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A passenger security system for mass transit electric buses: a case study of the Kayoola EVS bus

Koojo, Ivan

NM-AIST

A PASSENGER SECURITY SYSTEM FOR MASS TRANSIT ELECTRIC BUSES: A CASE STUDY OF THE KAYOOLA EVS BUS

Ivan Koojo

A Dissertation Submitted in Partial Fulfillment of the Requirements for the Degree of Master of Science in Embedded and Mobile Systems Engineering of the Nelson Mandela African Institution of Science and Technology

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ABSTRACT

Kiira Motors Corporation (KMC), a state-owned enterprise was established in 2011 to champion the development of the Ugandan automotive value chain for job and wealth creation. Kiira Motors Corporation has developed several electric vehicles on the African continent since 2011, key among them is the company's market entry product; the Kayoola EVS, a fully electric, low floor city bus with a passenger capacity of ninety-one.

Through the passenger security system, KMC sees to attain its core value of customer satisfaction and solve issues like rampant insecurity of passengers and their property which are not alien occurrences on commuter taxis and buses in many African cities. The system further seeks to address, the spread of contagious diseases like COVID-19 and its risks to bus passengers. And easen difficult, time consuming tasks like passenger counting, measuring/recording temperatures, and collecting contact information.

The system data and requirements elicitation was conducted using techniques like surveys, interviews, observation, literature review, webinars and desk research. These qualitative and quantitative approaches were adopted to offer insight on passenger security and mass public transport operations. A prototype of a comprehensive system comprising software and hardware components like cameras, web and mobile applications, was developed and its units' functionality tested in an office environment. The developed system denotes potential to ensure security on the Kayoola EVS bus. It also implies averting spread of contagious diseases, timely capture of contact tracing records plus easier management and accountability for the numbers of passengers on buses.

DECLARATION

I, **Ivan Koojo** do hereby declare to the Senate of the Nelson Mandela African Institution of Science and Technology that this dissertation is my own original work and that it has neither been submitted nor being currently submitted for degree award in any other institution.

Ivan Koojo

…………………………………… 28th September 2021 ………………………………………

Signature **Date**

The above declaration is confirmed

Dr. Dina Machuve

…………………………………… 21.10.2021 ………………………………………

Signature **Date**

Supervisor 1

Dr. Silas Mirau

…………………………………… 21.10.2021 ………………………………………

Signature **Date**

Supervisor 2

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CERTIFICATION

The undersigned certify that they have read and hereby recommend for acceptance by the Nelson Mandela African Institution of Science and Technology a dissertation titled; *"A Passenger Security System for Mass Transit Electric Buses: A Case Study of The Kayoola EVS Bus"*, in fulfillment of the requirements for the degree of Masters in Embedded and Mobile Systems Engineering of the Nelson Mandela African Institution of Science and Technology.

Dr. Dina Machuve

21.10.2021

…………………………………… ……………………………………

Signature **Date**

Supervisor 1

Dr. Silas Mirau

21.10.2021

…………………………………… ……………………………………

Signature **Date**

Supervisor 2

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DEDICATION

This dissertation is dedicated to the Almighty God who started a good work and continues to perform it till the day of the LORD.

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LIST OF ABBREVIATIONS AND SYMBOLS

AC	Alternating Current
APCs	Automatic Passenger Counter
ARM	Advanced RISC Machines
BNC	Bayonet Neil-Concelman / British Naval Connector
BSD	Berkeley Source Distribution
CCTV	Closed-Circuit Television
CDC	Centers for Disease Control and Prevention
COVID-19	Corona Virus Disease of 2019
Ctrl + N	Control Plus N
DC	Direct Current
DUV	Digital Uganda Vision
DVR	Digital Video Recorder
ERFs	Electronic Registering Fareboxes
EVS	Electric Vehicles
FPN	Feature Pyramid Network
Fps	frames per second
GDP	Gross Domestic Product
GHz	Giga Hertz
HSE	Health Service Executive
ICTs	Information and Communication Technology

IDE	Integrated Development Environment
iOS	iPhone Operating System
IP	Internet Protocol
IR	Infrared
KMC	Kiira Motors Corporation
KOTI	Korea Transport Institute
KPES	Kayoola Passenger Experience System
LAN	Local Area Network
LCD	Liquid Crystal Display
LED	Light-Emitting Diode
NITA-U	National IT Authority Uganda
OS	Operating System
PC	Personal Computer
PCB	Printed Circuit Board
PTS	Public Transport System
RAD	Rapid Application Development
RAM	Random Access Memory
RG59	Radio Guide-59
RJ45	Registered Jack-45.
ROI	Region of Interest
SDLC	Software Development Life Cycle

SOPs	Standard Operating Procedures
TB	Tera Byte
UITP	The International Association of Public Transport
USB	Universal Serial Bus
UTP	Unshielded Twisted Pair
V	Volts
WAN	Wide Area Network
WHO	World Health Organization
Wi-Fi	Wireless Fidelity
YOLOv3	You Look Only Once

CHAPTER ONE

INTRODUCTION

1.1 Background of the Problem

Kiira Motors Corporation (KMC) is a state-owned enterprise that was established to champion the advancement of the automotive value chain in Uganda, and advance job and wealth creation. The company developed Africa's first electric vehicle in 2011, Africa's first hybrid vehicle in 2014 and Africa's first solar electric bus in 2016 (Kiira Motors, 2020). The company's market entry product is the Kayoola EVS, a fully electric, low-floor city bus with a range of 300 kilometers on a full charge (Kiira Motors Corporation, 2019). Kiira Motors Corporation aims to avail a remarkable passenger experience on the Kayoola EVS bus through deploying the Kayoola EVS Passenger Experience System (KPES). A major part of this experience includes passenger security, convenience, safety as well undemanding management on the side of bus owners and operators.

Public transport using high passenger capacity electric buses avails numerous benefits like safer travels, reduced expenditure on transport, health benefits, less congestion on roads, less pollution, less effort and better predictability in comparison to other forms of road transport like fourteen-seater taxis, private cars and motorbikes (Christopher, 2019). On the contrary, the existence of diverse barriers preventing or limiting the use of public transport cannot be denied, the barriers range from hard barriers like travel time or financial cost to soft barriers such as information provision or perceived comfort (Luis *et al.*, 2019).

It is also factual to say that compared to riders that travel by private car, cycling and walking, riders who travel by bus and train experience the most unpleasant emotions (Guerra & Morris, 2015). The same can be said about the travel experience of passengers in commuter taxis also known as matatu in many cities of Sub-Saharan Africa. The use of public transport also bears a negative effect on travel satisfaction, and it is essential to make public transport an attractive alternative and consequently improve the wellbeing of passengers (Friman *et al.*, 2017). Low-cost means of improving the quality of public transport and encourage its use might involve comfort and convenience improvements (Litman, 2008).

The use of technology has immense potential to deliver the desirable changes needed to increase efficiency in bus transportation and improve the experience of passengers (Oliveira *et al.*, 2017). Drawing the middleclass urban society to use public transport more frequently requires the enactment of measures that make the journey more pleasurable. Some of those measures include strategies to enhance convenience, increase information provision and communication, improve control and facilitate journey planning (Luis *et al.*, 2019).

This study, therefore presents a technological solution to issues pertaining urban mass transportation using buses with a focus on ensuring security of passengers and their property, saving time and providing a way to lessen the burden of difficulties in management and accountability assessment of bus passenger numbers for the stakeholders of the Kayoola EVS bus.

1.2 Statement of the Problem

A study by Nnassuuna (2014) on the state of public transport in Kampala, Uganda, revealed that majority of the people use public transport to commute in different places with over 90% traveling by means of commuter taxis. The commuters spend an average time of one hour to move to the main city center. It also revealed that commuters find the current Public Transport System (PTS) unfavorable to use in terms of among an array of aspects; security and safety.

There is also high levels of passenger insecurity and discomfort when using the available limited options of public transport in the city. Keeping track of the number of passengers on the bus and whether they're following the guidelines like social distancing is another uphill task for the owners and managers of buses. Many of them perform such tasks using head count, physical bus tickets and physical observation of passengers (Anwar, 2009). Such eminent barriers convey the message that the quality of services needs to be improved. In addition, measuring human temperature using conventional means like mercury thermometers in public places like buses leads to increased operational costs and slow passage of people when entering buses due to time constraints (Deng & Su, 2020).

In the wake of the COVID-19 pandemic, governments came up with guidelines to slown down the spread the disease and others of its kind. Some major guidelines include; observing social distance among the passengers, checking and recording temperature and implementation of a contact tracing strategy. Therefore, leveraging technology to and speed up some if not all of these activities does not only save time but also avails records that can serve an array of purposes.

1.3 Rationale of the Study

An all-encompassing Kayoola EVS Passenger Experience System generally aims to establish a unique and remarkable passenger experience to promote the Kayoola brand and help attract new customers as well as retain existing ones. It also, seeks to offer the Kayoola EVS bus brand a competitive advantage over other local and international brands. The realization of this system is also aimed at utilizing technology to improve efficiency, increase productivity and capitalize on the existing technological and expert local human resource to help realize Uganda vision 2040, Digital Uganda Vision (DUV).

The focus of this study however, is the distinct Passenger Security System for the Kayoola EVS Bus that aims at leveraging existing technologies to solve problems affecting urban mass transportation in many African cities. The system not only aims at availing colossal benefits to travelers that use public means of transport but also seeks to lessen the burden of bus owners and managers by availing information that they can base on to make better decisions like trips and route planning.

1.4 Research Objectives

1.4.1 Main Objective

To develop a comprehensive system to ensure passengers security, safety and diminish the risk of the spread of contagious diseases like COVID-19 on the Kayoola EVS Bus.

1.4.2 Specific Objectives

(i) To identify and establish system requirements of the passenger security modules (surveillance, contact tracing, thermal imaging and passenger count) of the comprehensive Passenger Security System for the Kayoola EVS bus.

(ii) To design and develop the modules of the Passenger Security System for the Kayoola EVS bus.

(iii) To deploy, test and validate the modules of the comprehensive Passenger Security System for the Kayoola EVS bus.

1.5 Research Questions

(i) What is the state of passenger security on public means of transport in Sub-Saharan African cities?

(ii) How can the development of a passenger security system for the Kayoola EVS Bus be achieved?

(iii) What will be the value the passenger security system for Kayoola EVS Bus to stakeholders in the public transport sector in Sub-Saharan African cities?

1.6 Significance of the Study

The successful accomplishment and adoption of the anticipated results of this study will avail the following contributions:

(i) The much-needed capitalizing on a blend of new and old technologies to guarantee the security of bus passengers and their property while on the bus. It will also enable secure remote viewing of live and recorded CCTV surveillance feeds over basic internet connection for purposes of remote system monitoring and management.

(ii) The study avails scalable value addition to CCTV surveillance through employing a machine learning model to detect people, count them and analyze social distancing and other necessary factors about bus passengers as need might arise.

(iii) The study also adds to the available digital forms of COVID-19 contact tracing by allowing voluntary submission of information through a mobile application which limits the labor and time that bus operators spend on the manual process.

1.7 Delineation of the Study

This study largely focused on the needs of the host organization and as thus, the data and respondents considered were only those that were deemed to meet the organizational goals of KMC, meet the set time limits, as well as avoid conflict in the deliverables. Other bus manufacturing organizations and bus transportation companies were not physically engaged due to copyright considerations and time constraints. The study also focused on the surveillance recording and analysis of live and recorded video footages with the aim of not changing the behavior of passengers while boarding, travelling and alighting the buses.

CHAPTER TWO

LITERATURE REVIEW

2.1 Public Transport System and its State in Sub-Saharan Africa Urban Centers

Across several developing countries of Sub-Saharan Africa, transport authorities grapple to meet the mobility needs of precipitously swelling populations, notably the urban poor, and Uganda is no alien to such predicaments. The existing transportation systems that are intended to connect commuters to markets, services and jobs shoulder a burden of limited capacity, loose regulation, and high levels of inefficiency (Mfinanga *et al.*, 2015).

Uganda's public transport structure like in other Sub-Saharan states, is comprised of four tiers, i.e., buses, mini buses/matatus (locally called taxis), motorcycles ('Boda-Boda') and car-taxis ('special hire'). Matatus, buses and motorcycles, which make up a massive portion of the public transport supply side, account for close to half (46%) of the traffic on Uganda's roads—with Kampala driving the national picture; for instance, 80% of the matatus in Uganda ply their trade in the capital (Kamuhanda & Schimdt, 2009).

In several cities these matatus stop anywhere along their route to pick up or drop off passengers, raising the risk of accidents. It is also reported that passenger security in the vast majority of matatus and city buses is poor, particularly for women and assaults on drivers and vandalism are common occurrences (Kumar & Barrett, 2008). In addition, they provide a largely solid and recurrent service, however, levels of comfort and safety are miserable, and the services are mostly viewed as muddled and unreliable. Multitudes of urban passengers have on several occasions expressed great frustration with the quality of service offered on the public transport vehicles, both in terms of passenger comfort and driver discipline (Sub-Saharan Africa Transport Policy Program [SSATP], 2005).

2.2 The Adoption and use of ICT and Related Systems in Public Transportation

In April 2015, the Korea Transport Institute (KOTI) and the World Bank convened a joint meeting placing focus on how Information and Communication Technologies (ICTs) can be leveraged in the transport sector, it was discussed that mobile technologies, Intelligent Transport Systems and Big Data bear the budding capacity to offer safer, smarter and greener transport options, thus improving transport services and influencing the travel behaviour, of commuters. This is a significant indicator about how leveraging ICTs can facilitate the evolution of the Ugandan and Sub-Saharan transport sector (The World Bank, 2015). With continued adoption of ICTs in various fields of life and businesses, it is important to explore how ICT can be applied to solve transportation problems like capacity and quality in the transport sector. In particular, with a surge in the demand for local, national and international transport, there's need for information especially in transport telematics in order to provide a satisfactory level of reliability, efficiency, and security on the transportation avenues (Hodge & Koski, 1997).

2.3 Related Systems

2.3.1 People Counting Systems in the Transportation Industry

World over, the transportation industry has a long history of counting passengers on buses, trains and mini buses. This began from manual means like paper and pencil, currently used within many agencies today, to automated technologies that have evolved to incorporate handheld units, automatic passenger counters (APCs), electronic registering fareboxes (ERFs) and smart cards. Counting passengers to estimate ridership plays a weighty role in transport service planning, timetabling, and forecasting. This is attributed to the fact that ridership is a vital measure of transit service effectiveness as well as a key aspect in analyzing performance and throughput (applying measures like passengers per revenue mile or cost per passenger) (Daniel, 1998).

In developed countries many agencies rely on a single mode or a combination of counting modes, i.e., on manual counts, ERFs, and APCs. The situation is quite contrasting in Uganda and other Sub-Saharan Africa countries where a traffic checker (taxi/bus conductor) is employed on the moving vehicle to manually count passengers as they board and alight, as well as collect fares made on each trip. The information is either recorded using pen and paper and at some instances not recorded. Sometimes, the information is recorded on a preprinted form that includes the stops along the route and the number of passengers onboard who are counted manually and recorded at that instance. The use of electronic registering fareboxes (ERFs) requires the intervention of operators to count commuters. The operator strikes one of a sequence of keys on a keypad linked to the ERF to point to the kind of fare each passenger pays as they board, in addition, the operator must enter a code to show the route, run number, and beginning of each trip. In most cases, ERF data are aggregated at the trip level and stop-level information is not usually available.

Using an APC passenger boarding and alighting are automatically recorded using Infrared beams or treadle mats, which associate a time with each stop, and traces the stop via signposts positioned all over the system, from odometer readings, or even via satellite (Ivano & Ciara, 2010). Figure 1 and Fig. 2 show some of the technologies used for automatic passenger counting on mass transit vehicles. Transportation operators count and group ridership at various levels, depending on the kind of data required. Top managers might be mainly concerned with systemwide ridership trends. Trip planners and schedulers need to information about passenger numbers at key points and by time of day along the routes whereas marketers and planners may require fare classification information. No single passenger counting procedure matches all of the mentioned data needs. As the array of choices broadens, choices regarding the kinds of technologies and procedures that can be deployed to count passengers have become more difficult and therefore, it is essential to have information on how well various measures can help to meet the needs (Daniel, 1998).

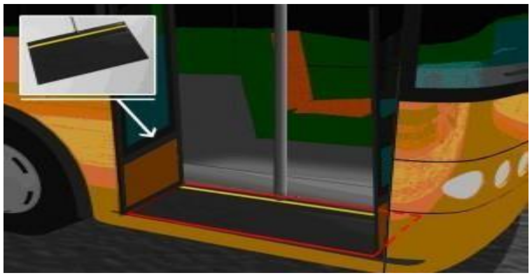


Figure 1: Photo Showing Treadle Mat Sensor Installation on a Bus Door for Automatic Passenger Counting

Figure 2: An Installation of Infrared Emitters on Bus Door for Passenger Counting Purposes

2.3.2 Contactless Temperature Measurement Systems

With unprecedented and continuous growth of society, the number of human activities has greatly expanded to a huge scale, resulting in new ways for the outbreak and spread of infectious diseases instigated by bacteria and viruses. To restrain the outbreak and spread of such sicknesses, timely monitoring is a necessity. Currently, large-scale outbreaks of infectious diseases are generally characterized by abnormal human body temperature, as a key symptom. With the outbreak of the COVID-19 pandemic in the year 2019, a system to quickly detect the occurrence of infectious diseases using human body temperature as a refence indicator is painstakingly invaluable. The most commonly employed temperature measurement methods include; contact and non-contact means. Contact measurement is a traditional temperature measurement method commonly done using a mercury thermometer placed in the armpit, or other body parts.

This kind of measurement must be done in close contact with the person being tested and thus, the state of the person being contacted must be put into consideration. When this is employed in public places, the measurement instrument easily catches dirt and needs to be cleaned from time to time. Since it takes a long time to capture temperature values, the passage of people at entrances is also slowed down leading to unnecessary congestion and queues, on another note, the wear and tear as a result of frequent contact and use also culminates in increased operational costs. During the perilous periods of infectious disease outbreaks, body contact measurement can easily ignite the transmission of deadly viruses. On the other hand, non-contact temperature measurement comprises forehead thermometers, ear thermometers, among others., which employ infrared temperature measurement technology to obtain body temperature values (Deng & Su, 2020). It is therefore necessary to avail a temperature measurement solution that doesn't require humans to operate at every instance.

2.3.3 COVID-19 Contact Tracing

Contact tracing is one of the crucial surveillance approaches to curtail the spread of infectious diseases like COVID-19. It is a practice of observing persons who have come in contact to another person infected with a certain disease. In the context of COVID-19, a contact is any person who has undergone the following exposures two days before or fourteen days after the inception of indications of a confirmed or probable case: Face-to-face contact with a proven or probable case within a distance of one meter. Personal physical contact with a proven or probable case. Direct care for a patient with confirmed or likely COVID-19 diagnosis lacking appropriate personal protective gear. Other circumstances like closed environment (classrooms, places of worship, hospital waiting rooms, shared transport vehicles) (World Health Organisation [WHO], 2020).

The contact tracing exercise includes contact identification, contact listing and follow-up of individuals who got in contact with an ill person; (a) Contact identification: This is a key part of epidemiological examination for all instances meeting the standard case characterizations of COVID-19. The cases are categorized as suspected, probable or confirmed. Identification of contacts is done by investigating the activities of a certain case and the events and roles of the people around that particular case from the time of infection. (b) Contact listing: Every person regarded to have had notable exposure is recorded as a contact, in the contact listing form. Attempts are made to physically identify each recorded contact and notify them about their contact status. Contact identification and listing, including the process of informing contacts of their status, is often done by a surveillance officer or an epidemiologist.

(i) Sample Contact Tracing Systems

A number of solutions have been developed to aid the contact tracing activity in a number of countries. We explore a few solutions in the next paragraphs.

Corona Virus Disease Tracker Ireland

This is a solution by the Health Service Executive (HSE) and the Irish government aimed at giving them a better picture of the spread of the COVID-19 virus and to help carry out contact tracing. The application's main features include; Daily health check-in: The COVID-19 Tracker app allows users to check-in every day, and share information like if they have any cold, flu or coronavirus symptoms, or if they're feeling well. This helps in mapping the spread of the virus and to respond accordingly. The app uses a phone's Bluetooth technology to take record of when a person is close to other app users. If an app user tests positive for COVID-19, the HSE can request for the records on their app account. This helps the HSE to reach out to other people who might have been affected, and offer them any advice and help deemed necessary. The application is implemented with consideration of data and privacy; where by it does not: publicly identify persons with COVID-19, make their personal data available to the HSE without their consent or use the data for any purpose apart from contact tracing and reporting illness levels anonymously (Executive, 2020). Screenshots of the app are shown in Fig. 3.

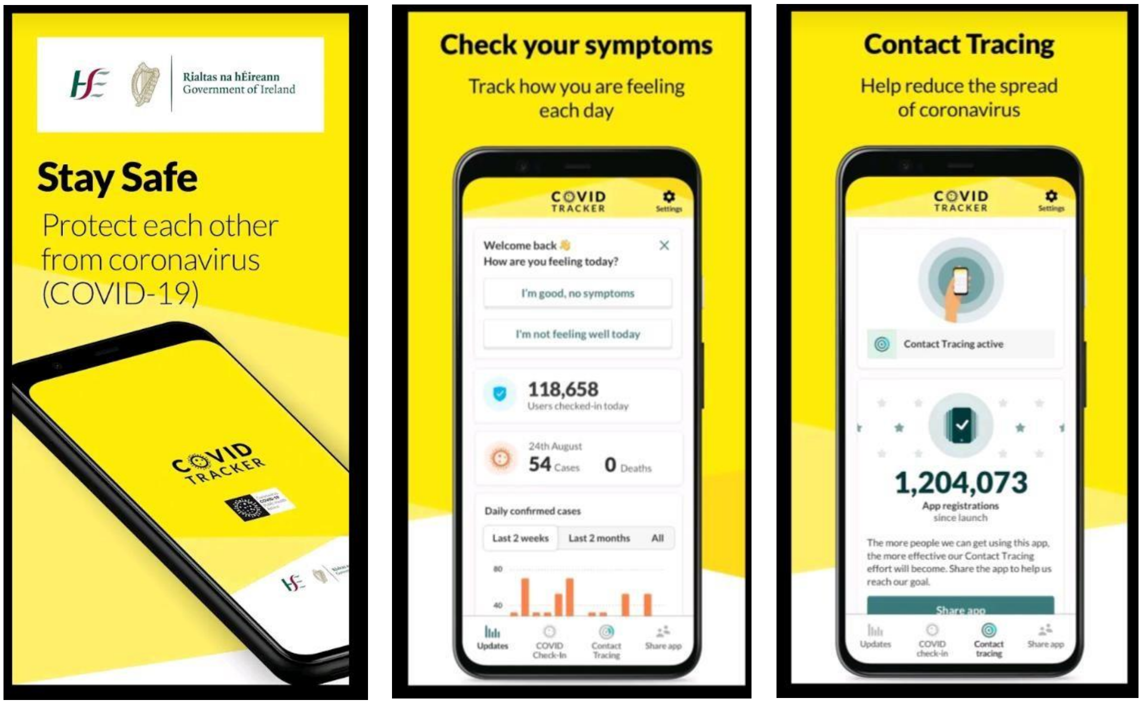


Figure 3: An Over View of the COVID Tracker Ireland App

Trace Uganda (Contact Tracer)

This mobile application was developed by the Ministry of Health in collaboration with NITA-U to ease the tracking of COVID-19 cases and the people they've been in contact with. It works by using Bluetooth to detect nearby devices such that if a person came in close contact with a COVID-19 case, contact tracers from the Ministry of health can quickly contact him/her. Its main features include Bluetooth detection of nearby devices and uploading of data by the users (Kadowa, 2020).

2.3.4 Closed-Circuit Television Surveillance Security Systems

Video surveillance is one of the common technologies used in different environments including public transportation. It is largely used for security purposes, although it also has other uses and is a solution highly valued by staff and passengers. A survey conducted by UITP, together with Axis Communications to understand the various aspects of video surveillance from transport operators in 30 countries between April and September 2015 indicates that almost all responders had surveillance equipment and 74.3% of responders had investment plans for new surveillance systems (Axis & International Association of Public Tranaport [UITP], 2018). Although this is a reality in many developed countries, the technology in Uganda has not been largely embraced in public transport with its application largely found in security systems for buildings. Once employed in public transport like buses, this technology has tremendous benefits like improved security, minimizing, deterring and managing various types of criminality, helping investigations into crimes, injuries on the bus and accidents, it can be further extended to aid in fire and smoke detection, detection of left luggage, overcrowding and to a small extent reducing fare evasion with its main drawbacks being privacy concerns and vandalism of surveillance equipment.

(i) Analog Cameras

For decades, analog CCTV security cameras have been the standard industry devices employed in CCTV surveillance tasks, and with respectable reason. They're a dependable security surveillance choice and quite easy to install, use and maintain. They are compatible with all standard power/video BNC cable connectors. When connected to Digital Video Recorders one can remotely observe live feeds from analog CCTV cameras and review past videos on a personal computer, tablet or smart phone. They boast of benefits like low cost, simplicity, lower bandwidth requirements and a variety of design options and their drawbacks include; need for cabling, low image quality, narrow field of view, limitations in wireless capability, encryption, positioning and number of ports (Customer First, 2017).

