FTP server domain name or IP address. **** is the domain name or the IP.
AT+FTPPORT=***	OK	Sets FTP server port. *** is the port.
AT+FTPUN=”***”	OK	Sets user name for FTP server access. *** is the user name.
AT+FTPPW=”***”	OK	Sets password for FTP server access. *** is the password.
AT+FTPPUTNAME="****"	OK	Sets destiny name for the file.*** is the name of the file.
AT+FTPPUTPATH="****"	OK	Sets destiny file path. *** is the path of the file.
AT+FTPPUT	OK	Use to put a file into the FTP server.
AT+FTPGETNAME="****"	OK	Sets origin name for the file.*** is the name of the file.
AT+FTPGETPATH="****"	OK	Sets origin file path. *** is the path of the file.
AT+FTPGET		Use to get a file into the FTP server.