(ii) Digital/IP Security Cameras

These cameras capture and send video footage using IP networks, and thus enable users to watch, tape, store, and manage their video surveillance records either locally or remotely over the network infrastructure. IP cameras have their own IP address and unlike a webcam, don't require to be connected to a personal computer to operate. In addition to streaming video footage, IP network cameras may possess several additional features, like motion detection, pan/tilt/zoom (PTZ) operation, integration with alarms and other security systems, automated alerts, audio surveillance, intelligent video analytics, and many others. Their installation is flexible, they're easy to use, stable, offer higher-quality images, and they're scalable since new cameras can be easily added to the network. They're also a better option in terms of image quality, coverage area, less cabling requirements, wireless capability, encryption, ports and positioning (Sarah, 2018). They however, have high initial costs, high storage and bandwidth requirements and they're more complicated to set up. Closed-Circuit Television surveillance cameras are widely produced by a host of companies including Sony, Samsung, Honeywell, CHTC automobile, among others.

One of the key transport related surveillance tasks includes monitoring of crowds and individuals in public transportation areas like bus parks, train stations and bus stops (Bird *et al.*, 2005). Although their's growing demand and clear benefits of automated video surveillance on public means of transport (Ho *et al.*, 2008). In cities like Kampala, little has been done with scenarios on-board buses. Attempts of video surveillance on buses are largely limited to boarding passengers when buses are stationary at bus stops and their's minimal 'in-journey' surveillance (Bartolini *et al.*, 1994). It's thefore imminent to develop solutions to address the identified gaps.

Neil *et al.* (2008) proposed video surveillance with an approach of automatic human behavior recognition and its explanation. This approach is deemed very useful to surveillance officers when dealing with large volumes of data to automatically report on human activity in videos. Another study by Boon *et al.* (2000) proposed a surveillance method that comprises an elliptical head detection algorithm using the curvature profile of the human head as a cue. It detects passengers on-board public transport vehicles with the aim of monitoring their behaviors under suspicious circumstances for purposes of ensuring security. The current surveillance methods and applications provide for monitoring of live/playback video from the surveillance cameras and allow performing some operations on the video data like exporting video, snapshot generation (Seshukumar *et al.*, 2012). However, to enhance the security and safety of the passengers we propose an additional feature to the existing generic surveillance applications. This additional feature is measuring the distance between passengers aboard the bus while also counting the passengers and displaying the output on the user interface. Counting the passengers is accomplished in two ways, when they're entering and leaving the bus and while seated on the bus. Employing the two modes is intended to cover for the errors that might result from either of the criteria.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Study Area and Scope of the Research Project

The research project activities were conducted within a nascent automotive company in Uganda mainly with emphasis on public transportation using buses in Kampala city because of the city's population and the company's target to market its products, key among them, the Kayoola EVS bus to Kampala as the entry market. Kampala is the capital city of Uganda, a country located in the Eastern part of Africa. The city has a population of approximately 4.5 million people with over 80% of these using public transport as the main mode of travel within the city (Kampala Capital City Authority [KCCA], 2020).

This work only considers the safety and security of passengers while on the bus but does not include the security and safety concerns after or before boarding the buses. The boundaries and high-level components of the passenger security system for the Kayoola EVS bus are shown in the Fig. 5, Fig. 6 and Fig. 7, it comprises of CCTV media surveillance, contactless temperature measurement, social distance analysis and passenger counting modules.

3.2 Development Approach

The development of the system follows a blend of prototyping and agile methodology using an iterative and incremental approach with a focus on process adaptability, customer satisfaction and timeliness with basis on the standard software development lifecycle. This combination enables incremental and progressive system development as well as facilitates user involvement through the system development process leading to high levels of user requirement fulfilment. Figure 4 shows the various stages of the agile methodology based on the standard software development life cycle upon which the system was built.

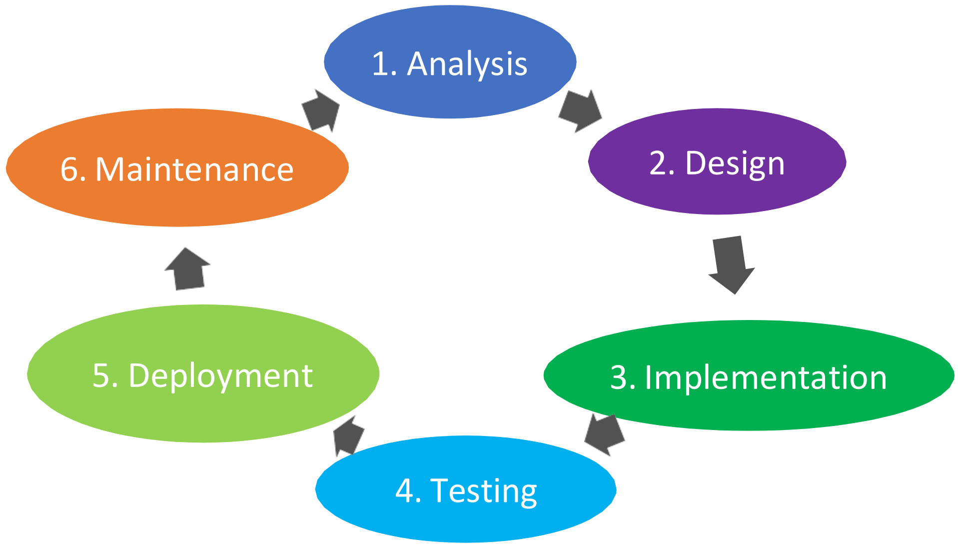


Figure 4: An Illustration of the Agile System Development Life Cycle

The merger of approaches was chosen because it combines the advantages of the approaches and each one covers the weaknesses of the other. Other methods like waterfall and spiral were not used because they allow low work distribution, low client interaction and minimal team interaction. On the other hand, the selected methods enable high flexibility, client interaction, team interaction, work distribution, error, and risk containment and minimize overall project costs. Table 1 shows the agile and prototyping methods compared to spiral and waterfall methodologies with regards to flexibility, cost and delivery prediction, client interaction, team interaction, work distribution and phase containment error.

Table 1: Comparison of Contemplated System Development Methodologies

Model	Flexibility	Cost and Delivery prediction	Client Interaction	Team Interaction	Work Distribution	Phase Containment of Error
Agile	High	Medium	Very high	Very High	High	Medium
Waterfall	No	Medium	One time	Low	low	Low
Spiral	high	low	low	Low	low	high
Prototyping	Medium	Medium	High	High	low	High

3.2.1 Data Collection Methods

Data for this project was collected through document review, observation, a survey questionnaire, desktop research and benchmarking of industry-standard approaches to identify development methodologies, development technologies, and to acquire video recordings. A large portion of obtained data was qualitative, a small portion was quantitative in nature while another portion was in media format, i.e., photos and videos. A questionnaire was prepared and shared as an e-form via the google forms platform and responses were captured in a form response sheet where quantitative aspects were analyzed. The approaches employed during this phase are briefly described in the subsequent sections.

(i) Desktop Research and Benchmarking

This involved re-analyzing, interpreting, or reviewing past data about passenger safety and security systems for public transport. The main objective was to help determine how the historical data and existing systems could inform the study and development of the system. This helped with basic theoretical understanding of security safety systems hence laying a foundation for implementation and improvements.

(ii) Questionnaire

The Google forms electronic platform was used to prepare and distribute the questionnaire instead of the conventional paper-based questionnaire system to reduce costs and save time. The questionnaire comprised of direct questions, open ended questions and multiple-choice questions. It was only distributed to the staff of the organization to help obtain end user input. The aim was to obtain end user input about the ideal features of the system.

(iii) Interviews

Interview sessions were conducted with key system staelholders majorly considering the owners and funders of the project who are the primary decision makers and are essential in ensuring it's adaptability withinin the organization. The stakeholder responses were vital in establishing the system's feasibility before decision was taken to advance it's design and development.

(iv) Observation

Observation was done on the Kayoola EVS bus in situations where the bus was parked and when the bus was travelling to observe bus operator behaviors and processes, passenger processes and behavior and the existing system. The main objective of this activity was to establish a clear conceptual perspective in correspondence to passenger and bus operator responses with emphasis on their challenges and the procedures they go through while travelling.

(v) Document Review

This involved reading different works and documents about and from the organization and other related works. This was primarily done to obtain an understanding of the organizational processes, goals as well as the products produced by the organization and assess where the passenger security system fits into the organization and how best it could be implemented to meet the goals of the organization as well as meet the end user needs.

(vi) Video Recording

This involved the use of cameras on laptops and CCTV cameras to capture video footage of people. The videos were then stored on local storage platform i.e., the computer hard disk drive and a hard disk drive inside a camera Digital Video Recorder (DVR). The main objective of this exercise was to obtain video data that could be used in the development and testing of a machine learning model to detect, count and analyze certain aspects in video files.

3.2.2 Data Analysis Methods

Using the data collection methods i.e., document reviews, desktop research and benchmarking, questionnaires and observation methods during the study, most of the data obtained was qualitative, and a minimal portion of data was quantitative. Responses to questionnaires shared via google forms were received in electronic format with the details aggregated in a spread sheet file. The obtained quantitative user responses were analyzed using the inbuilt google forms analytics to come up with different graphs from which conclusions were drawn. The results from the analysis of user responses are presented in Section 4.2 of this document.

3.2.3 Requirements Analysis

User requirements were gathered, examined and then classified into two categories, that is functional requirements and non-functional requirements.

(i) Functional Requirements

In principle, functional requirements describe what the system should do (Gabriela, 2017). For example, a definition of what kinds of inputs the system can take in, what kinds of information the system should give as output, what kind of data should be stored on the system that other systems might use, the kinds of computations and processing the system accomplish, as well as the timing and synchronization of the data and processes mentioned. Table 2 shows the functional requirements of the passenger security system for the passenger security system for the Kayoola EVS bus.

Table 2: Functional Requirements

Subsystem	Requirement	Description
Passenger counter	Person detection	The system should detect objects such as a person
	People addition and subtraction	The system should add and deduct persons as they enter or leave the bus and keep count of the number of people on the bus at all instances during a trip.
	Sending count notifications	The system should send notifications when the (desired) maximum number of people are in the bus.
	Remote passenger count data access	The system should send passenger count data to a remote system like a web application.
	Passenger count data storage	The system should store a log of the number of people for every trip
Multimedia surveillance	Capture video feeds	The system should capture and store video feeds from all cameras connected to the DVR on the bus.
	Special events alerts	The system should send alerts in case of special events as specified by the user

Subsystem	Requirement	Description
Multimedia surveillance	Store additional media information	The system should store additional information like the date and time when a video or image is captured.
	Capture still images	The system should capture and store an image when a user selects the option to capture a still image.
Contactless temperature sensing	Read skin temperature	The system should read the temperature from the skin of a person within its reading distance range.
	Display temperature readings	The system should display the temperature values of the person whose temperature has been read.
	Record temperature and time values	The system should record each read temperature along with the time and date.
	Alarm for abnormal temperatures	The system should set off an alarm when abnormal temperature is detected.
	Remote access to temperature readings	The readings captured by the contactless temperature sensor module should be remotely accessible via a web platform.
Contact tracing	Capture passenger information	The system shall capture passenger information through a digital form implemented in a mobile application
	Store information in remote database	The system shall store the captured information in a remote database
	View information on web platform	The system shall enable users to view information of high-risk passengers on a web platform for contact purposes
People detection, counter and social distancing analyzer	Detect people	The system shall detect people in recorded and live video frames or still pictures.
	Count and display people	The system shall count and display the number of detected people in the video frames or photos.
	Label and classify	The system shall measure social distance with respect to COVID-19, label and classify the degree of risk to passengers as safe, low risk and high based on the distance between the passengers

(ii) Non-functional Requirements

Non-functional requirements of a system majorly define the constraints that the developers of a system ought to adhere to during the design and implementation(development) of that particular system (Shahid & Tasneem, 2017). In this study, they describe of how the passenger security and safety system for the Kayoola EVS bus should function, they are elucidated in Table 3.

Table 3: Non-functional Requirements

Requirement	Description
Performance	The system shall process user requests in the shortest possible time, availing up-to-date responses and saving records. Login, logout process shall be done quickly
Security	The system and its subcomponents shall enable authentication of users using username and password before full access is granted, the system should be able to remember the users' password and username and grant access if the right credentials are entered.
Usability	The system shall be easy to use and understand by users since it follows conventional standards in computing.
Robustness	The system shall be able to recover from failure in case of problems with connection of either hardware or software.
Availability	The system shall be available to the users whenever needed
Language	The system shall be availed and documented in English language with an option of incorporating other languages as might be required by the key stakeholders.

3.2.4 Architectural Design

This section describes the architectural design of the system, a system architectural design is modelled in the early stages of the system development process and encompasses identifying the main components of a system and their communications. In this study the architecture is represented using a blend of both formal and informal models. Informal architectural models comprise simple block diagrams showing entities and relationships to aid easy communication with system stakeholders and project planning. General architectural design also aids in system analysis, and avails reusable models for future related systems. Formal models express system entities and their relationships in industry standard syntax and semantics for technical purposes. A composite architectural model for the proposed system is shown in Fig. 5, an abstract conceptual model of the system is presented in Fig. 6, and Fig. 7 is a conceptual model summarizing the components of the proposed system.

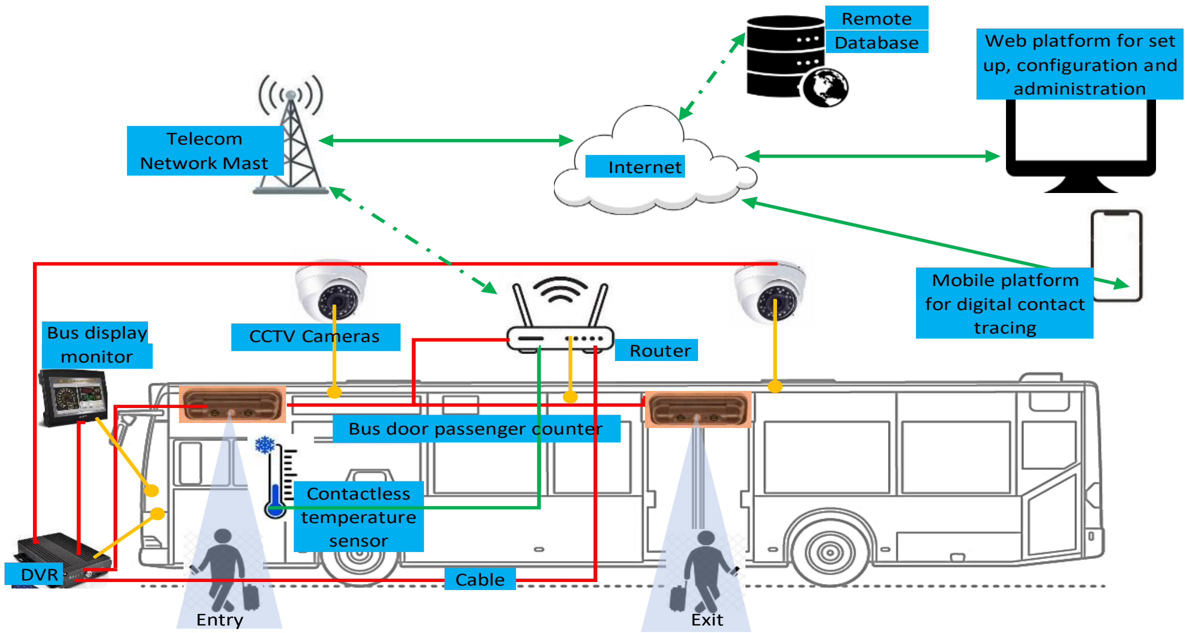


Figure 5: A Comprehensive Architectural Design for the Proposed System

The design presents the various system hardware components, their installation on. the Kayoola EVS bus, the connectivity among them as well as the communication connections they exhibit with other remote platforms.

(i) The Digital Contact Tracing System

This digital contact tracing system shall be used by passengers /customers of the Kayoola EVS buses as well as the operators of the buses. It consists of a World Health Organization (WHO) and Center for Diseases Control (CDC) standard mini-questionnaire form for COVID-19 preliminary testing availed via a mobile application platform. The form automatically collects the user's name and contact and has fields that a user can fill indicating the symptoms they have. The submissions of the passengers are stored in a real-time database which can be queried and the required information availed via a web platform to inform the relevant authorities i.e., forwarded to the Ministry of Health officials to take the necessary actions when required.

(ii) The Web System

A web system avails a robust integration platform for easy access and management of the various subcomponents of the passenger security system for the Kayoola EVS bus.

It provides an interface to access, manage and monitor some key components of the system.

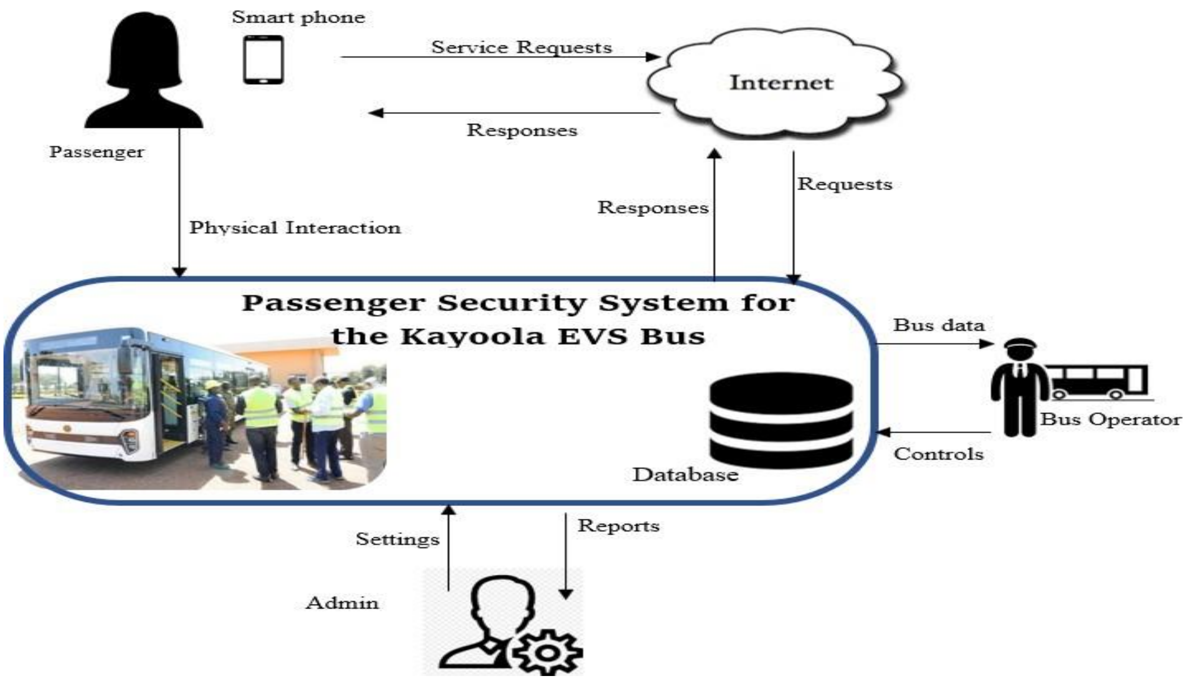


Figure 6: Conceptual Frame Work for the Proposed System

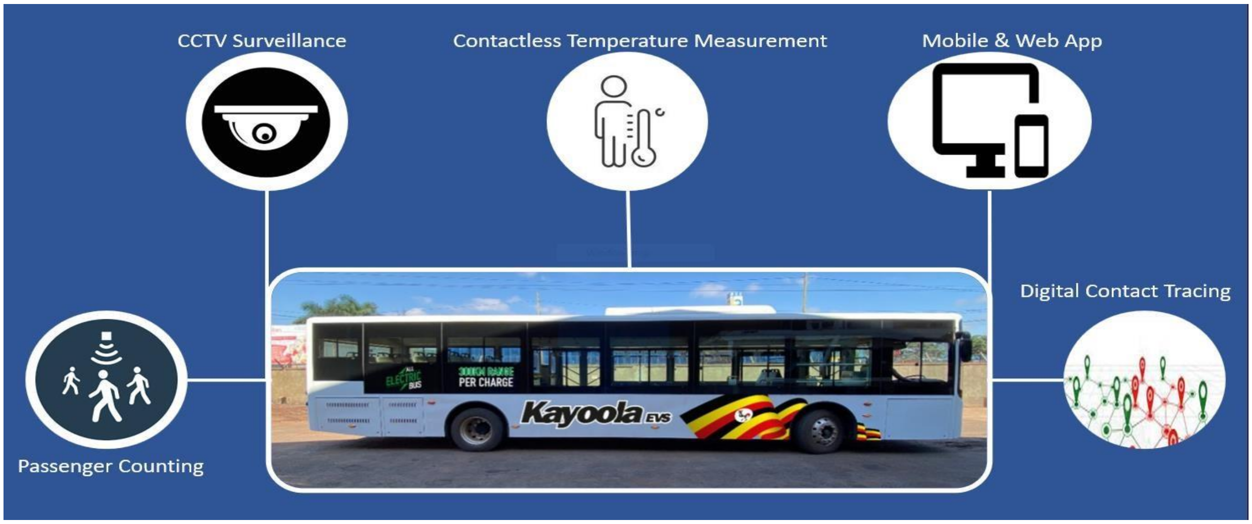


Figure 7: Conceptual Framework for the Components of the Proposed System

(iii) Context Diagram

A context diagram also known as DFD level 0 illustrates the relationship between the system and its surrounding (i.e., the system users and other associated systems). It portrays the dealings of the existing entities with other system processes. A context diagram denotes the top-level view of the system consisting of a single process i.e., process 0 which is a generalization of the overall functionality of the entire system in with respect to its external entities. The context diagram for the system is shown in Fig. 8.

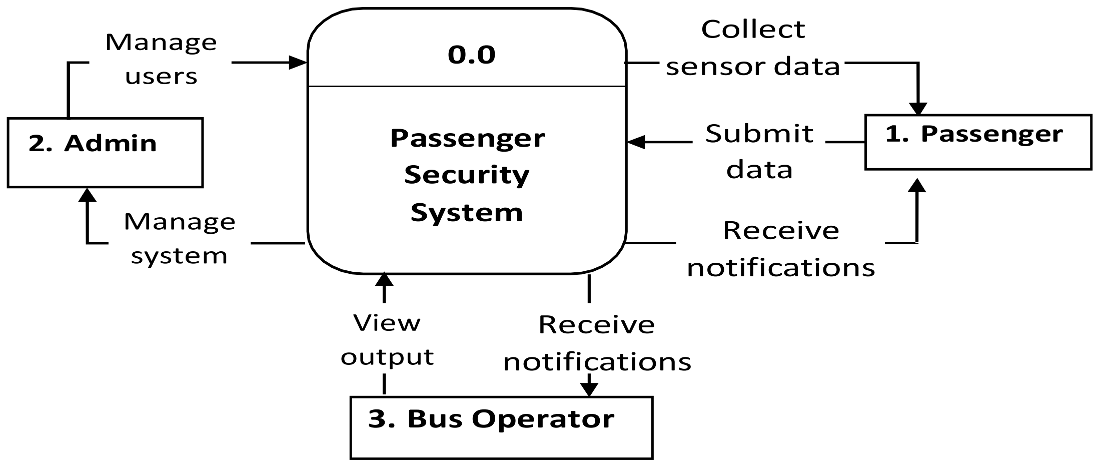


Figure 8: System Context Diagram

(iv) Use Case Diagram

A system Use Case Diagram illustrates user interactions with the system. It shows the actions and or processes that users can accomplish within the system boundary. The actions in the system Use Case Diagram are referred to as Use Cases while Cases and external entities are called Actors A use case diagram for the system is shown in Fig. 9.

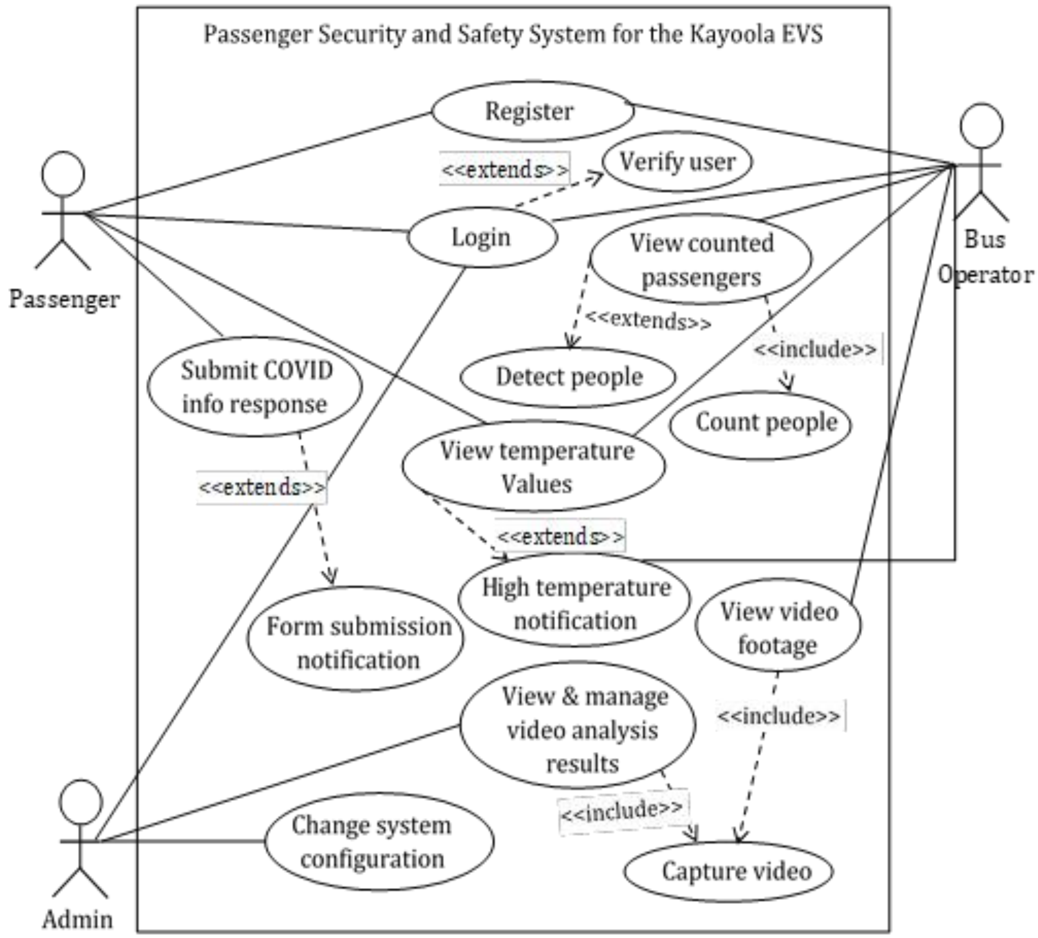


Figure 9: Use Case Diagram for the Proposed System Showing Various System Users

Identified Actors of the proposed system solution are the Admin (also called a System Manager), Passenger (Passenger of the Kayoola EVS Bus), and Bus Operator (Staff responsible for the operation of the bus on and off the road). The main Use Cases include; login, register for a new account, detect people, count passengers, display counted passengers, view temperature values, capture video, view video footage, view video analysis results, change system configurations and send notifications.

3.2.5 System Development Tools and Technologies

(i) Software Environments and Libraries

Flutter

Flutter is a cross-platform user interface toolkit that is designed to permit code reuse across operating systems like android and iOS, at the same time, it also allows applications to directly interface with fundamental platform services. It is majorly aimed at enabling developers to avail high-performance applications that have a natural feeling on a variety of platforms, incorporating divergencies while at the same time sharing as much code as possible.

During the development process, Flutter applications run in a Virtual Machine that provides stateful hot reload of modifications without needing to fully recompile. For distribution, Flutter applications are compiled directly to machine code, whether Intel x64 or ARM instructions, or to JavaScript if targeting the web. Flutter is an open-source framework, with a lax Berkeley Source Distribution (BSD) license, and has a thriving ecosystem of third-party packages in addition to the core library functionality. It employs Dart, a fast, object-oriented language which boasts features like minix, isolates, generics, and optional static types

Python

Python is a high-level, object-oriented, interpreted programming language with dynamic semantics. It is very enchanting for Rapid Application Development (RAD), as well as a glue or scripting language to connect existing components together due to its high-level in-built data structures, blended with dynamic typing and dynamic binding. The cost of maintaining Python programs is quite minimal compared to other languages because the language is simple and its syntax is easy to learn and easy to read. It is also easy to modularize and reuse Python code since it supports modules and packages. The Python interpreter and the extensive standard library are freely accessible and distributable in source or binary form for all major platforms.

Often times, Python is the language of choice for several programmers because it provides increased productivity. The cycle to edit-test and debug is incredibly fast given that there is no compilation step. On another note, debugging and diagnosis of Python code is a bit simple: a bug or bad input does not cause a segmentation fault. On the contrary, when the interpreter uncovers an error, it flags an exception. In instances where the program doesn't catch the exception, a stack trace is printed by the interpreter. A source level debugger enables inspection of local and global variables, setting breakpoints, evaluation of arbitrary expressions, stepping through the code a line at a time, and so on. The debugger is programmed in Python itself, bearing witness to Python's introspective ability.

OpenCV

Unlike other languages such as C and C++, Python is slower. However, OpenCV-Python, provides a key attribute of Python in that it can be easily extended with C/C++. This feature aids in writing of computationally intensive code in C/C++ and creating a Python wrapper for it so that these wrappers are used as Python modules. This provides two advantages: namely, the written code is as fast as original C/C++ code (since the C++ code actually works in the background) and second, it is quite simple to write Python code. Therefore OpenCV-Python works as a Python wrapper around the original C++ implementation. It also supports Numpy which makes the complex image and video processing task much easier.

NumPy

NumPy stands for Numerical Python. It is a highly optimized Python library for numerical operations. It gives a MATLAB-style syntax. It also possesses features for working in the domain of Fourier transformation, linear algebra, and matrices. All OpenCV array structures can be converted to-and-from NumPy arrays. Therefore, whatever operations that can be done in NumPy, can be combined with OpenCV. Python language contains lists that serve the same purpose as arrays; however, they are slow to process. The NumPy library helps to provide an array object that is up to fifty times faster than the traditional lists in Python. The object of an array is called ndarray in NumPy, it avails a lot of supporting functions that make manipulation of ndarray a bit easy. Arrays are very frequently used in data science projects like the object detection algorithms, where speed and resources are very important.

Imutils

This library comprises of a series of convenience functions to make basic image processing operations like resizing, translation, skeletonization, rotation, and displaying Matplotlib images simpler with OpenCV.

YOLOv3

YOLOv3 is a real-time, single-stage object detection model which is an improvement of YOLOv2 in several aspects. The improved aspects include the use of a new backbone network, Darknet-53 that leverages residual connections, or as the author states, "those newfangled residual network stuff", in addition to some enhancements to the bounding box prediction step, and using three distinct scales from which to extract features similar to a Feature Pyramid Network (FPN).

C++

The C++ programming language is a cross-platform language that is commonly used to develop high-performance applications. The language was developed by Bjarne Stroustrup, as an extension to the C language. C++ enables programmers to have a high level of control over system resources and memory. The language was updated 3 major times in 2011, 2014, and 2017 to C++11, C++14, and C++17. It is one of the world's most popular programming languages and is found in several operating systems, Graphical User Interfaces, and embedded systems. The C++ language is object-oriented and gives a clear structure to programs on top of allowing code to be reused, thus reducing development costs. It is also is portable and hence can be used to develop applications that can be adapted to multiple platforms. It is quite close to C# and Java, which makes it easy for programmers to switch to C++ or vice versa

(ii) Development Hardware

Closed-Circuit Television System Hardware

The key hardware components used include CCTV surveillance cameras which come in various specifications like pixel levels, day and night vision, analog and digital formats, among others. The cameras are connected to a single controller device known as a digital video recorder (DVR) which has a number of ports (channels) for connecting multiple cameras as well as processing, storage and communication interfaces for the videos. The DVR and cameras are connected using RG59 coaxial cables and RG59 BNC plenum compression connectors. A monitor is used to view output from the DVR and a router is used to relay video footages for internet viewing and storage.

Laptop/ Personal Computer

A laptop (personal computer) was the main development hardware tool used in the design, development, configuration and documentation of the various components of the system. Some of the main features necessary for the laptop to be used for the tasks of this project include; a Windows 10 Pro 64-bit operating system (OS), intel core i5 processor with 4 Central Processing Units at a processing speed of 2.6 GHZ, a hard disk of 500 GB and a Random-Access-Memory (RAM) of 6GB. A relatively high processor speed and moderate RAM are necessary for running applications like Android Studio that require more computing resources than most desktop applications.

Arduino Uno

The Arduino microcontroller unit board was used to program the contactless temperature sensing system. This microcontroller unit is quite popular among people starting out or prototyping with electronics. Unlike many of the programmable circuit boards, the Arduino does not need a programmer (i.e., a separate piece of hardware) when loading new code on the board. Instead, a simple USB cable is used to upload code from the computer to the micro controller unit. In addition, the Arduino board provides a standard form factor that breaks out the functions of the micro-controller into a more accessible package.

Other Hardware and Devices

Other devices used include an Arduino Uno board used to connect and power different devices, a breadboard used to extend the Arduino board, the MLX90614 contactless temperature sensor that was connected to and powered by an Arduino UNO micro controller unit board to sense temperature values, a 16x2 LCD screen used to display temperature readings from the MLX90614 sensor, LEDs used to indicate whether the detected temperature values lie within the normal human body temperature range, a potentiometer used as a voltage divider to vary the light intensity of the LCD screen to obtain clear readings, jumper cables used to connect different components to the

Arduino Uno board, an ESP8226 Wi-Fi module used to send the sensed readings over the internet to the ThingSpeak platform. Pictures of the different hardware used are shown in the appendices.

(iii) Data Base Implementation

Cloud Firestore

The database of the system is implemented in the google Cloud Firestore platform. Cloud Firestore is a NoSQL document-based database that was built specifically for mobile and web application development. It leverages Google's powerful cloud infrastructure and lets users easily store, sync, and query data in real-time with low latency, all at a global scale. Its key capabilities include; Flexibility by offering support for flexible, hierarchical data structures. Storing data in documents, grouped into collections. The documents often store multifaceted nested objects as well as subcollections. Expressive database queries are employed to retrieve specific individual documents or all the documents in a collection that match the set query parameters. The queries often include combine filtering and sorting, multiple filters, and chained filters. Database queries are indexed by default, this makes query performance proportional to the size of the result set, and not the data set. Realtime updates where Cloud Firestore uses data synchronization to update data on any connected device as is the case with Google's Realtime Database. However, it's also designed to efficiently make simple, one-time fetch queries. It also has offline support where the data that an application is actively using is cached, so that it can write, read, listen to, and query data even if the device is offline. When the device gets back online, Cloud Firestore synchronizes any local changes.

(iv) Source Code Editors

Arduino IDE

Arduino is an open-source platform used for programing electronics projects. Arduino has both a physical programmable circuit board (commonly called a microcontroller) and a piece of software. The software is an IDE (Integrated Development Environment) that runs personal computers, it is used to write and upload computer code to the Arduino microcontroller board. The Arduino IDE employs a simplified version of C++, making it quite easy to program. It was used to write C++ code for the contactless temperature measurement system.

Jupyter Notebook

The Jupyter Notebook is an open-source web application that one can use to create and share documents that contain live code, text, equations and visualizations. Jupyter notebooks are a derivative development from the IPython project, which used to have an IPython Notebook project itself. The name, Jupyter, is derived from the main supported programming languages that the platform supports: Julia, Python, and R. Jupyter ships with the IPython kernel, which allows programmers to write codes programs in Python, however, there are currently over 100 other kernels that can be used. This was used to write code and run tests for the passenger counting and social distance analysis module of the system.

Android Studio

The Android Studio integrated development environment is the official IDE for developing Android applications. It is based on the IntelliJ IDEA, a Java integrated development environment for software, and integrates its code editing and developer tools. Android Studio uses a Gradle-based build system, an emulator, GitHub integration and code templates, to support the development of applications within the Android OS. Every project in Android Studio has one or more modalities with source code and resource files. These modalities include Android app modules, Library modules, and Google App Engine modules. This IDE was used in developing the contact tracing mobile application screens of the system.

3.2.6 Assumptions and Dependencies

(i) It is assumed that the system users (system administrators, bus operators and mobile app users) have access to a smartphone, personal computers and internet.

(ii) Each bus on which the system is used has ample space for DVR installation and wiring

(iii) Each bus has a router with active internet connection while in operation.

(iv) The primary users of the system shall have basic knowledge about connecting computing devices.

(v) Remote system availability is dependent on having internet connectivity for the devices sending data as well as on the user’s device.

(vi) The system hardware components shall be installed on a bus and connected to a LAN via a router.

(vii) The data from the devices shall be safely made available for internet access through the router on the bus.

(viii) The deigned contactless temperature sensing system is a proof-of-concept system that may not be deployed on the bus.

3.3 Summary

This chapter presented the materials, technologies and methods employed in this project by describing the case study area, data collection and analysis methods. Furthermore, it elaborated both functional and non-functional requirements of the passenger security system that help in ensuring the developed system does what it is supposed to do in an appropriate manner thus providing much needed security and safety measures for bus passengers on the Kayoola EVS bus and other buses in African cities. The chapter also described the architectural design of the proposed solution. It also described the development of the proposed system by discussing technologies used and why they're used.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Introduction

The preceding chapter unveiled the materials and methods used in the design and development of the project. It also presented particulars on the area of study, data collection methods and the necessary requirements for the design and development of the proposed solution. This chapter parades the results and discussions of the data collection exercise, system design and system development.

4.2 Findings from the Respondents

4.2.1 Demographics of the Respondents

A total of 22 responses were collected from the organization's office staff where by 14 (63.6%) of the respondents were males, 7 (31.8%) of the respondents were females and 1 (4.5%) of the respondents opted not to reveal their gender. A gender analysis of the respondents is shown in Fig. 9. It was desirable to have more respondents, however, given that the organization has a policy of keeping information about the products under development inhouse, only the available staff of the organization were considered as respondents. A balance in gender was of significance concerning the selection of the sample. However, there was a challenge presented by the fact that the number of female respondents were less than the male respondents. To counter this challenge and meet this gender balance, the efforts were taken to email the female members of staff to receive input from them.

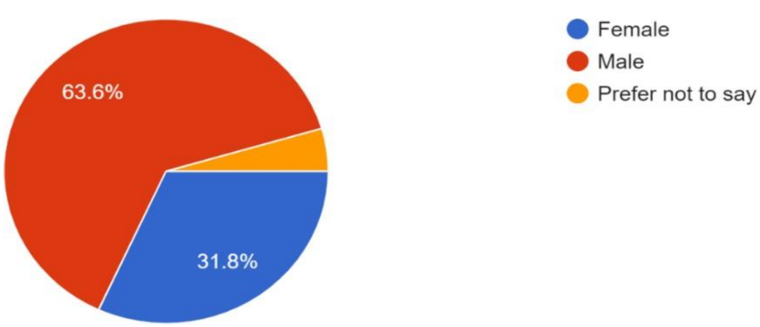


Figure 10: Gender Analysis of Respondents

In addition, the researcher sampled the survey participants based on age group and the analysis revealed that 9 (40.9%) were between 18-25 years old, 10 (45.5%) were between 26 - 40 years old and 3 (10.6%) of the respondents were above 41 years. Analysis results for the age group of respondents in presented in Fig. 10. This implies that most of the respondents were youth.

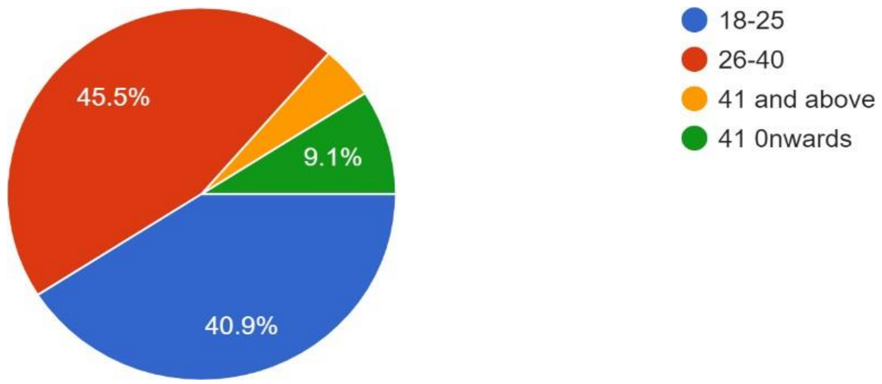


Figure 11:A Pie Chart Showing an Analysis of the Age Group of Respondents

4.2.2 The Key Considerations and Concerns of Respondents When Using Public Means of Transportation

The study aimed at finding out the perception of respondents concerning the relevance of passenger security systems on buses used to provide public transportation services. A number of key factors were listed as options inquiring about what the respondents considered as the most important factors when choosing a means of transportation to use. As demonstrated in Fig. 11, 46.7% of the respondents considered cost or fare of a trip as the most important factor, 26.7% of the respondents considered accessibility and 20% considered security as a key determinant of their choice. The fact that a fair portion of the respondents have security as a concern when making their choice to travel implies it is a relevant factor worthy of consideration by transport operators and car makers.

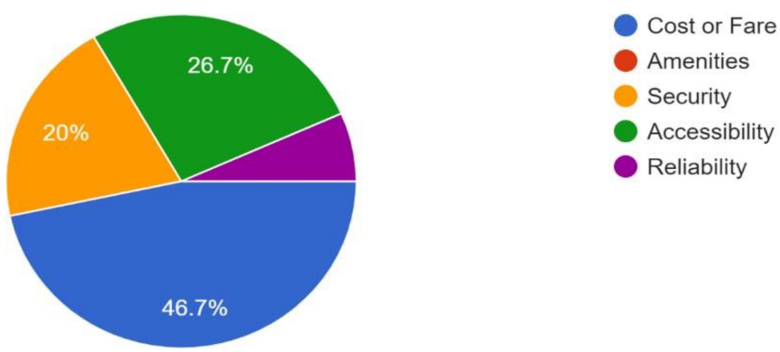


Figure 12: A Pie Chart Showing Analysis Results of the Most Significant Factors that Determine the Choice of Respondents when Travelling using Public Means

4.2.3 Respondents Perception of the Use of Video Surveillance Systems in Public Transport Vehicles

The study also sought to find out the perception and opinions of the respondents concerning the use of surveillance systems on public transport vehicles. The results as presented in Fig. 12 showed that 81.8% of the respondents answered “Yes” implying they had no objection to the use of video surveillance to monitor passengers while travelling on public buses. On the other hand, 18.2% of the respondents answered “No” implying they were opposed to the use of video surveillance on public transport vehicles. Since majority of the respondents showed support for the use of video surveillance, there is a very high chance that bus companies that employ video surveillance will not lose clients.

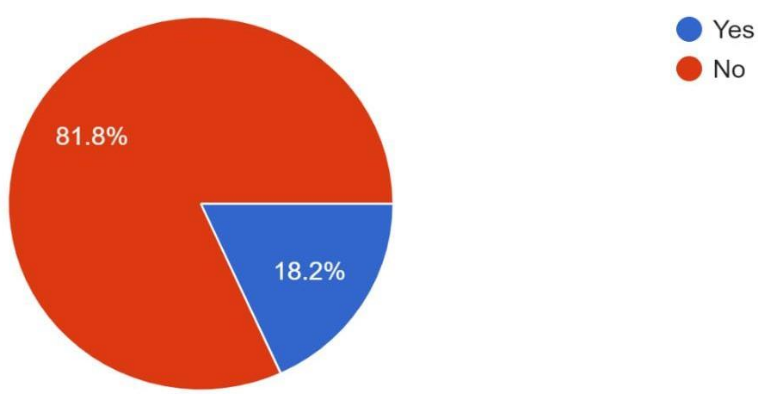


Figure 13: A Pie Chart Showing Analysis of Acceptability of Video Surveillance on Buses.

4.2.4 Substantiation of the Backing to Employ Artificial Intelligence Like People Recognition AI in Public Transportation

The other goal was to substantiate whether the use of artificially intelligent technologies like face recognition from analysis of photos and videos of passengers that use public transportation for security passes and identification of offenders. A five-point Likert scale was used to obtain the responses. The results obtained showed that 26.7% of the respondents strongly supported the use of such technologies, 46.7% somewhat supported their use, 13.3% were neutral to the idea implying that they neither supported nor opposed its use, 13.3% strongly opposed the use of facial recognition technology while no respondent somewhat supported its use. The results are shown in Fig. 13. Since the biggest percentage of respondents is not opposed to the use of artificial intelligence technologies, it can be concluded that AI and such similar technologies can be employed in public transport to serve various purposes and benefit passengers, bus owners and other authorities in the transport sector.

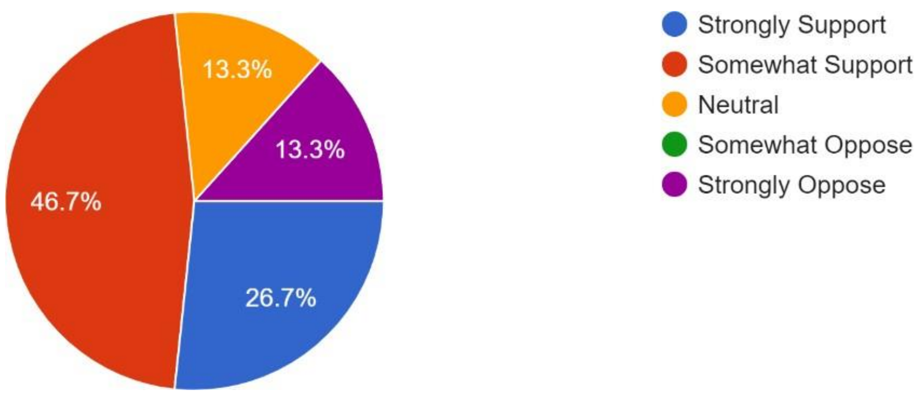


Figure 14: A Chart Showing the Opinion of Respondents Towards the use of Artificial Intelligence Technology on Buses

4.3 Outcomes and Discussion for the Designed and Developed System Components

4.3.1 Contactless Temperature Measurement

The Fritzing sketching software was used in the design of a Printed Circuit Board (PCB) sketch for the contactless temperature measurement system which forms part of the bigger passenger security and safety system. The outcome is presented as a breadboard schematic diagram that shows the physical subcomponents of the system in graphical and colored format. The results of the PCB design are shown in Fig. 14. The sketch consists of numerous parts including the MLX90614 contactless temperature sensor which is used to capture passengers' temperature values as they enter a bus within a distance range of zero to five centimeters, a 16x2 LCD display screen that displays the read temperature in degrees centigrade, a potentiometer which is used to set and vary the brightness of the LCD screen for proper visible display of text, an Arduino UNO board onto which the code for the system is uploaded and all processing of the program that runs the functioning of the various devices is performed, the esp82066 Wi-Fi module that is used to send the temperature readings to the ThingSpeak cloud platform for remote aggregation, analysis and visualization of sensor values as long an active wireless internet connection exists, and two LED bulbs, a green one that is intended to light for a period in case the captured temperature value of the person is within the accepted range and the red LED that is supposed to light as a warning that the captured temperature value is outside the acceptable normal temperature range for a human being. The different components are connected to the Arduino board via the breadboard using jumper wires.

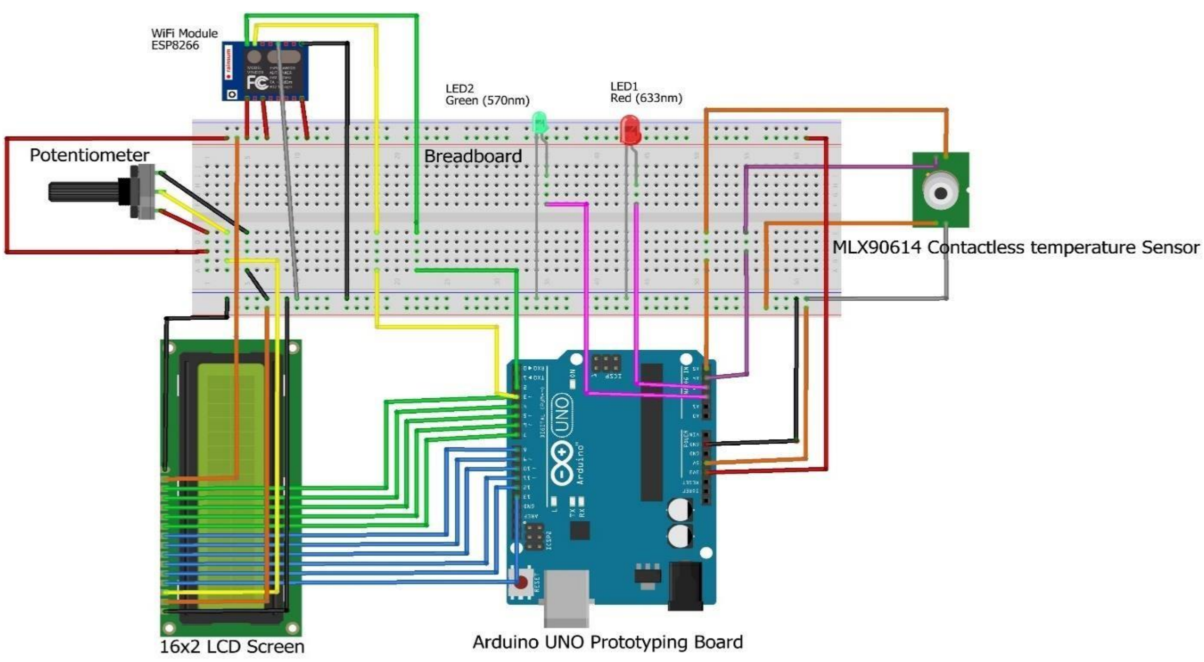


Figure 15: A Breadboard Schematic Sketch for the Contactless Temperature Sensing Subsystem

The other output from the sketching tool is an electrical circuit schematic that shows details of the connection pins of the various sensing and actuating components and where they are connected on the Arduino board. This is very helpful in the physical connection of the various devices in future instances. The outcome of the schematic is shown in the Fig. 15. The diagram shows the different parts with the appropriate electrical symbols for example the red and green LEDs are shown using the standard symbol for LEDs and the potentiometer is shown using a symbol for a potential divider while the rest of the components are shown with full details of their pins and where each is connected on the Arduino board for apt system functioning. These two diagrams make the physical wiring of components easier to figure out and repeat whenever the need arises. The electrical circuit schematic also makes it easy to have compact system design, easy testing and repair as well as minimal errors when assembling the parts of the system.

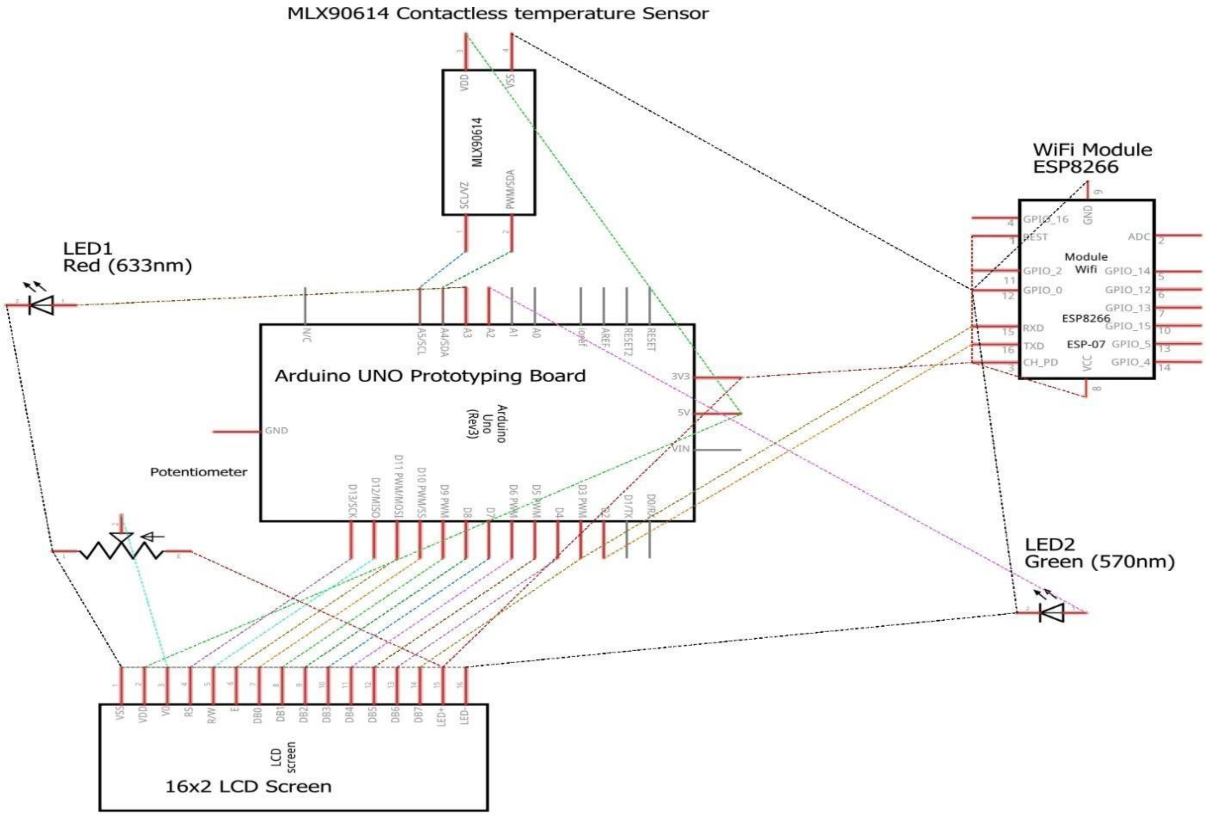
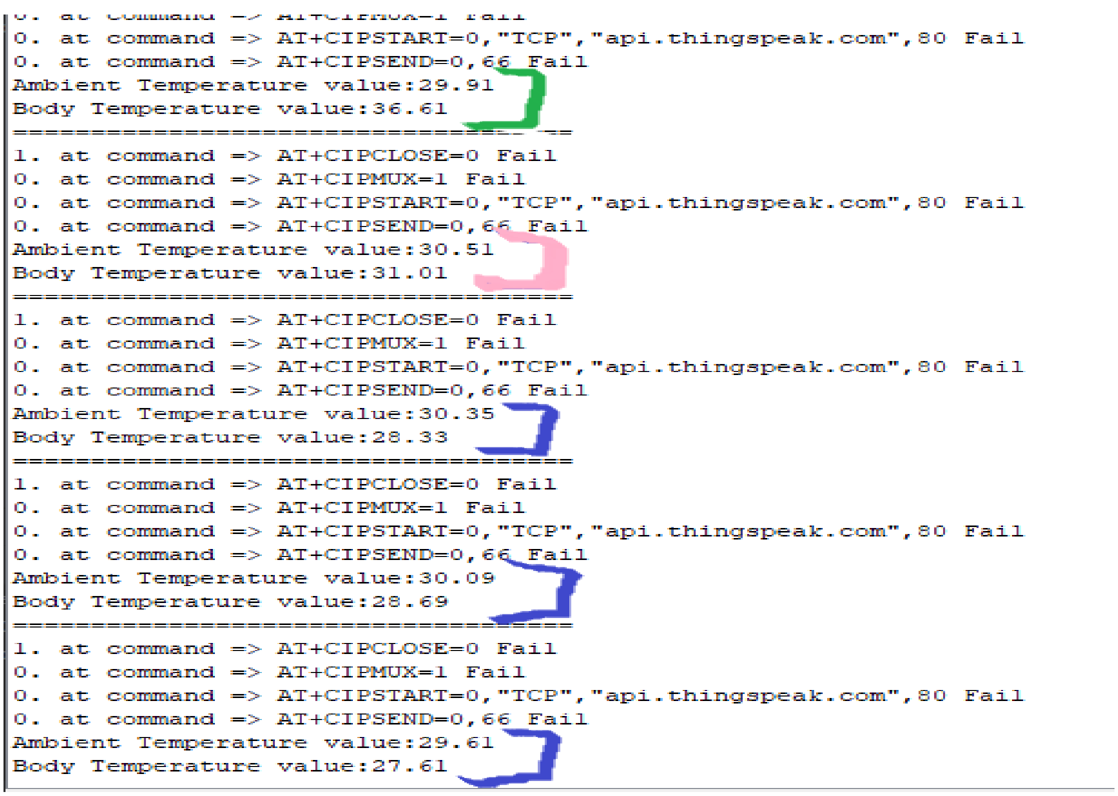


Figure 16: An Electrical Circuit Schematic for the Contactless Temperature Sensing Subsystem

(i) Outcomes from Running the Code on Arduino IDE and Arduino UNO Board

The program for the subcomponent was written in C++ in the Arduino IDE and uploaded to the Arduino UNO board for processing purposes using a USB cable from the laptop to the board. The cable serves the purpose of the linker for program interpretation and power supply. The program ran successfully after the parameters for the Wi-Fi access point name and password were passed to the esp82066 module. The temperature sensor picked ambient temperature values from its surrounding which ranged from an average minimum of 26.1 degrees centigrade to an average maximum of 31.0 degrees centigrade. A screenshot of the ambient temperature readings without any person in the reading range of the sensor are shown in Fig. 17 with blue markings at the righthand ends. This is further illustrated by the photo in Fig. 18 where ambient temperature values from the sensor are displayed on an LCD screen.



```
0. at command => AT+CIPSTART=0,"TCP","api.thingspeak.com",80 Fail
0. at command => AT+CIPSEND=0,66 Fail
Ambient Temperature value:29.91
Body Temperature value:36.61
=====================================
1. at command => AT+CIPCLOSE=0 Fail
0. at command => AT+CIPMUX=1 Fail
0. at command => AT+CIPSTART=0,"TCP","api.thingspeak.com",80 Fail
0. at command => AT+CIPSEND=0,66 Fail
Ambient Temperature value:30.51
Body Temperature value:31.01
=====================================
1. at command => AT+CIPCLOSE=0 Fail
0. at command => AT+CIPMUX=1 Fail
0. at command => AT+CIPSTART=0,"TCP","api.thingspeak.com",80 Fail
0. at command => AT+CIPSEND=0,66 Fail
Ambient Temperature value:30.35
Body Temperature value:28.33
=====================================
1. at command => AT+CIPCLOSE=0 Fail
0. at command => AT+CIPMUX=1 Fail
0. at command => AT+CIPSTART=0,"TCP","api.thingspeak.com",80 Fail
0. at command => AT+CIPSEND=0,66 Fail
Ambient Temperature value:30.09
Body Temperature value:28.69
=====================================
1. at command => AT+CIPCLOSE=0 Fail
0. at command => AT+CIPMUX=1 Fail
0. at command => AT+CIPSTART=0,"TCP","api.thingspeak.com",80 Fail
0. at command => AT+CIPSEND=0,66 Fail
Ambient Temperature value:29.61
Body Temperature value:27.61
```

Figure 17: Screen Shot Showing Temperature Readings on the Arduino IDE Serial Monitor at a Baud Rate of 9600

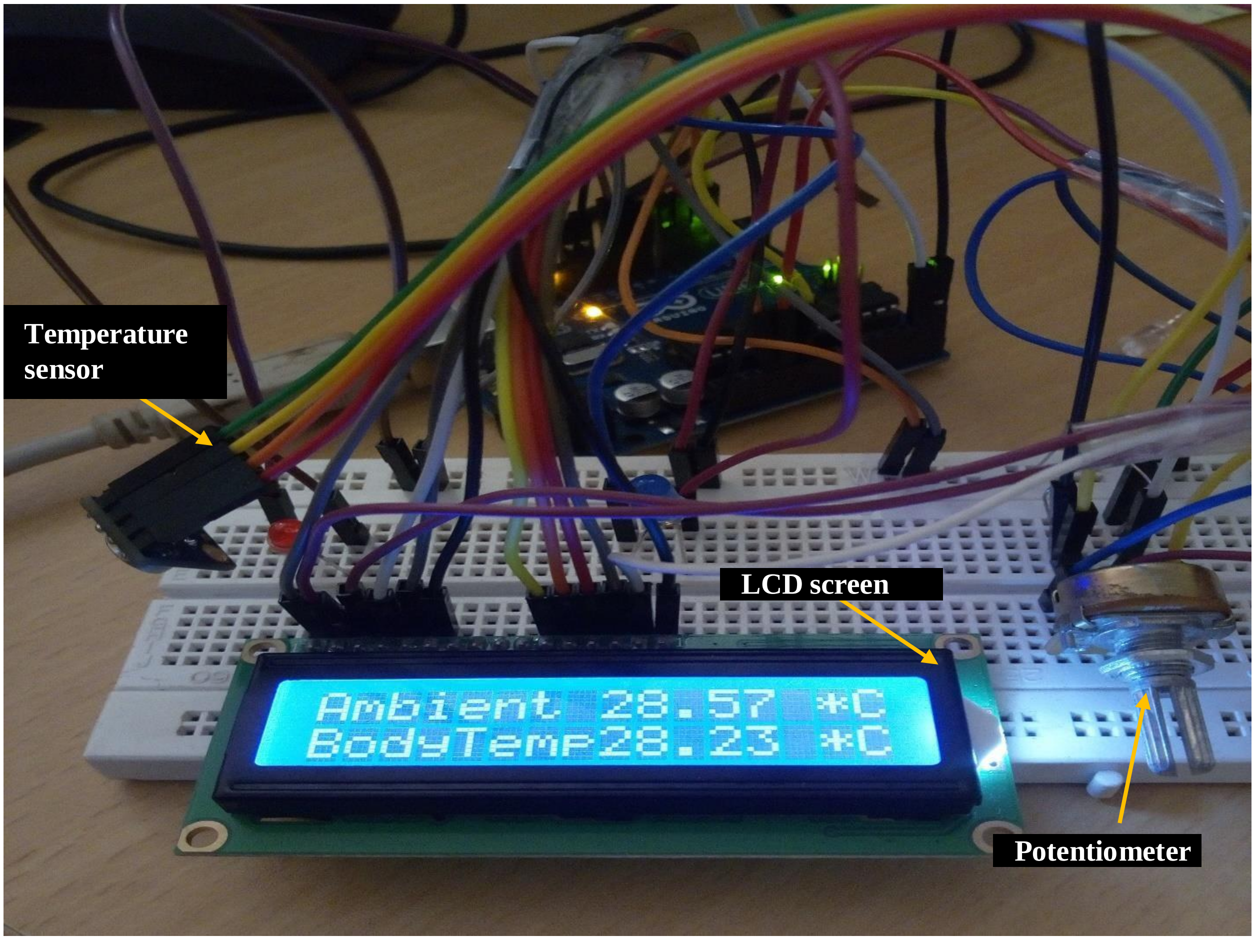


Figure 18: Photo Showing MLX90614 Sensor Ambient and Body Temperature Values when There's no Human Body Within the Distance Range of the Sensor

On the other hand, the body temperature values picked from the sensor and displayed in the Arduino IDE serial monitor and LCD screen ranged from 32.2 degrees centigrade to 37.4 degrees centigrade. Figure 16 shows a screen shot of temperature readings observed over a period of time in different situations. The first reading (labelled with green) was obtained with a human body within the reading range of the sensor, the next values (labelled with pink) was obtained with the human body near the sensor but out of its reading distance range, while the rest of the values (labelled with blue) were obtained when there was no body near and within the reading distance range of the temperature sensor. The variation in human body temperature readings is due to variations in the preceding conditions of the body part from which the values were read. For example, when a hand that had been exposed to cold water was immediately placed within the sensor's reading range, it was observed that the temperature value of the body was lower than the normal human body temperature as illustrated in Fig. 20.

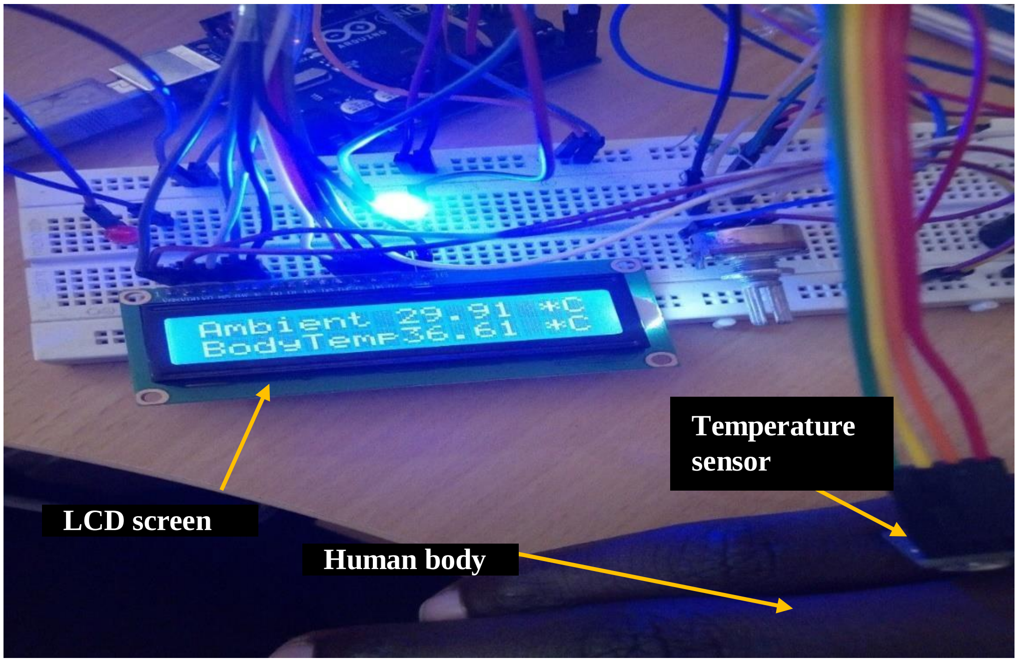


Figure 19: A Photo Showing Normal Human Body Temperature Display on the LCD Screen

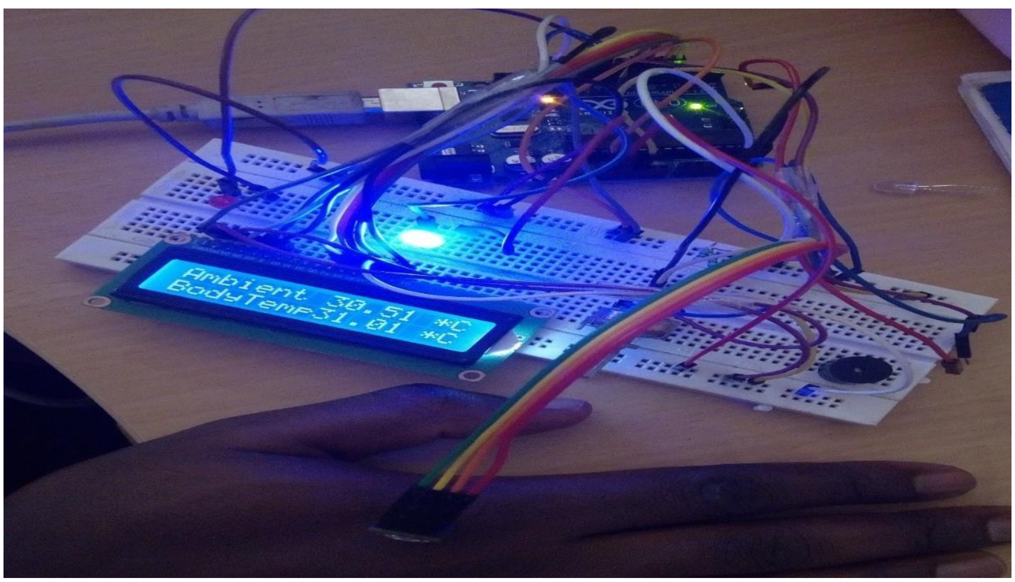


Figure 20: A Photo Showing Temperature Value Reading from a Hand that had Just been Exposed to Cold Water at Room Temperature

It was also observed that the body temperature values had a slight variation from the ambient temperature values when there was no human body within the reading range of the sensor, every time a human body was brought within the reading distance range of the sensor, a new body temperature value was captured by the MLX90614 sensor and displayed on the LCD screen and the Arduino IDE serial monitor output as shown in the Fig. 19 and Fig. 20.

The brightness of the screen is also varied by turning the knob on the potentiometer in different directions. In case an Internet connection is available, the esp8266, uploads new values of ambient and object temperature to the ThingSpeak cloud platform where values are aggregated, analyzed and visualized using graphs of temperature values against time as illustrated in Fig. 21.

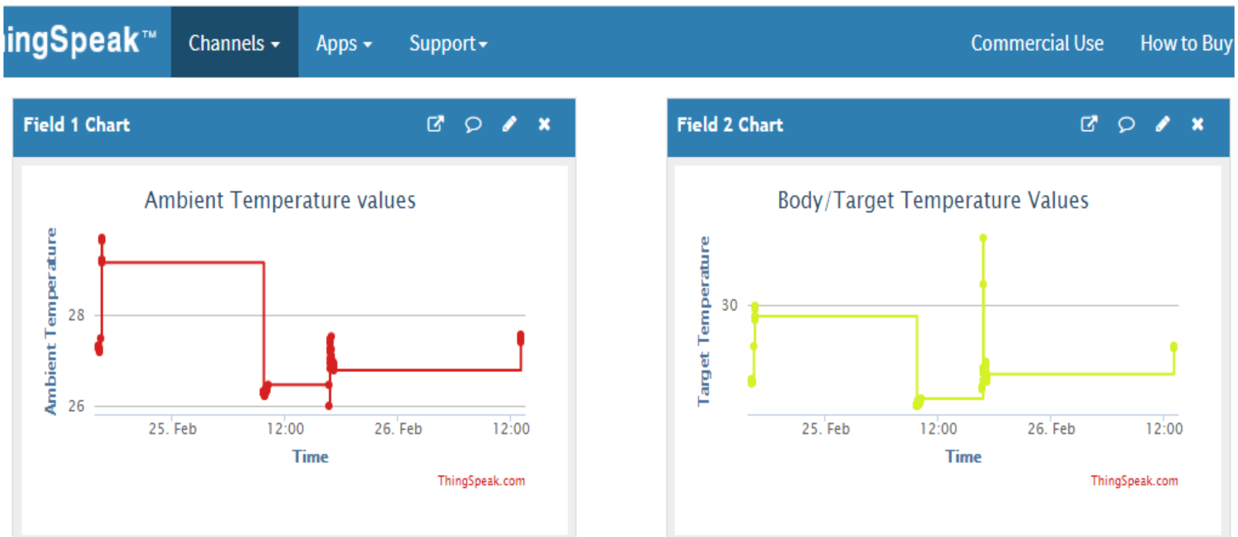


Figure 21: A Screenshot of the Graphs of Temperature Sensor Values on the ThingSpeak Platform

4.3.2 Closed-Circuit Television Surveillance System

(i) Closed-Circuit Television Surveillance System Design Outcomes

A design of the CCTV surveillance system was modeled to ease communication with stakeholders and offer time saving guidance during the system deployment process. The design outlines the Kayoola EVS bus floor/roof structure and identifies specific spots on the bus where the different parts of the system are to be placed as well as the connectivity among them. Two passenger count cameras are placed at the two bus doors, two surveillance cameras are placed in the bus (one at the front to cover the front part and another at the back to surveil activities at the rear end of the bus). All the cameras are connected to a DVR (placed at the front of the bus) using twisted-pair cables for video transmission. A screen is also connected to the DVR to view camera video footage. The DVR and bus door passenger count cameras are connected to a router using ethernet cables for network connectivity and enable data transmission for remote viewing and control of data. The CCTV and passenger count camera layout network diagram for each bus is shown in Fig. 22.

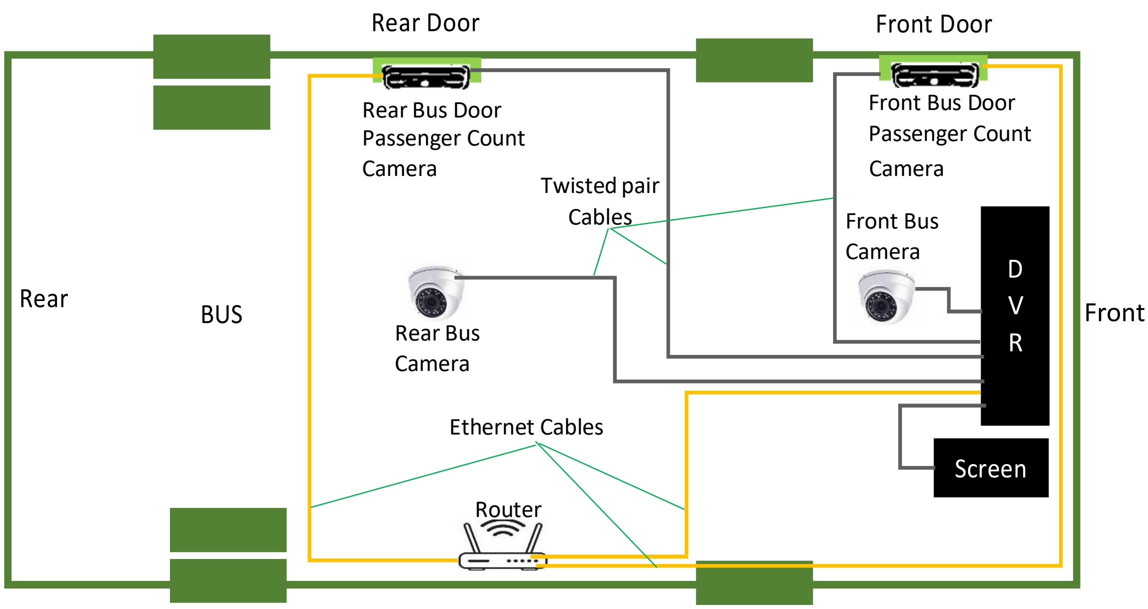


Figure 22: A Layout Design for CCTV Surveillance Components on the Kayoola EVS Bus

(ii) Closed-Circuit Television Surveillance System Implementation Outcomes

The CCTV surveillance system was set up in the office working area for configuration and testing purposes. It was set up with various components including a 1080-pixel colored Infrared (IR) camera that captures images in both high and low light intensity conditions. The camera was powered using a 12V-24V AC to DC convertor adapter cable and connected to a DVR component using a coaxial cable that for transmission of video streams. The DVR is the primary processing element of the surveillance system capable of capturing and processing both video and audio feeds from connected cameras. It also has the primary storage component for the system, i.e., a hard disk drive. A disk drive of one tera byte (1TB) was used on this project, it is capable of storing video footage from a single camera for a period of 60 days under continuous recording mode. The DVR used in this project has a total of 8 channels implying it has a capacity accommodating up to 8 analog wired cameras. The DVR was also connected to a desktop monitor to provide a visualization interface of the video footage and system settings. It is also mounted with a mouse for screen action control purposes. The DVR is connected to a router using the RJ45 ethernet cable to provide network connectivity and enable remote system control and monitoring. Figure 23 Shows the physical connection and labeling of the devices of the implemented CCTV surveillance system.

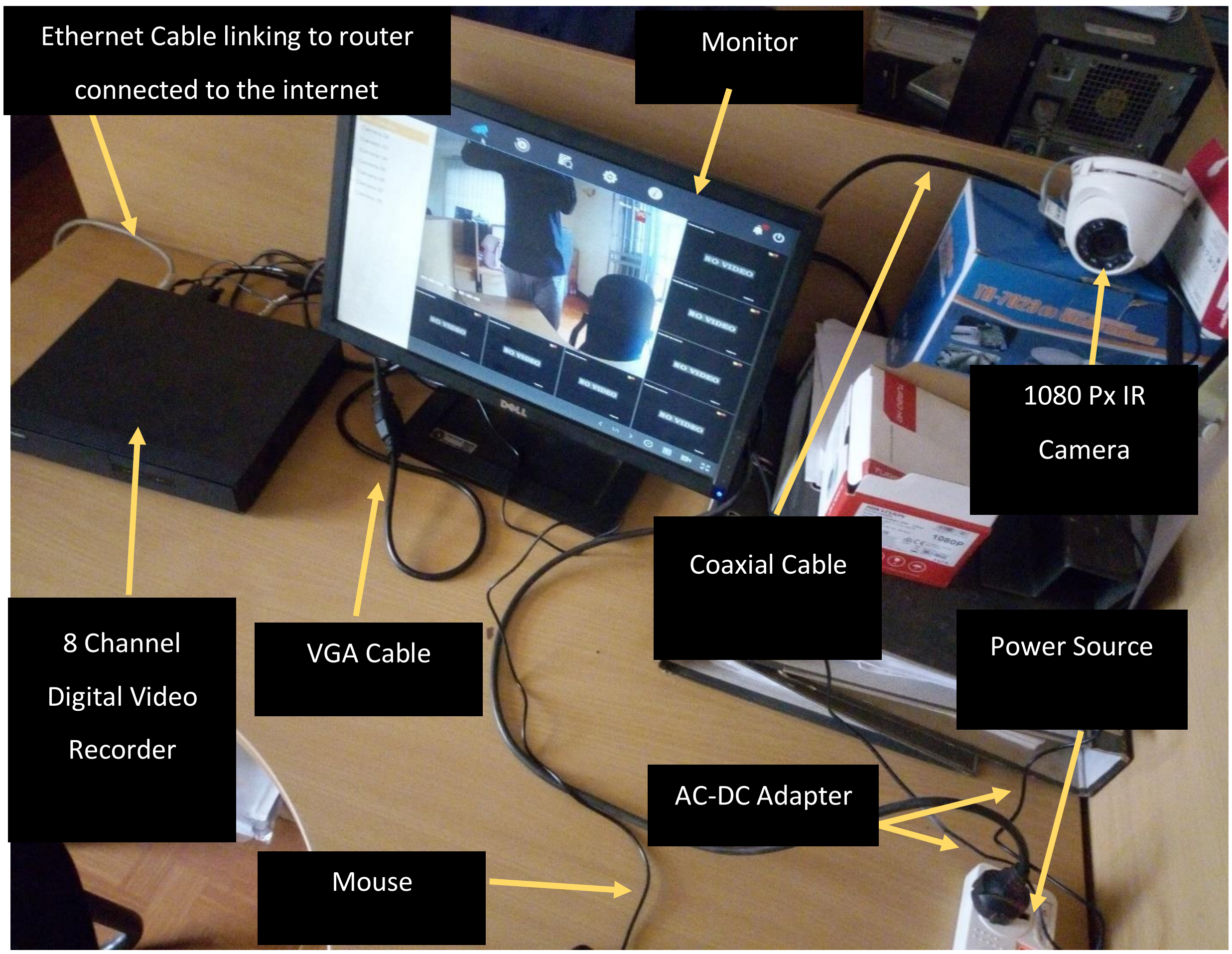


Figure 23: A Photo Showing the Physical Set Up and Components of the CCTV Surveillance System

The DVR was made accessible on a Local Area Network of the organization by passing its Internet Protocol (IP) address to a web browser. The IP address is in the form 192.168.254.XXX. Through this IP address the properties and settings of the CCTV system can be accessed and configured. The IP address is set to be dynamic for security reasons. For remote secure access to the system over the Internet, the router used on the project was configured to enable port forwarding options by setting the various parameters of the DVR like the service type (HTTP), external port (80), internal IP (in the form 192.18.XXX.XXX), internal port (80), protocol (UDP or TCP) and status as active. The configuration of the DVR for remote internet access is shown in the screen shot in Fig. 24.

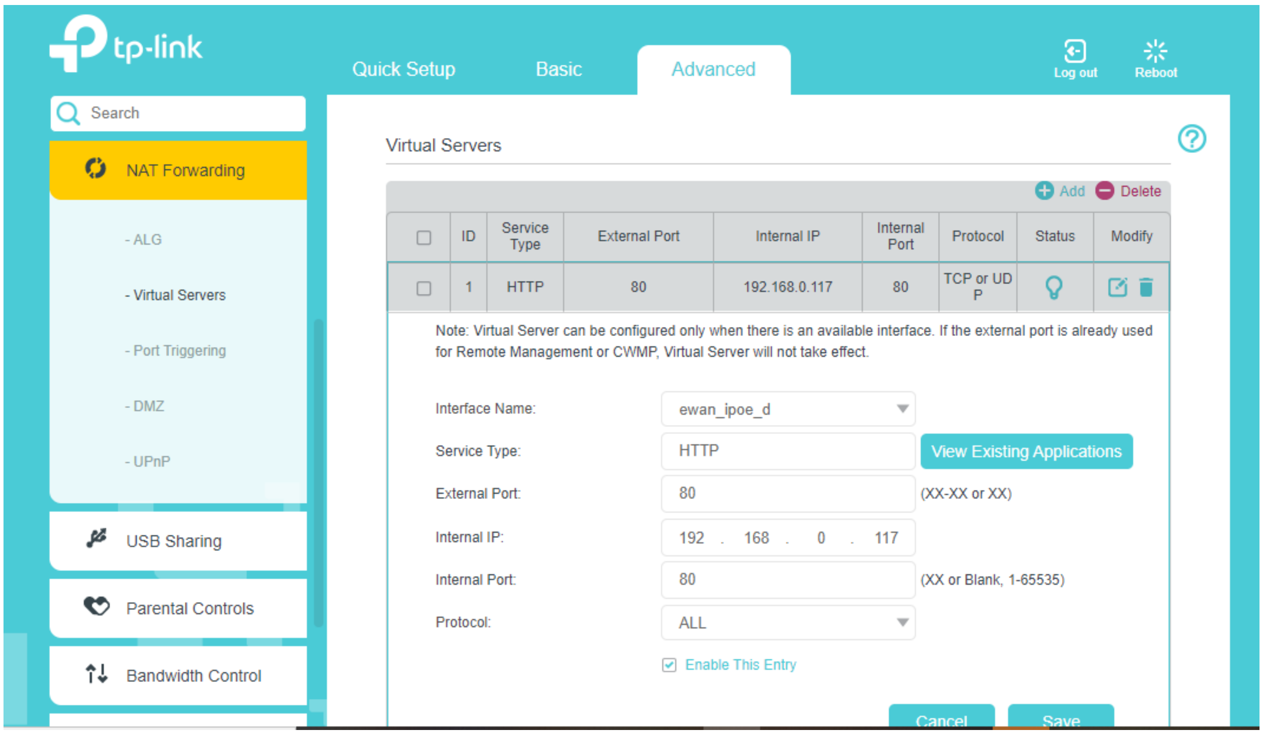


Figure 24: Screen Shot Showing the Port Forwarding Fields of a Tp-Link Router used on the Project

Live video surveillance feeds were then made accessible for remote secure viewing over the internet by providing a link. This link was tested using the VLC media player desktop application on a laptop running Windows 10 OS and by pressing the Control Plus N (i.e., Ctrl + N) keys on the key board simultaneously, passing the link to a text field and then pressing the play button. A live video footage captured by the camera was made visible on a laptop connected to the internet using cellular data, i.e., a different network from the one provided by the router. In addition, the system output was accessible via a web browser (Google Chrome) by passing the DVR's IP address. Figure 25 shows the login screen of the CCTV surveillance system and Fig. 26 shows a screenshot of a live video stream and a device configuration panel for the system.

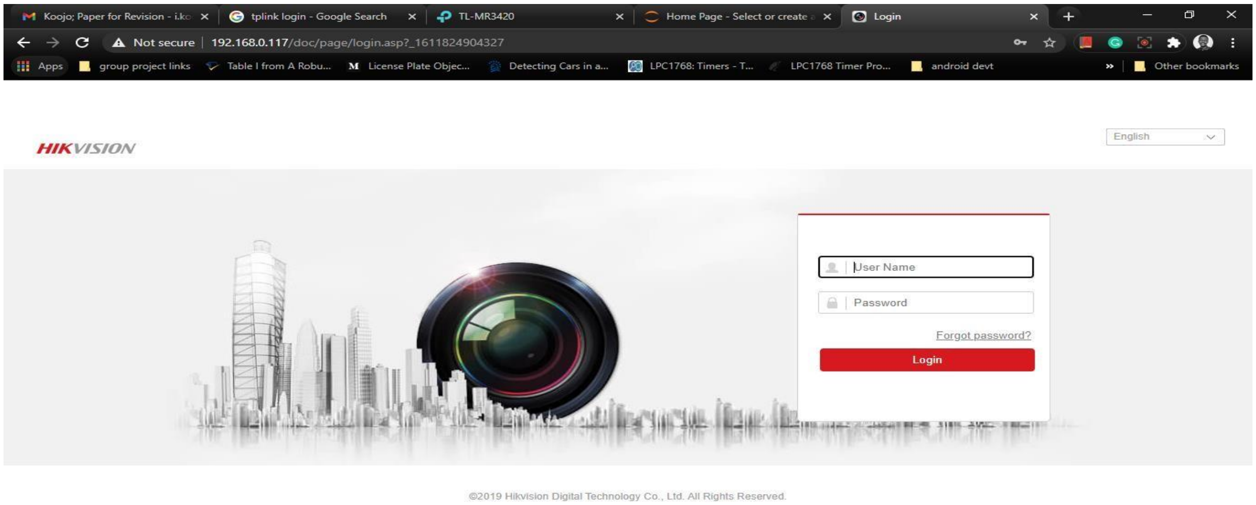


Figure 25: A Screen Shot Showing the Login Screen for the CCTV Surveillance System

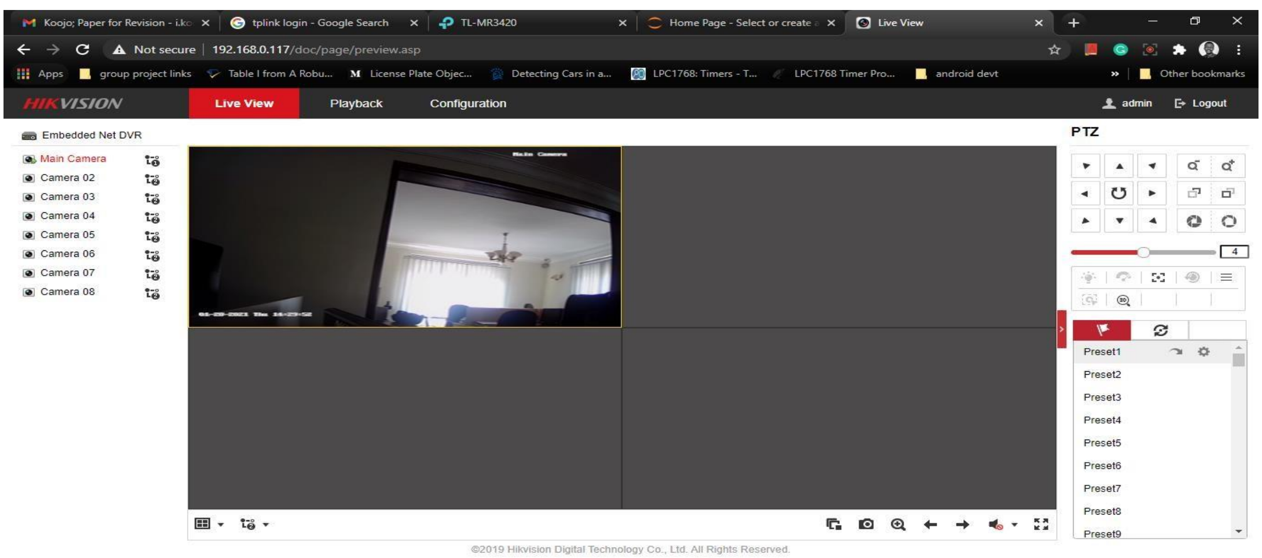


Figure 26: A Screenshot Showing the CCTV Surveillance System Management and Configuration Panel and Live Video Footage via a Web Browser.

4.3.3 Passenger Count and Social Distance Analysis

The video footage from the networked CCTV Surveillance system was processed using a video analysis machine leaning model. The model was built based on the (You Look Only Once version

3) YOLOv3 frame work with consideration of one class of objects, i.e., person. The implementation of the model was achieved using Python version 3.71. employing OpenCV, a powerful image processing library on the Jupyter notebook environment installed on Anaconda. A pretrained yolov3 weights file was used for purposes of saving time and minimizing computing resources required in the model training process. The model was then tested to detect people in photos, recorded videos and live video feeds from a laptop webcam. Each object classified with more than 60% probability of being a person was marked out using a bounding box by the model. The model was further set to count the number of people in the video frames and display the results in a section of the screen next to a python output window displayed on the screen. The model was also tested using live footage from one channel of the CCTV surveillance system, the outcomes of the test on one a frame of the live video is shown in the Fig. 25.

The model was tested on two separate computers with varying specifications and computing power. One of the computers was a core i5 processor with a processing speed of 2.6 GHZ, and a RAM of 6 GB. The results from the detection were observed to average approximately 4 frames per one minute. The other computer was a server computer with a processing speed of 2.8 GHZ and RAM of 16 GB and the results obtained showed an average of 10 frames detected per second. This implies, a computer with high computing power and RAM should be used to obtain faster processing and output form the model.

The obtained results also included a computation of the total number of people in a frame, the number of people that are safe, the number of people at low risk and those that are at high risk. From the tests, it was noticed that if a distance of at least 2 meters existed between two people, they were labeled and marked out using green bounding boxes and counted within the safe count. Such people were considered to be observing one of the main SOPs, i.e., the recommended social distance with respect to COVID-19, and thus they are safe at the instance that the frame is captured. A screenshot of people considered to be observing the recommended social distance (at least 2 meters) with respect to COVID-19 is shown in Fig. 27.

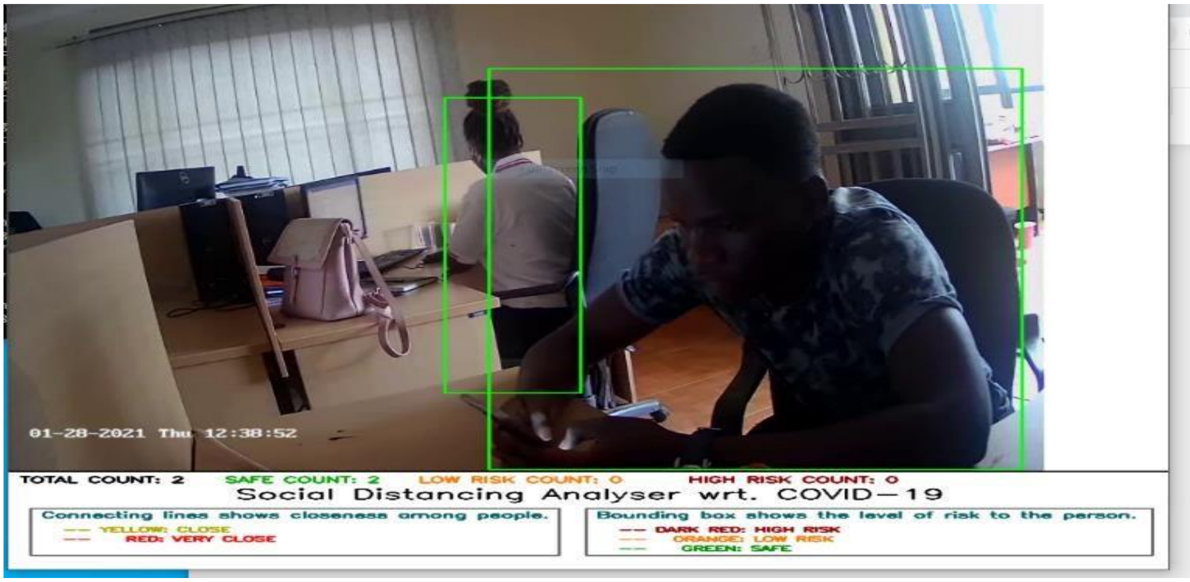


Figure 27: A Screenshot of the Analysis Results Showing People Within Safe Distance

It was also noticed that when people moved close to each other and the distance became less than 2 meters, the color of the bounding box changed from green to orange the people were counted in the low-risk count implying that the likelihood of those to contracting the COVID-19 virus form one another within that distance was intermediate at the time the frame was captured. The outcome showing people with orange bounding boxes and counted within the low-risk count is shown in Fig. 28.

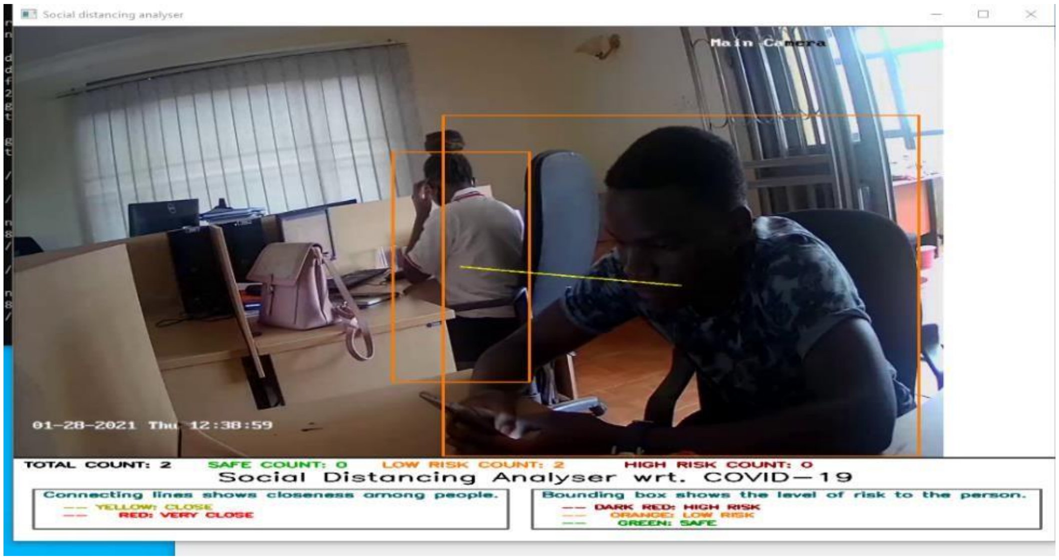


Figure 28: A Screenshot of the Analysis Results Showing People Within Low-Risk Distance

It was also noticed that when another person came between the people that were at a safe or low risk social distance, the bounding box around each of the people turned to red and they were categorized among the high-risk count because the people got too close to one another i.e., a distance of less than one meter between them placed them at a very high risk of contracting the virus in case any of them had it. Figure 29 shows a screen shot of people within a high-risk distance to each other.

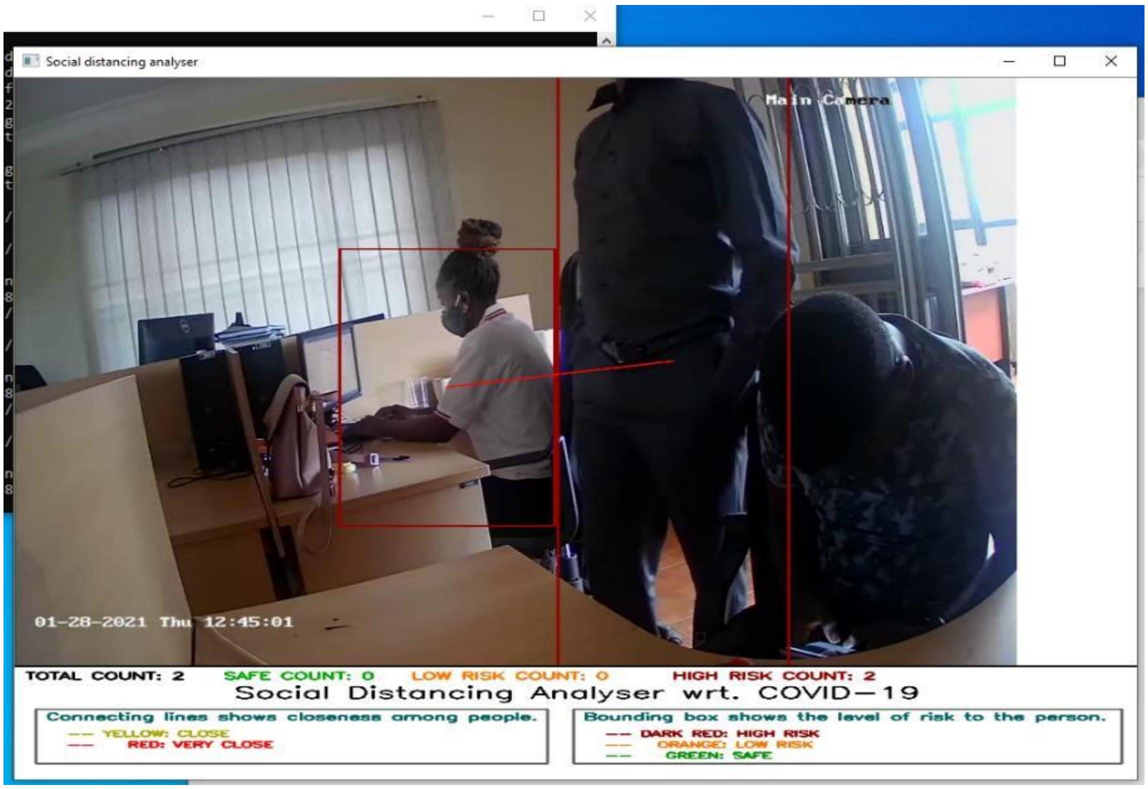


Figure 29: A Screen Shot of the Analysis Results Showing People Within High-Risk Distance

4.3.4 Web Portal

An integrated web system is under development to provide a simple and robust management and integration platform for the different components of the Passenger security system. Its development is done using the Vue JS platform in Visual Code Studio development environment. The web app is a big system with multiple features, but the concentration of this project was adding the security and safety aspects of the passengers to this system. These features include the CCTV surveillance module, passenger count module and contactless temperature measurement values for each bus as well as an aggregation of contact tracing data submitted by passengers. Work on the web application is still ongoing at the time of submission of this document and it's scheduled for completion in September 2021.

4.3.5 Digital Contact Tracing Platform

This platform was implemented in an application developed for android mobile smartphone device users. The implemented solution consists of a navigation platform to the digital contact tracing form and the digital form itself. The form captures necessary information of a mobile app user like the name, phone number, and symptoms of Covd-19 that a user might have; presented as multi-selection check boxes that a user can check and submit a response by clicking a button at the bottom of the screen. The navigation drawer and the digital contact tracing form implemented for the solution are shown in Fig. 30.

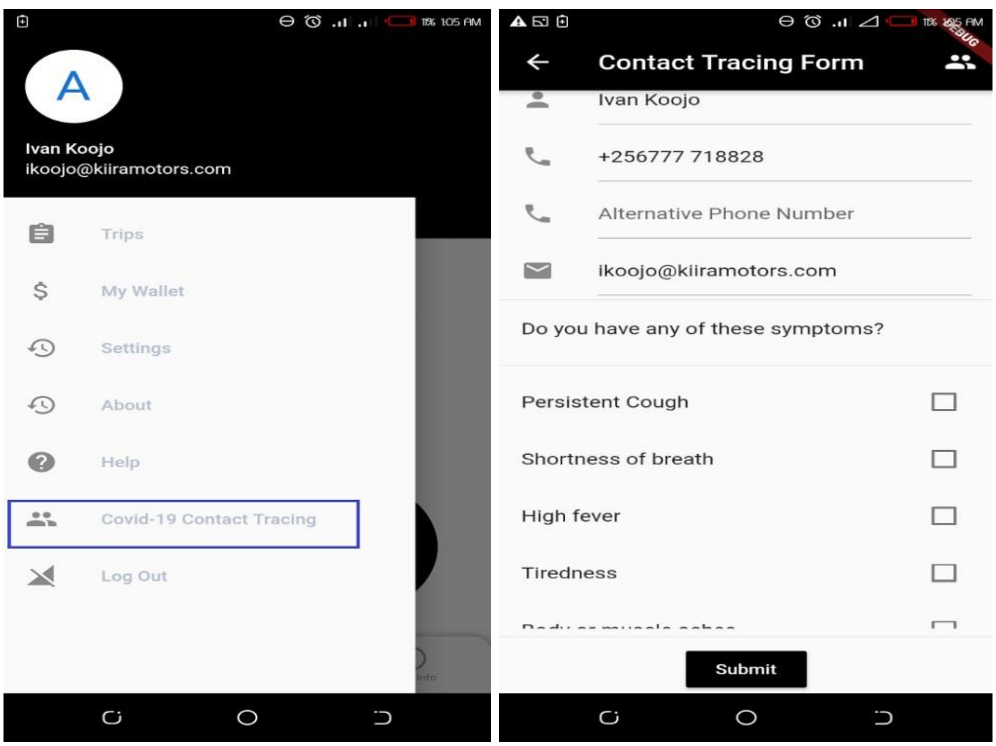


Figure 30: Screenshots Showing the Navigation Panel and Digital Contact Tracing Form Implemented in the Mobile Application

The response of each user is sent to a remote database over the internet. In instances where a user's phone lacks an active internet connection, the data is stored on a phone's local database and later on sent to the remote database when an internet connection is restored. The user responses submitted to the cloud Firestore database are stored in database collection as documents each with a unique identifier (Id). A sample of user data filled out in the implemented form and submitted to a database document is shown in Fig. 31.

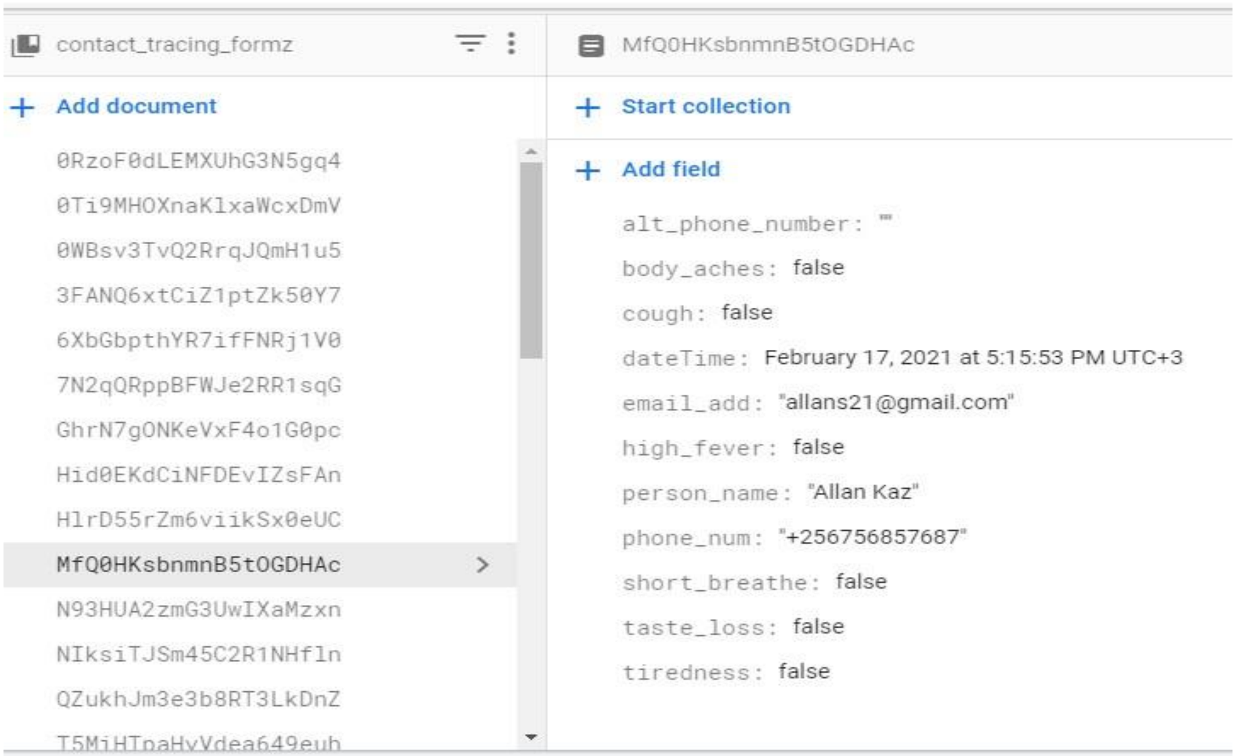


Figure 31: A Screenshot Showing Dummy Contact Tracing User Responses Submitted to the Database

4.3.6 Bus-Door Passenger Counting

This module, along with the CCTV surveillance system was also implemented within the organization's office premises with simulation of a bus door. The design for this component is incorporated in the CCTV surveillance system design presented in Fig. 22. The sub system was made up of an IR camera with a line marking and detection model implemented using the OpenCV library. The camera was connected to a 12-24 volts power source and connected to a DVR using standard UTP cables and a BNC communication interface for transfer of video data from the camera to the DVR of the CCTV surveillance component. The connection of the physical devices for this module is shown in Fig. 32. Both the DVR and the camera were connected to a network using an RJ45 network interface for purposes of remote viewing and control.

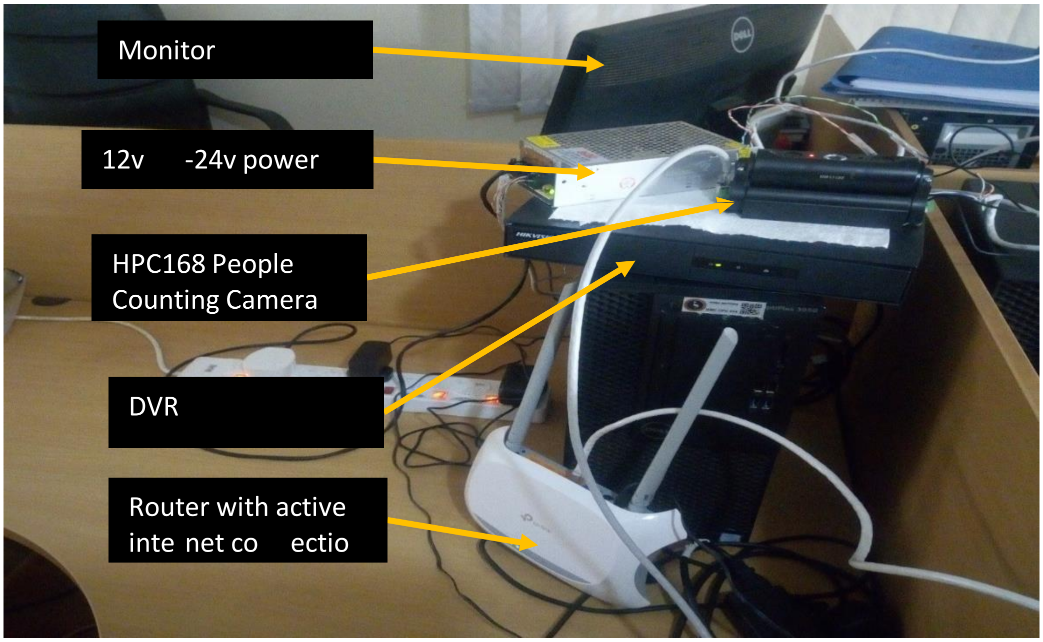


Figure 32: A Photo Showing the Connection of the Bus-Door Passenger Counting System

The people counting camera device was configured by setting network parameters illustrated in Fig. 33 and a region of interest (ROI) which is the main area of focus for the functionality of the device. The ROI is marked out using two horizontal lines as illustrated in Fig. 34.

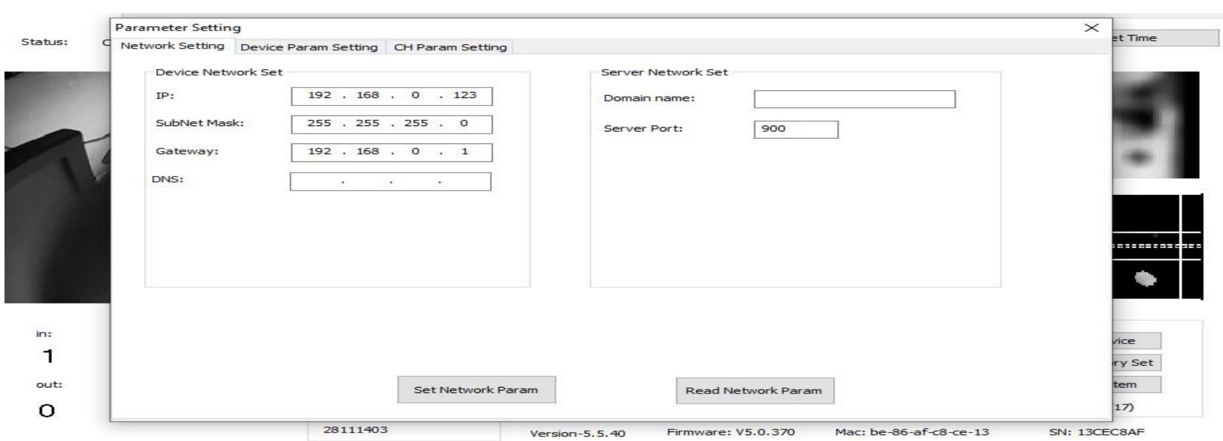


Figure 33: A Screenshot Showing Network Parameter Settings for the Bus-Door Passenger Counter

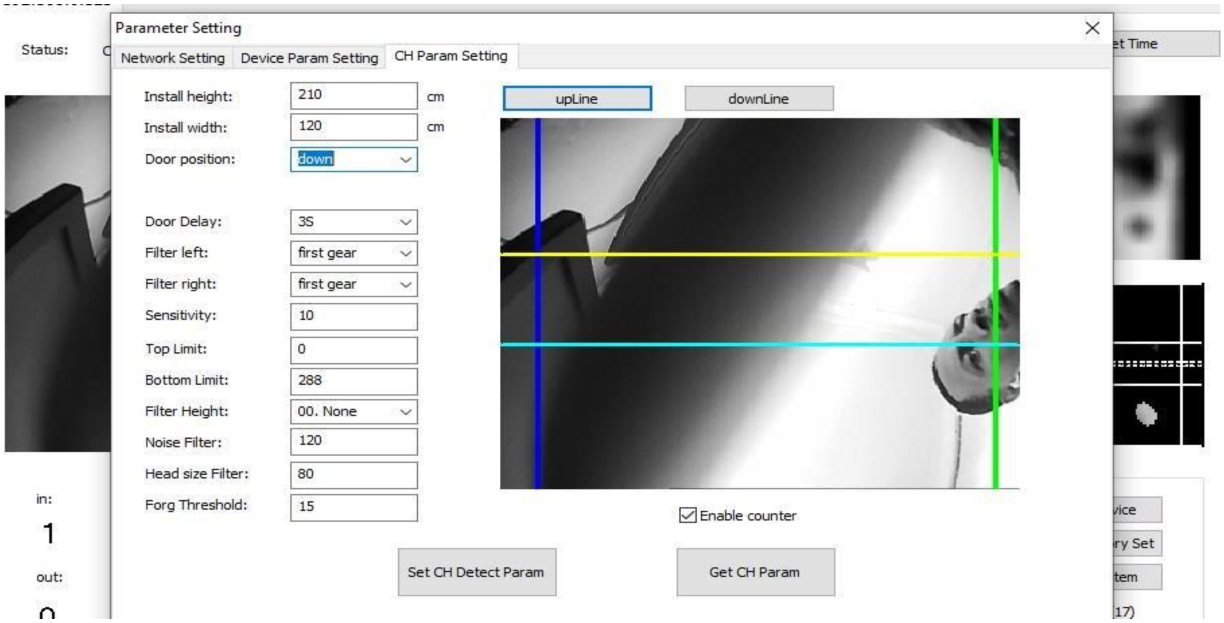


Figure 34: Screenshot Showing Count-Path Parameter Settings for the Bus-Door Passenger Counting Device

The lines are used to indicate the count criteria as “IN” and “OUT” from which the total count can be determined. For instance, if a person if a person crossed from the direction of the upper line towards the lower line and goes past the marked region, that person is considered to be entering the bus and counted as “In”. On the other hand, if a person crosses from the direction of the lower line across the region to the upper line and move across, that person is considered to have stepped off the bus and the count is added to the “Out” value as shown in Fig. 35. The total number of passengers on the bus is indicated by the “Total” variable at the bottom right of Fig. 36, it is obtained by deducting the number of people that have stepped off the bus from the number of people that stepped into the bus.

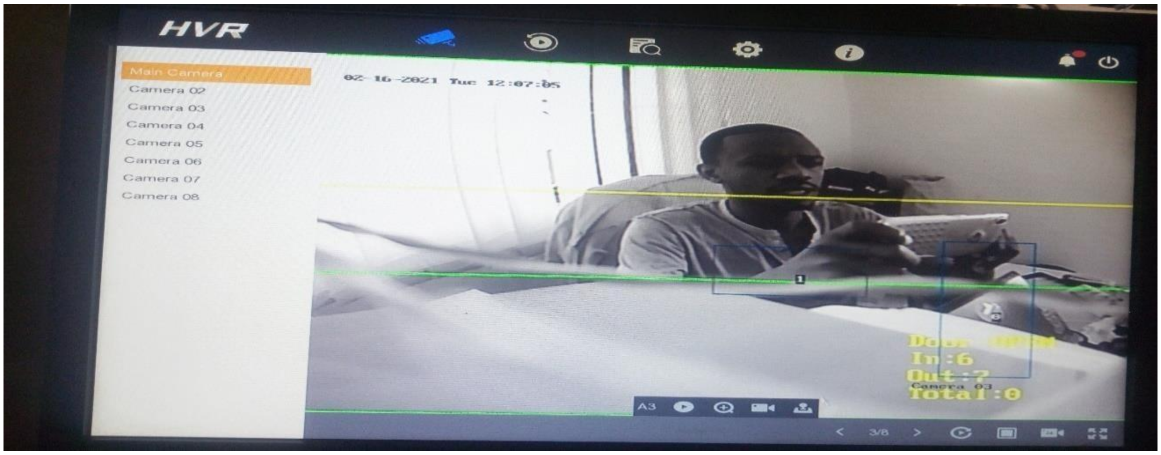


Figure 35: A Photo Showing the Output of the Bus Door Passenger Counting System on a Monitor

Records of passenger count data from the device over time are saved and can be exported in text or excel file format from the passenger count camera configuration and management application. Figure 36 shows the process of saving passenger count data in excel file format on a computer.

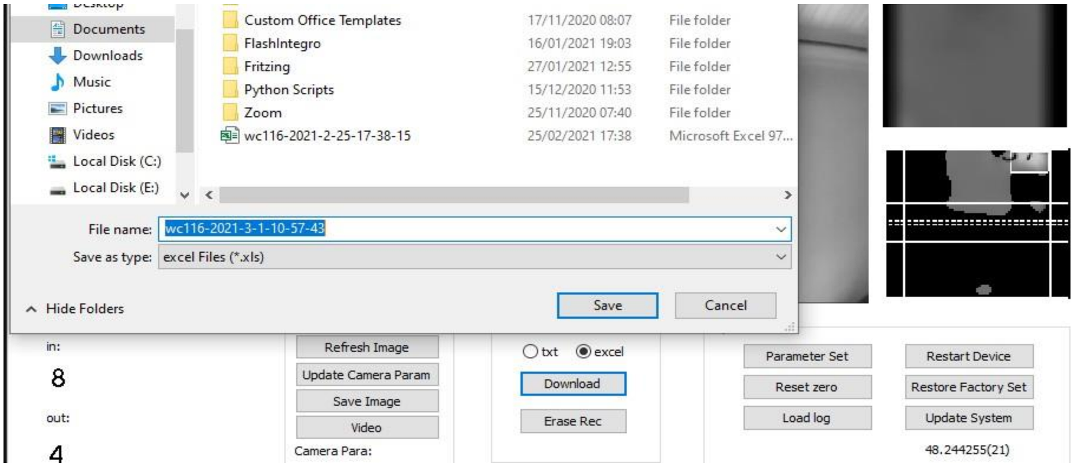


Figure 36: A Screenshot Showing the Process of Exporting Passenger Count Data Files

The saved files show an event index, timestamp, entry number, exit number, and a classification of the event type in columns. Figure 37 shows sample passenger flow data in an excel file (on the left) and a text file (on the right) respectively. Such records can be analyzed and visualized to draw necessary conclusions and guide decision making for bus staff in different positions and levels of management.

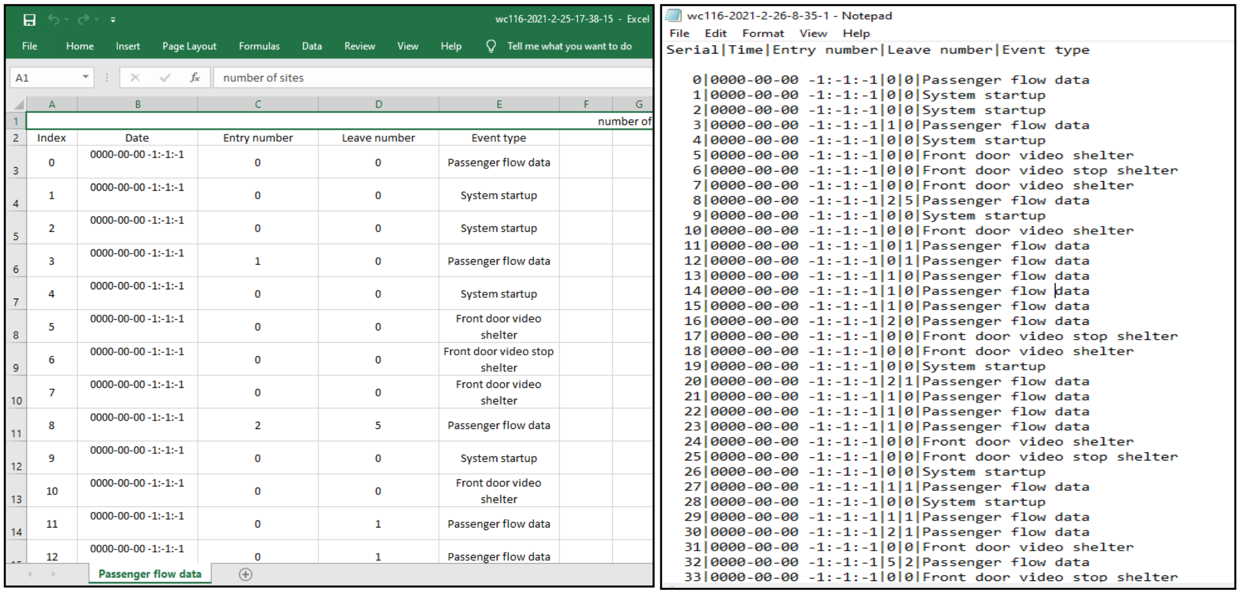


Figure 37: A Screenshot of Passenger Flow Data in an Exported Excel File (Left) And Text File (Right)

4.4 Validation

Validation is the confirmation by assessment and the delivery of unbiassed indication that the explicit requirements for a certain envisaged purpose are satisfied. This guarantees that the user needs are met and fulfilled. Validation is not only limited to testing and it is therefore inevitable that system requirements be clearly stated and the evidence for the anticipated purpose should be provided (Kamalrudin & Sidek, 2015). In the case of the passenger security system, several validation steps were considered and applied including; unit testing, integration testing, system testing, acceptance testing and regression testing.

4.4.1 Unit Testing

Unit testing is aimed at the verification of the functional demeanor of the minute units of the system (Dybå & Dingsøyr, 2008). For the proposed system, the units that were tested are; the form fields of the contact tracing screen of the mobile application, the remote database unit, the cameras, and DVR of the CCTV surveillance subsystem, the people detection unit, the people counting unit, the social distance measurement and determination functionality as well the risk classification component of the passenger count and social distance analysis machine learning model.

4.4.2 Integration Testing

This form of testing is aimed at proving that the minutest modules validated in the unit testing stage can work cohesively and to confirm that they are in harmony with requirements stipulated in the low-level design of the system (Nidhra, 2012). Several functional units were tested and integrated to establish that they can work together properly. For instance, the people detection and social distance analysis model was configured to attain video footages from the CCTV surveillance system remotely over separate internet connections to perform perfect analysis and avail accurate results. The design and development of the CCTV surveillance system component and the passenger count and social distance analysis model were done separately but with an end goal that the two system components can work cohesively to transmit CCTV surveillance video footage and analyze them to avail results like the number of persons detected and the social distance between them. Thus, integration tests were carried out by deploying the passenger count and social distance analysis model on computers and connecting the computers to the CCTV surveillance system over either a LAN and the internet to transmit video footage and analyze them.

4.4.3 System Testing

System testing is performed subsequent to the integration testing exercise to ascertain that the functioning of the developed system matches with the business requirements of the system's end users. It is the end result of all the tested and integrated functional elements that have effectively undergone the system integration process. It does not deal with structural features of the written source codes but rather deals with the functional features which are perceptible to the end users of the system (Nidhra, 2012). The system passed majority of the integration tests performed when running the program on a laptop in different network conditions i.e., when not connected to any network, when connected to a Local Area Network as well as when connected to the Internet. The information submitted through one component of the system can be successfully retrieved and used by another component. Table 4 illustrates a synopsis of the system testing outcomes.

Table 4: System Testing Outcomes

Subsystem	Requirement	Description	Test Score
Passenger counter	People detection	The system should detect objects such as a person	Pass
	People addition and subtraction	The system should add and deduct people when they enter or leave the bus and keep count of the number of people on the bus at all instances during a trip.	Pass
	Sending count notifications	The system should send notifications when the (desired) maximum number of people are in the bus.	Pass
	Remote passenger count data access	The system should send passenger count data to a remote system like a web application.	Pass
	Passenger count data storage	The system should store a log of the number of people for every trip	Pass
Multimedia surveillance	Capture video feeds	The system should capture and store video feeds from all cameras connected to the DVR on the bus.	Pass
	Special events alerts	The system should send alerts in case of special events as specified by the user	Pass
	Store additional media information	The system should store additional information like the date and time when a video or image is captured.	Pass
	Capture still images	The system should capture and store an image when a user selects the capture image option	Pass
Contactless temperature sensing	Read skin temperature	The system should read the temperature from the skin of a person within its reading distance range.	Pass
	Display temperature readings	The system should display the temperature values of the person whose temperature has been read.	Pass
	Record temperature and time values	The system should record each read temperature along with the time and date	Pass
	Alarm for abnormal temperatures	The system should set off an alarm when abnormal temperature is detected.	Pass

Subsystem	Requirement	Description	Test Score
Contactless temperature sensing	Remote access to temperature readings	The readings captured by the contactless temperature sensor module should be remotely accessible via a web platform.	Pass
Contact tracing	Capture passenger information	The system shall capture passenger information through a digital form implemented in a mobile application	Pass
	Store information in remote database	The system shall store the captured information in a remote database	Pass
	View information on web platform	The system shall enable users to view information of high-risk passengers on a web platform for contact purposes	Pass
People detection. counter and Social distancing analyzer	Detect people	The system shall detect people in recorded and live video frames and or still pictures	Pass
	Count and display people	The system shall count and display the number of detected people in the video feeds at every moment	Pass
	Label and classify	The system shall measure social distance with respect to COVID-19, label and classify the degree of risk to passengers as safe, low risk and high based on the distance between the passengers	Pass

4.4.4 User Acceptance Testing

Acceptance testing is performed with the consideration and input of the expected system users or customers. The main objective of acceptance testing is to identify whether the system is working appropriately and meets the key business requirements of its users. Privileged system users are allowed to interact with the functional units of the system to evaluate their precision and additional performance related factors such as ease of use, responsiveness and speed (Nidhra, 2012).

4.5 Discussions

The findings of this project show that there are number of key concerns from passengers that use or would opt to use buses as a public means of transportation. For quite a number of passengers, one of the key concerns is the aspect of passenger safety and security on the means of transport to choose. It is also evident that body contact and human labor dependent methods of temperature measurement are not only time consuming but also ignite the spread of infectious diseases and result in increased operational costs due to frequent wear and tear. It therefore necessitates the use of non-contact temperature measurement mechanisms that curtail human involvement and have the capacity to store the obtained readings for future use, reference and analysis purposes.

The results from the deployment of the CCTV surveillance system show that transmission of video footage over a network was achieved. The viewing of live footage in third party applications like VLC media was possible by passing a link for each channel, however, only one channel could be displayed at a time. Network transmission was obtained by passing the IP address of the DVR device on the local network; however, more complex procedure was required to transmit the footage over a WAN.

The results also indicate that people detection, counting and social distance analysis were successful and the results were effortlessly reflected with frequent updates when the model was deployed on a computer with high processing power, however, when a computer with lower processing power was used, the updates obtained were less frequent and often times the computer hang after processing a few frames. This is because the video analysis model requires robust computing resources for better efficiency. The observed results also showed that the model performed well in different light variations i.e., ranging from very brightly lit to very dimly lit environments, however, some times when people got too close to one another, one of them was not detected, this was because one person was covered by another.

The results from using the digital contact tracing form show that the data of a registered user was obtained from a remote database and displayed on the user's screen, at the same time the user was able to add their data by clicking a checkbox or remove that data by clicking the selected box. When the submit button at the bottom of the screen was clicked, the data in the form was sent to a remote database from which it can be queried.

The results of contactless temperature measurement indicated close or similar values obtained for the ambient temperature and the body temperature when there was no object/human body close to the sensor and the sensor's front part was only facing the air around it rather than an object like a table. The sensor captured and displayed readings every 10 milliseconds if a delay or condition to capture and display values was not specified, when a delay of 200 milliseconds was specified in the code, new temperature values were displayed every 200 milliseconds. The brightness of the LCD screen used to display the temperature values was also varied using a potentiometer which was used to regulate the voltage of the LCD device.

CHAPTER FIVE

CONCLUSION AND RECOMENDATIONS

5.1 Conclusion

The preceding chapter presented the results and discussion of this project work. It told a description of the analysis and the results attained during the different phases of the development of the system. The chapter also availed the analysis and results found from the research study area and the developed passenger security system for the Kayoola EVS bus which has elements for collecting data from the bus environment like temperature values, video footage and relaying it to other components for processing, storage and retrieval over both LAN and WAN. Clear video data can be obtained in various situations i.e., when the light intensity is high and when it is low. It can also be stored on a local hard disk drive fixed in the systems DVR. At the instance live video footages are captured by the cameras, they are stored on the local storage device and live feeds from the system can be accessed remotely over a network with the help of a web browser or any other desktop application that supports the rendering of the data transmitted for example VLC media player application for windows.

The transmitted video footage was successfully processed by a machine learning model and the object class of a person was detected and marked out with a label (i.e., a bounding box). In instances where more than one person was detected in a video frame, multiple bounding boxes were drawn, each around one person. The people were also counted and classified as safe, low risk and high-risk passengers based on the distance between them.

Furthermore, smart phone users running Android OS can also fill out the fields of the digital contact tracing form and submit their results by clicking the submit button at the bottom of the screen. The submitted results are sent to a remote database from which they can be easily retrieved when required for other purposes.

The contactless temperature measurement system was able to capture the varying ambient and target temperature values from the surrounding within a maximum distance range of 5 centimeters from the front end of the sensor. The values were displayed and viewed on the Arduino IDE Serial monitor output as well as on the LCD screen display. In instances of abnormal temperatures an alarm was set off for a set time to alert the users about the abnormality.

Compared to other previously developed works, the passenger security for the Kayoola EVS bus adds value to the already existing generic surveillance methods by further analysing surveillance footages for observance of social distancing and counting of onboard passengers. This aids bus operators to not only gain better security on the buses but to also obtain data that can be used for future planning, scheduling and decision making. The proposed solution further avails a mechanism to automatically collect and store temperature values of passengers in a digital format for purposes of analysis and future reference unlike the method of using temperature guns and recording values using paper and pen currently employed by bus transporters

The proposed the future works to improve this system include: (a) completing the implementation of a web system to aggregate the different sub components of the passenger security system into a single robust system with capabilities to manage and view video footage from multiple independent CCTV surveillance systems installed in different locations. (b) hosting the passenger detection, counting and social distance analysis model on the web system to perform analysis on footages from multiple cameras. (c) adding motion and distance sensing technology to the contactless temperature measurement system to only measure temperature when a person is within the certain range and save energy resources, using a sensor with a longer distance range for faster results and adding internet connectivity to the system to transmit and store the obtained values to the internet for analysis and visualization purposes.

In conclusion, it is important to note that the cost of developing and setting up such a system is fairly high, however, its benefits are enviable in the long run. It is therefore advisable that the system is used for atleast ten years before it can be replaced inorder to have optimal benefits. Some of the main benefits include saving time through automating activities like counting passengers on buses, reading temperatures and storing the data for reference, analysis and report generation to aid decision making, bus scheduling and planning, safe travels for bus staff and passengers, plus availability of evidence incase of vandalism, or property loss among others.

5.2 Recommendations

Public transport operators and bus makers in Sub-Saharan African cities and beyond need to consider the aspect of passenger security as a major concern mainly in the urban places where masses of people use public means of transport for transit. This is essential in assuring travelers that they and their property are safe even on public means of transit in cities.

Organizations dealing in public human transport should consider the adaptation of ICTs like the Passenger Security System to improve the quality of their services to customers, eliminate time consuming manual works and recordings, obtain detailed and summarized statistics of some of their operations involving the numbers of passengers.

Transport operators should invest in the training of their staff to use computerized systems on mass transit means like buses to simplify time demanding and labor-intensive tasks like passenger counting and manual recording of contact tracing information and thus obtain better levels of accuracy and speed in passenger counting, and vital data and information that can be analyzed and visualized to inform accountability, planning, and route scheduling among others.

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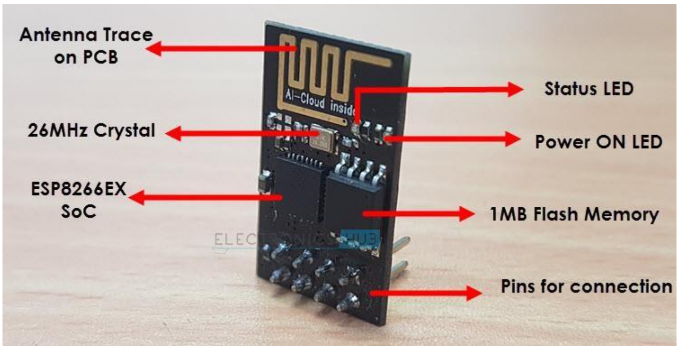
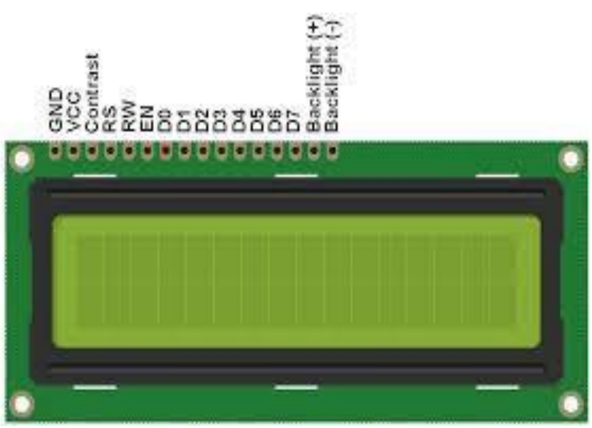
APPENDICIES

Appendix 1: A Diagram of an ESP8266 Wi-Fi Module

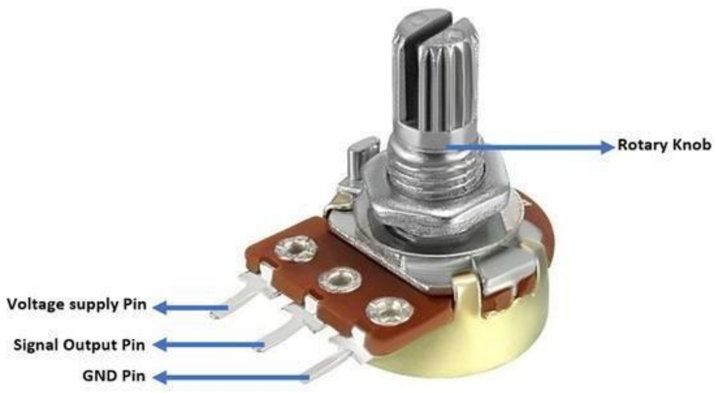


Appendix 2: A Photo of the Arduino UNO Board

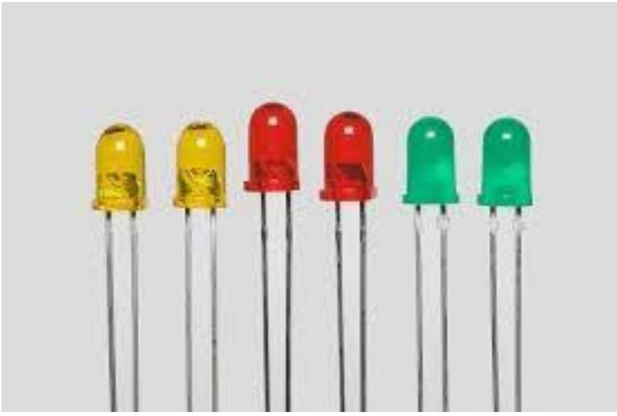
Appendix 3: A Photo Showing the 16X2 LCD Screen with its Pins Labeled



Appendix 4: A Photo of a Potentiometer (10k Resistor) with its Main Parts Labeled

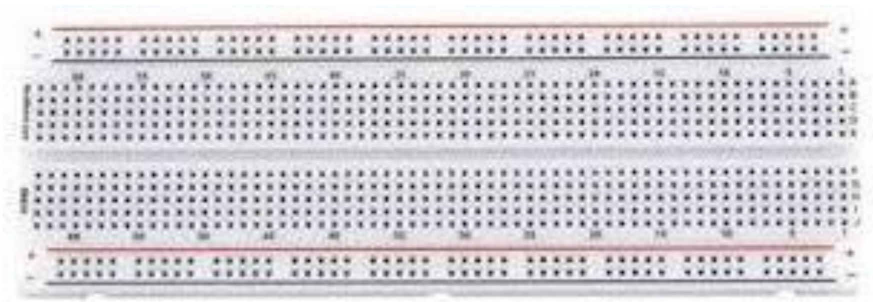


Appendix 5: A Photo Showing Arduino UNO Board Compatible LEDs in Different Colors



Appendix 6: A Photo of Sample Jumper Cables used in Connecting Components and Controllers of Embedded Systems

Appendix 7: A Photo of a Solderless Bread Board Used to Extend Micro Controller Unit Board Pins



Appendix 8: Variations of the RG59 BNC Male and Connectors Used to Connect Cameras and the DVR Device

Appendix 9: Survey Questionnaire for the Passenger Security System

SURVEY FOR THE KAYOOLA EVS PASSENGER SECURITY SYSTEM

Requirements elicitation in the context of organizational information systems is a very hard task, being very dependent on the experience of the team performing the elicitation. In such a context the use of interviews is common and seen as the major technique for obtaining the requirements from the Stakeholders of the system being developed. With this form, we shall be able to conduct a general interview and our results will represent the view points of the different stakeholders of the Passenger Security System for the Kayoola EVS Buses.

* Required

Email address *

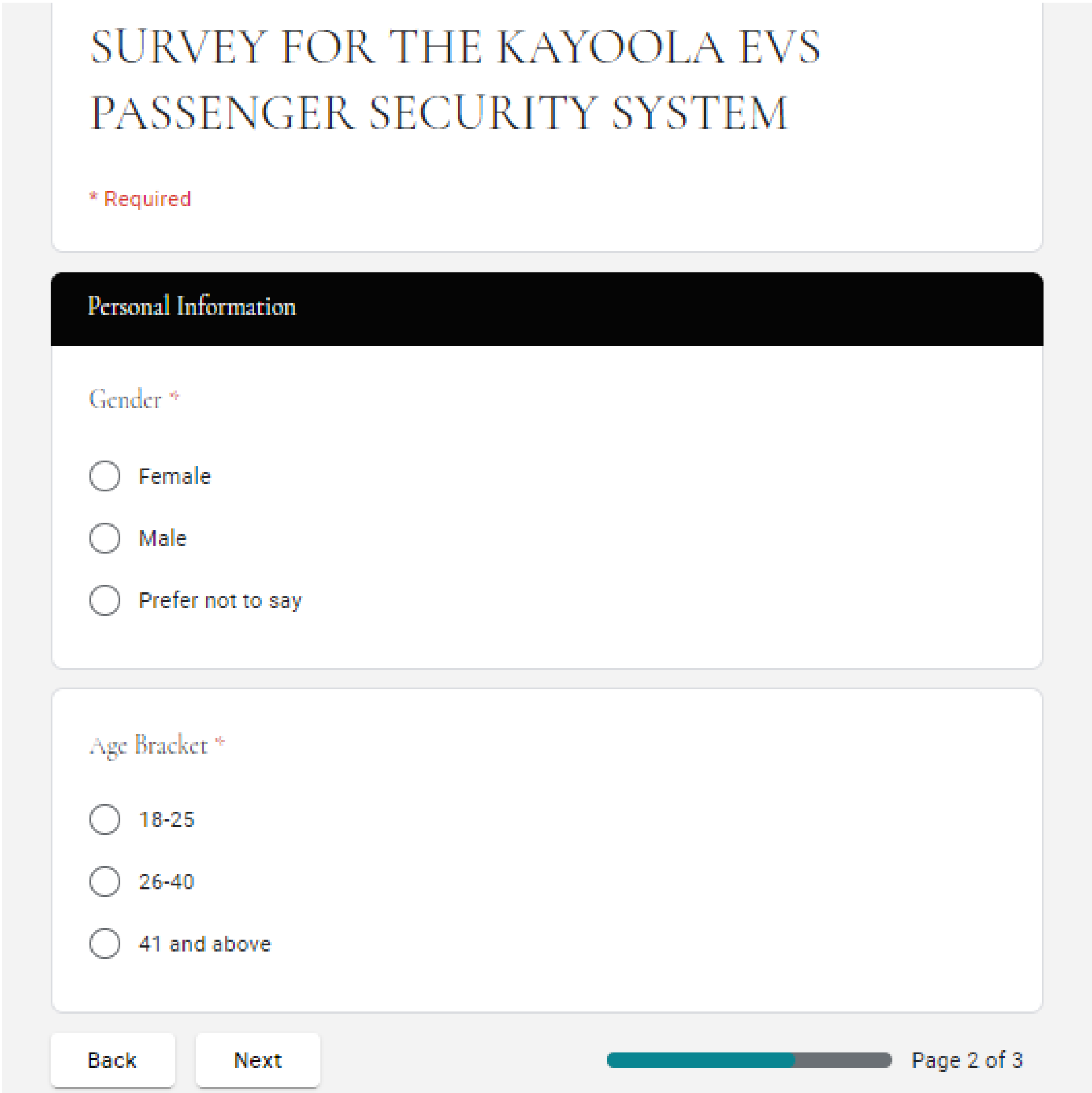
Your email

Date of Entry

Enter the date when this form was filled

Date

dd/mm/yyyy



SURVEY FOR THE KAYOOLA EVS PASSENGER SECURITY SYSTEM

* Required

Personal Information

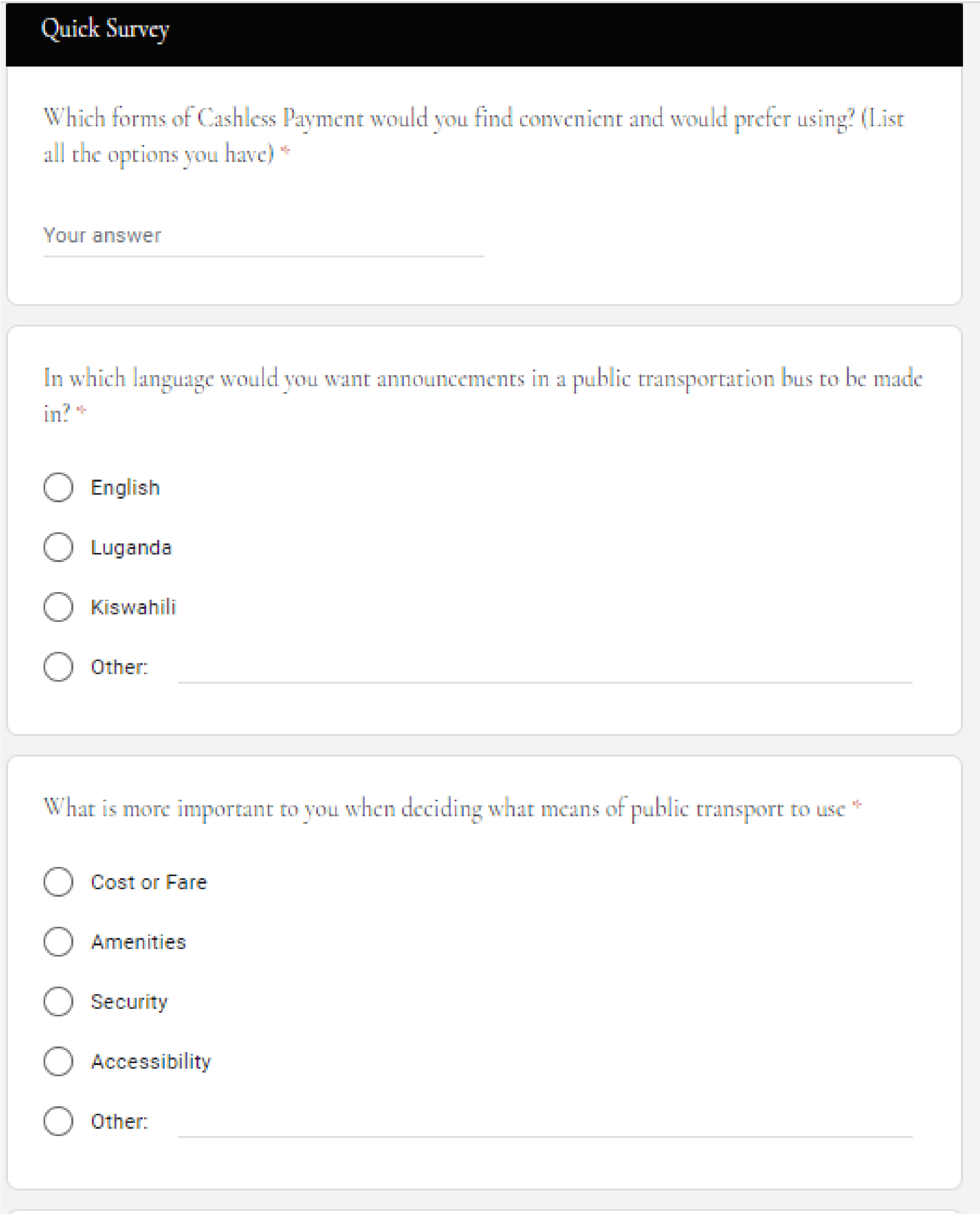
Gender *

- Female
- Male
- Prefer not to say

Age Bracket *

- 18-25
- 26-40
- 41 and above

Back Next Page 2 of 3


Quick Survey

Which forms of Cashless Payment would you find convenient and would prefer using? (List all the options you have) *

Your answer

In which language would you want announcements in a public transportation bus to be made in? *

- English
- Luganda
- Kiswahili
- Other:

What is more important to you when deciding what means of public transport to use *

- Cost or Fare
- Amenities
- Security
- Accessibility
- Other:

Are you comfortable using Public Wi-Fi? *

- Yes
- No

Do you have any objections to video monitoring of passengers during public transportation? *

- Yes
- No

Do you support the use of Artificial Intelligence like facial recognition technology in public transportation? *

- Strongly Support
- Somewhat Support
- Neutral
- Somewhat Oppose
- Strongly Oppose

What mobile operating system do you have on your primary smartphone? *

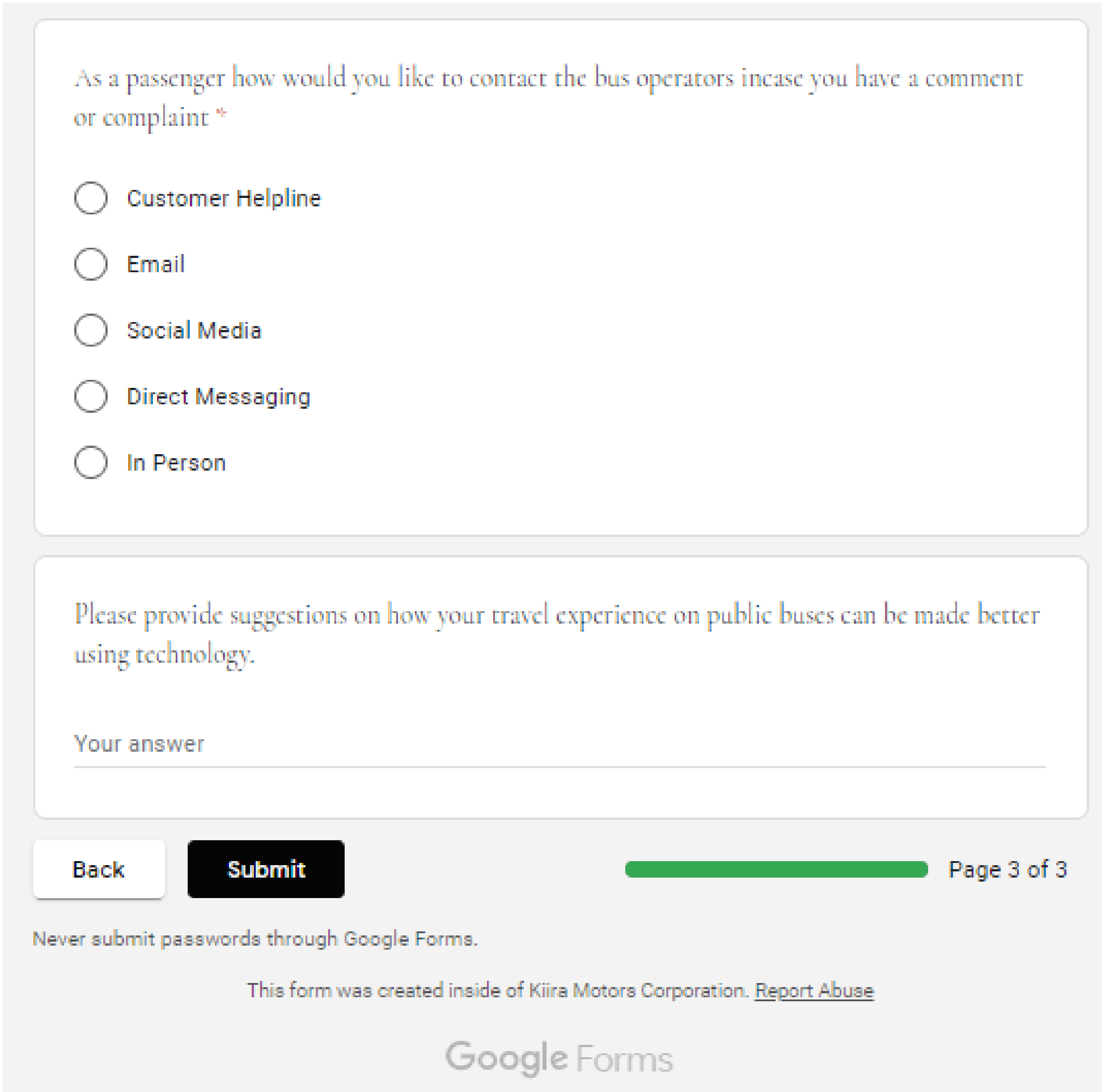
- ◯ Android
- ◯ iOS
- ◯ Other: ____________

What information would you like to be notified about on a public transportation Mobile Application? *

- ☐ Upcoming Events (Eg. Promotions)
- ☐ Trip Updates (Departure and Arrival Times)
- ☐ Transaction Alerts
- ☐ Passenger On-board Temperature
- ☐ Other: ____________

As a passenger how would you like to contact the bus operators incase you have a comment or complaint *

- ◯ Customer Helpline
- ◯ Email
- ◯ Social Media
- ◯ Direct Messaging
- ◯ In Person



As a passenger how would you like to contact the bus operators incase you have a comment or complaint *

- Customer Helpline
- Email
- Social Media
- Direct Messaging
- In Person

Please provide suggestions on how your travel experience on public buses can be made better using technology.

Your answer

Back | Submit | Page 3 of 3

Never submit passwords through Google Forms.

This form was created inside of Kiira Motors Corporation. Report Abuse

Google Forms

Appendix 10: Multimedia Surveillance System Survey Checklist for the Kayoola EVS Buses

CCTV Technology Handbook

KPES – Multimedia Surveillance System Site Survey Checklist

Operational Environment	
Indoor	✓
Outdoor	
Exposure to:	
Water	✓
Corrosives	
Explosives	
Fire	
Extreme Temperatures	
Location of Cameras	
Access Points: Doors/Gates	✓
Building Exterior	
High-Security Interior Areas	
High-Security Exterior Zones	
Hallways/Corridors	✓
Parking Lot	
Perimeter	
Other	✓

Light Levels			
Day	✓	Night	✓

Lens	
Wide Angle	✓
Normal	✓
Telephoto	
Zoom	
Camera Power	
12 Volts Direct Current (DC)	✓
24 Volts DC Power S	
120 Volts Alternating Current (AC)	

Cameras			
Indoor			
Fixed	✓	Pan-Tilt-Zoom	
Outdoor			
Fixed		Pan-Tilt-Zoom	
*Total Number of Cameras			5

Housings	
Dome	✓
Weather-Resistant	
Tamper-Resistant	✓
Other (e.g., Specialized Housings)	

Mounts			
Wall	✓	Ceiling	✓
Pole		Corner	
Fences		Building Exterior	

Display/Monitors	
Size	
Split-Screen Displays	✓
Multi-Screen Displays	✓
Video Walls	
Recorders	
Digital Video Recorders (DVRs)	✓
Network Video Recorders (NVRs)	
Hybrid DVRs	

Transmission			
Wired			
Coaxial	✓	Twisted Pair	✓
Fiber Optics		Telephone	
Category 5			

Wireless	
Laser	
Infrared	
Radio Frequency	
Microwave	
IP-Based	
Internet Protocol (IP)-Based	✓
Network Storage	
Direct Attached Storage (DAS)	✓
Storage Area Network (SAN)	
Network Attached Storage (NAS)	
Other	

RESEARCH OUTPUTS

(i) **Output 1:** Koojo., Machuve, D., Mirau, S., & Miyingo, S., P. (2021). Design of a Passenger Security and Safety System for the Kayoola EVs Bus, *IEE AFRICON 2021 Conference*, 15.

(ii) **Output 2:** Poster Presentation

Design of a Passenger Security and Safety System for the Kayoola EVs Bus

Ivan Koojo
College of Computing and Information Sciences
Nelson Mandela African Institution of Science and Technology
Arusha, Tanzania
ikoojo@nm-aist.ac.tz

Dina Machuve
College of Computing and Information Sciences
Nelson Mandela African Institution of Science and Technology
Arusha, Tanzania
dina.machuve@nm-aist.ac.tz

Silas Mirau
College of Computing and Information Sciences
Nelson Mandela African Institution of Science and Technology
Arusha, Tanzania
silas.mirau@nm-aist.ac.tz

Simon Peter Miyingo
Department of Product Development
Kiira Motors Corporation
Kampala, Uganda
simon.miyingo@kiiramotors.com

***Abstract*—Kiira Motors Corporation seeks to avail customer satisfaction, by providing noteworthy passenger experience on its market entry product, the Kayoola EVs bus through deploying a passenger security and safety system to curtail rampant snags like passenger insecurity, loss of passenger property, shortcomings in management and accountability as well as the spread of contagious sicknesses like COVID-19 which are not alien occurrences on commuter taxis and buses in African cities. On this project, a comprehensive system was designed for remote CCTV video surveillance, video analysis for people detection, passenger count and social distance analysis, as well as digital contact tracing to solve the challenges. It denotes significant potential to improve the security of property and passengers, shrink the risk of the spread of contagious diseases, enable timely capture of contact tracing records and lessen the burden of management, monitoring and accountability for the numbers of passengers on buses for fleet owners.**

Keywords— Kayoola EVs bus, passenger, security, safety

I. Introduction

Kiira Motors Corporation (KMC) is a state-owned enterprise established to champion the development of the Ugandan automotive value chain for job and wealth creation. KMC developed Africa's first electric vehicle in 2011, Africa's first hybrid vehicle in 2014, and Africa's first solar electric bus in 2016 [1]. The company's market entry product is the Kayoola EVS, a fully electric, low-floor city bus with a range of 300 kilometers on a full charge and a capacity of 90 passengers [2]. KMC aims to avail a remarkable passenger experience on the Kayoola EVs bus through deploying the Kayoola EVs Passenger Experience System (KPES). A major part of this experience includes passenger security, convenience, safety as well undemanding management on the side of bus owners and operators.

Public road transport using high passenger capacity electric buses avails numerous benefits like reduced travel expenditure, health benefits, less effort and better predictability compared to other forms of like fourteen-seater taxis, private cars and motorbikes [3]. On the contrary, the existence of diverse barriers limiting the use of public transport ranging from safety, travel times and perceived comfort cannot be denied [4].

It is also factual to say that compared to riders that travel by private car, cycling and walking, riders who travel by bus and train experience the most unpleasant emotions [5]. It is therefore essential to improve the well-being of passengers [6]. Low-cost means of improving the quality of public transport might involve comfort and convenience improvements [7].

This work is funded by the Center of Excellence for ICT in East Africa (CENIT@EA).

The use of technology has immense potential to deliver the desired changes needed to increase efficiency in bus transportation and improve the experience of passengers [8]. Some of those measures include strategies to enhance convenience, increase information provision and communication, improve control and facilitate journey planning [4].

Several independent solutions have been crafted to address different aspects of passenger security and safety. However, they are largely and independently implemented in public places like offices, malls, supermarkets and even private homes but not mass transit vehicles for most cities in Sub-Saharan Africa. This paper therefore presents a project design of an integrated robust system that leverages existing technologies and aggregates them into a unit that surveils, counts, and analyses social distance of passengers onboard mass transit buses. captures and stores passenger temperatures and basic COVID-19 symptoms related data in a timely manner. The designed system aims to avail means to ensure security and safety of passengers and their property, and avail bus passenger data that can aid stakeholders to manage bus operations in African cities.

This paper is organized as follows: In Section 2, we present an introduction to related contributions in passenger security and safety. This is followed by the methods and approaches employed in the design of the proposed solution in Section 3. The system design outcomes and evaluation results are discussed in Section 4. Subsequently, the project discussion and conclusion are presented in Section 5.

II. LITERATURE REVIEW

Across several developing countries of Sub-Saharan Africa, transport authorities grapple to meet the mobility needs of precipitously swelling populations, and Uganda is no alien to such predicaments [9]. It is reported that passenger security in the vast majority of commuter taxis and city buses is poor, particularly for women and assaults on drivers and vandalism are common occurrences [10]. Innumerable passengers continue to express great frustration with the miserable comfort, safety, and the muddled services on these vehicles [11].

Intelligent transport systems and mobile technologies bear budding capacity to offer safer, secure, smarter and greener transport and improve transport services. [12]. As people and businesses continue to adopt technological solutions, it is important to explore how they can be applied to solve problems like security, capacity and quality in the transport sector. There's therefore need for information especially in transport telematics in order to provide a satisfactory level of efficiency, safety and security on the transportation avenues as demand surges [13].

World over, a number of ways are employed to count passengers and obtain data used to estimate ridership and aid planning and forecasting. Stretching from manual means like paper and pencil, to automated technologies like handheld units, automatic passenger counters, and smart cards. [14]. In addition, authors like [15] , [16] and [17] have employed video surveillance systems that monitor live/playback videos from surveillance cameras and allow some operations on the video data like exporting video, snapshot generation and even analyzing them for user behaviors for purposes of ensuring security. However, to enhance the security and safety of the passengers we propose an additional feature to the existing generic surveillance applications. This additional feature is measuring the distance between passengers aboard the bus while also counting the passengers and displaying the output on the user interface. Counting the passengers is accomplished in two ways, when they're entering and leaving the bus and while seated on the bus. This feature will enable us to meet passenger security and safety needs while availing passenger data for stakeholders using a single system.

During the perilous periods of infectious disease outbreaks, body temperature measurement avails an invaluable arena to identify cases using means like forehead thermometers, ear thermometers, among others., that are used to obtain body temperature values [18]. Furthermore, collecting contact tracing data is one of the crucial surveillance approaches to curtail the spread of infectious diseases like COVID-19. This is recommended when people access closed environments like hospital waiting rooms and shared transport vehicles [19]. Data from these exercises are largely recorded using pen and paper for travelers that use buses and other commuter taxi operators do not trace contacts at all, making the efforts applied elsewhere of no effect. It is common knowledge that records on paper are hard to backup, easy to lose/destroy and take more time to write [20]. We therefore propose a digital system to capture passenger temperature and data and store it for analysis while limiting the time spent on the process.

III. METHODOLOGY

The research was conducted within a nascent automotive company in Uganda with emphasis on public transportation using buses in Kampala city because of the city's population and the company's aim to market the buses in the city as an entry market. Kampala is the capital city of Uganda, a country located in the Eastern part of Africa. The city has a daytime population of approximately 4.5 million people with over 80% of these using public transport as the main mode to travel [21]. This work only considers the safety and security of passengers while on the bus but does not include such concerns after or before boarding the buses.

A. *System Development Approach*

The development of the system follows a blend of prototyping and agile methodology using an iterative and incremental approach focusing on process adaptability and customer satisfaction in a timely manner. This combination enables incremental and progressive system development and facilitates user involvement throughout the system development process leading to high levels of user requirement satisfaction. Fig. 1 shows the standard software development life cycle upon which the agile methodology is based. The merger of two approaches was chosen because it combines the advantages of the two and each one covers the weaknesses of the other. Other methods like waterfall and spiral were not used because they allow low work distribution, low client and team interaction, on the other hand, the selected methods enable high flexibility, client interaction, team interaction, work distribution, error, and risk containment and minimize overall project costs. Table I. shows the comparison of agile and prototyping methods versus waterfall and spiral methodologies in terms of flexibility, cost and delivery prediction, client interaction, team interaction, work distribution and phase containment error.

Data and system requirements for this project were collected through document review, observation, survey questionnaire, desktop research and benchmarking of industry-standard approaches to identify development methodologies and technologies and video recordings with people accessible at [22], [1] and [23]. A survey questionnaire was prepared and shared via google forms in electronic format with responses captured in a work sheet where quantitative aspects were analyzed.

B. *System Architecture Description*

The integrated passenger security and safety system architecture is illustrated in Fig. 2. On board each bus, the passenger security and safety system consist of CCTV cameras, passenger count cameras connected to a Digital Video Recorder (DVR) device for configuration and control purposes. A display monitor is connected to the DVR to view video footage from cameras. The DVR and each passenger count camera are connected to a router forming a Local Area Network (LAN) on each vehicle. A contactless temperature sensor interfaces with the internet via the router. A mobile platform and web platform are connected to a remote database accessible over the internet.

A context diagram, also known as a Data Flow Diagram (DFD) level 0 is used to illustrate the relationship between the system and its surrounding (i.e., the system users and other associated systems). It portrays the dealings of the existing entities with other system processes. A context diagram denotes the top-level view of the system consisting of a single process i.e., process 0 which is a generalization of the overall functionality of the entire system with respect to its external entities. This is illustrated in Fig. 3.

A system Use Case diagram illustrates user interactions with the system. It shows the actions and or processes that users can accomplish within the system boundary. The actions in the system use case diagram are referred to as Use Cases. External entities are called actors. The actors of the proposed system solution as shown in Fig. 4 are the Admin, Passenger and Bus Operator. The main use cases include; login, register for a new account, detect people, count passengers, display counted passengers, view temperature values, capture video, view video footage, view and manage system data and analysis results, change system configurations and notifications.

The passenger is the subject of focus for this system. He registers on the system using a mobile application, logs in and is verified through one time authentication implying he keeps logged in until he decides to log out. Once logged in, they're able to fill in a COVID-19 contact tracing form, submit it, and receive a notification once data is successfully sent to the database. A passenger is also able to view their temperature values on an LCD interface at the bus entrance before boarding. When the temperature is not normal, they receive a notification.

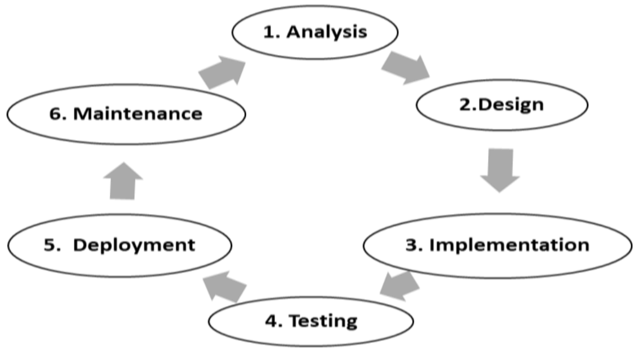


Fig. 2. An illustration of the agile system development life cycle

TABLE I. COMPARISON OF SOFTWARE DEVELOPMENT METHODOLOGIES [24].

Model	Flexibility	Cost and Delivery Prediction	Client Interaction	Team Interaction	Work Distribution	Phase Containment of Error
Agile	High	Medium	Very high	Very High	High	Medium
Waterfall	No	Medium	One time	Low	Low	Low
Spiral	High	Low	Low	Low	Low	High
Prototyping	Medium	Medium	High	High	low	High

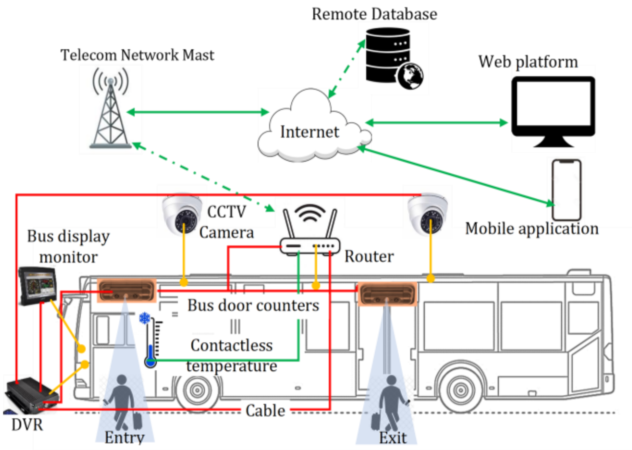


Fig. 3. The architectural design of the proposed system.

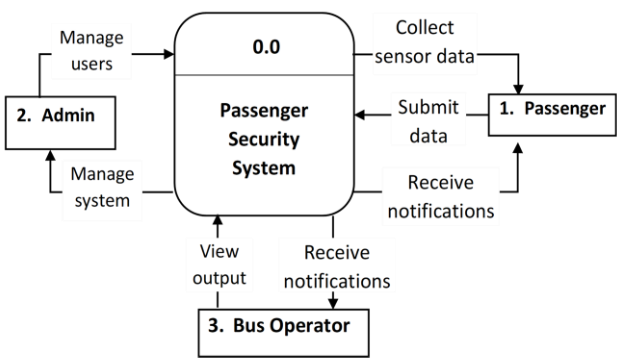


Fig. 4. System context diagram

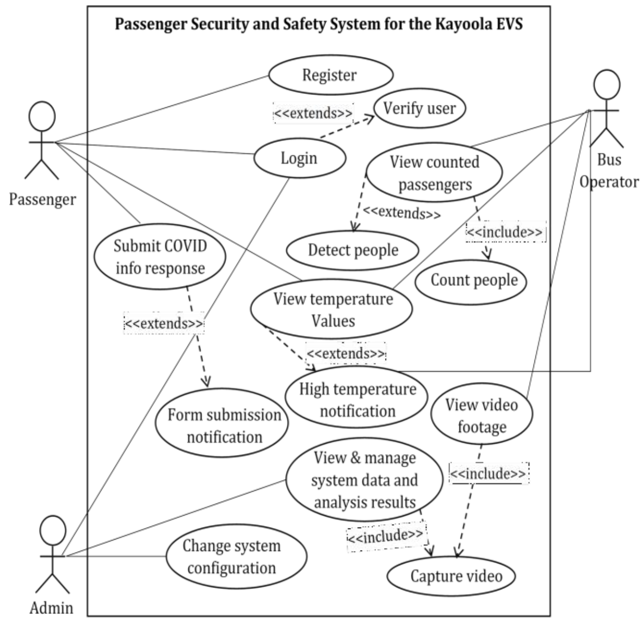


Fig. 1. Use case diagram for the proposed system

The bus operator is a key bus staff lie a driver or bus conductor and is a primary user of the system. He uses a monitor to view video footage captured by the bus cameras. He also views passenger temperature values and receives an alarm notification incase the passenger temperature is not normal. They then take appropriate corrective action by measuring the passenger temperature again or dismissing the passenger and recommending further tests to ascertain that the passenger is not infected with COVID-19.

The admin is a privileged user of the system. He is responsible for configuring the system and ensuring that it's in good shape. He also views and manages system data and the results from analyzing it.

C. *Survey Data and Analysis Results*

1) Survey demographics

A survey aimed at finding out the perception of respondents concerning the relevance of passenger security and safety systems on buses used in public transportation services was conducted. The questionnaire had a total of 22 respondents randomly selected to represent four groups of system stakeholders as shown in Table II. Majority of the respondents, 77.3% often use public mass transit means as shown in Fig. 5 while 99.3% have a basic understanding of technologies like AI and its applications as shown in Fig. 6.

2) The key considerations and concerns of respondents when using public transportation means

A number of key factors were listed as options to point out what the respondents considered as the most important factors when choosing a means of transportation to use. Fig. 7 shows that 46.7% of the respondents considered a trip's cost or fare as the most important factor, 26.7% of the respondents considered accessibility, 20% considered security whereas 6.6% considered reliability as a key determinant of their choice. The fact that a fair portion of the respondents has security as a concern when making their choice to travel implies it is a relevant factor worthy of consideration by transport operators and carmakers.

3) Substantiation of the backing to employ people recognition artificial intelligence in public transportation

The other goal was to substantiate opinions on the use of artificially intelligent technologies to analyse photos and videos of passengers that use public transportation for security purposes. A five-point Likert scale was used to obtain the responses. The results obtained showed that 26.7% of the respondents strongly supported the use of such technologies, 46.7% somewhat supported their use, 13.3% were neutral to the idea implying that they neither supported nor opposed its use, 13.3% percent strongly opposed the use of facial recognition technology while no respondent somewhat supported its use. This is presented in Fig. 8. Since the biggest percentage of respondents is not opposed to the use of artificial intelligence technologies, it can be concluded that such technologies can be employed in public transport to serve various purposes and benefit passengers, bus owners and other authorities in the transport sector.

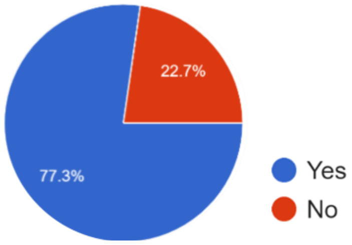


Fig. 5. A pie chart showing responsents that travel by public means

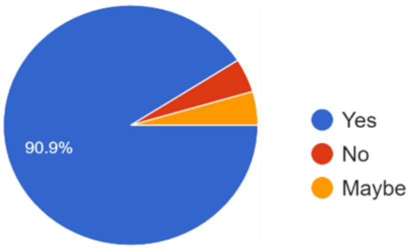


Fig. 6. Respondents' perception of Artificial Intelligence technology

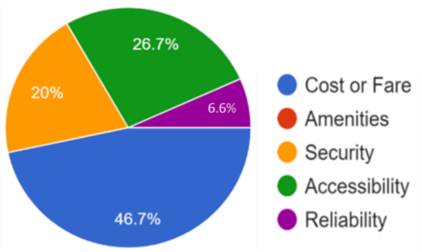


Fig. 6. A pie chart showing analysis results of the most significant factors that determine the choice of respondents when traveling using public means.

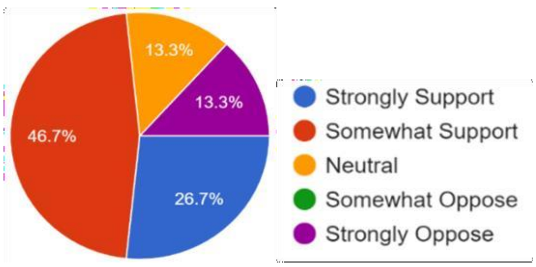


Fig. 5. A chart showing the opinion of respondents towards the use of technologies like artificial intelligence.

TABLE II. TABLE SHOWING SURVEY DEMOGRAPHICS OF RESPOSPONDENTS

Correspondents	Number
Bus staff	3
Bus passengers	9
Company managers	2
Other company staff	8

IV. OUTCOMES AND DISCUSSION FOR THE DESIGNED SYSTEM COMPONENTS

A. Contactless Temperature Measurement

The Fritzing sketching software was used in the design of a Printed Circuit Board (PCB) sketch for the contactless temperature measurement system which forms the bigger passenger security system. The outcome is presented a breadboard schematic diagram that shows the physical subcomponents of the system in graphical and colored format. The results of the PCB design are shown in Fig. 9. The sketch consists of numerous parts including the MLX90614 contactless temperature sensor which is used to capture passenger's temperature values as they enter the bus within the range of zero to five centimetres, a 16x2 liquid crystal display (LCD) screen that displays the temperature values in degrees centigrade, a potentiometer which is used to set and vary the brightness of the LCD screen for appropriate and visible display of the temperature readings, an Arduino UNO bord onto which the code for the system is uploaded and all processing of the program that runs the functioning of the various devices is performed, the esp82066 Wi-Fi module thatis used to upload the captured temperature values to the ThingSpeak platform for remote viewing and storage of values as long as the device has an active wireless internet connection and two light emitting diodes (LED), a green one that is intended to light for a period in case the captured temperature value of the person is within the accepted range and the red LED that is supposed to light as warning that the captured temperature value doesn't match with the acceptable temperature values for a human being. The different components are connected to the Arduino board via the breadboard using jumper wires.

The other output from the sketching tool is an electrical circuit schematic that shows details of the pins of the various components and which pins are connected to which pins. This is very helpful in the physical connection of the various devices in future instances. These two diagrams make the physical wiring of components easier to figure out and repeat whenever the need arises.

B. CCTV Surveillance System

The CCTV surveillance system design was drawn to save time and money during the installation process. The design outlines the bus floor/roof structure and identifies specific spots on the bus where the different parts of the system are to be placed as well as the connectivity among them. Two passenger count cameras are placed at the two bus doors, two surveillance cameras are placed in the bus (one at the front to cover the front part and another at the back to surveil activities at the rear end of the bus). All the cameras are connected to a DVR (placed at the front of the bus) using twisted-pair cables for video transmission. A screen is also connected to the DVR to view camera video footage. The DVR and bus door passenger count cameras are connected to a router using ethernet cables for network connectivity and enable data transmission for remote viewing and control of data using a local internet breakout connection for purposes of reducing traffic on the organization network core. The CCTV network diagram for each bus is shown in Fig. 10. The network requirements for this system are shown in Table III.

TABLE III. TABLE SHOWING NETWORK REQUIREMENTS [25]

Network Requirement	Video Stream Resolution		
	480p	*720p*	*1080p*
Minimum uplink bandwidth	0.6 Mbps	1.25 Mbps	2.75 Mbps
Minimum downlink bandwidth	1 Mbps	3 Mbps	5 Mbps
Recommended bandwidth	1.5Mbps	3 Mbps	5 Mbps
Communication protocols	TCP/IP, PPPoE, DHCP, Hik-Connect, DNS, DDNS, NTP, SADP, NFS, iSCSI, UPnP™, HTTPS, ONVIF, SNMP		

C. Passenger Count and Social Distance Analysis

The design for this component is presented in a workflow model for a machine learning model to detect a person object in images and video frames, count the people in a frame and analyse the distance between the detected objects with respect to covid-19 guidelines. The flow chart for the video analysis process is shown in Fig. 11. The process starts by passing a video frame to the model, the model checks if the object in a frame is a person and classifies the object as a person if it's true, the distance between the people is then measured and if it's less than 1 meter, they're considered to be at high risk, if the distance is less than 2 meters, they're considered to be at medium risk and if it's greater than 2 meters, they're considered to be safe.

The people in the frame are counted to obtain a total as well as subtotals for the groups, and the results of the analysis are displayed on a PC monitor alongside the video frame.

D. Digital Contact Tracing Platform

This platform was designed as part of a mobile application targeting mobile smartphone users. The designed solution consists of a navigation platform to the digital contact tracing

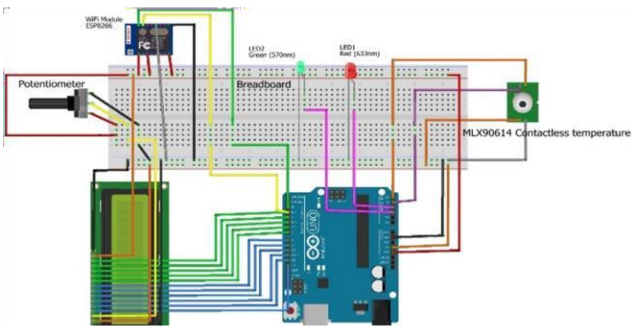


Fig. 9. A breadboard schematic sketch for the temperature sensing system.

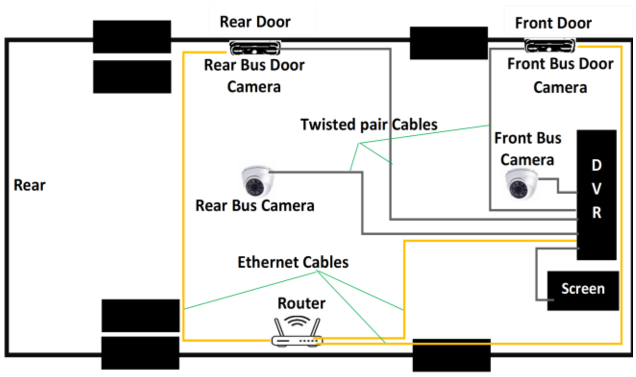


Fig. 10. Design of layout for cctv surveillance components on the bus

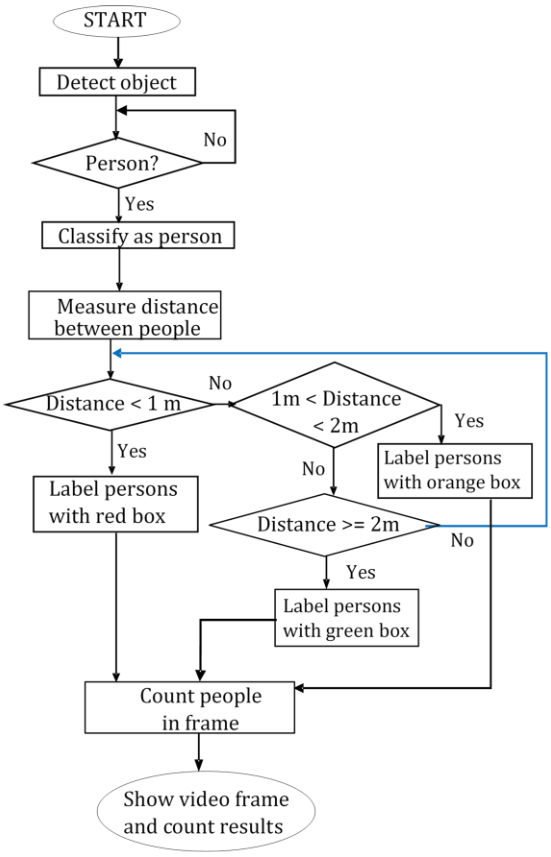


Fig. 11. Analysis process design for social distancing and passenger

form and the digital form itself. The form is intended to capture details of the mobile app user like the name and phone number, and the values of checkboxes that a user can check in case they have a certain symptom and submit their responses by clicking the submit button. The designed navigation drawer and the digital contact tracing form are shown in Fig. 12. Each user response is transmitted to a remote database. In instances where the phone may lack an active internet connection, the data is stored in the phone's local database and later on sent to the remote database when an internet connection is obtained.

E. Web Portal

An integrated web system was designed to provide simple and robust management and integration platform for the different components of the Passenger security system. Its wireframe design was attained using the AdobeXD prototyping tool. This web app is a big system with several other features, but the concentration of this project was adding the security and safety aspects of the passengers to this system. These features include remote access to the CCTV security surveillance web system, contact tracing information, and submitted temperature values from each bus.

V. CONCLUSION AND DISCUSSION.

Passengers and travellers that commute in most sub-Saharan Africa cities using the informal transport sector face an array of challenges key among which is the aspect of their security and safety in diverse aspects like the loss of their property, not overlooking the aspect of health safety in the perilous periods of contagious diseases like COVID-19. It therefore beneficial to passengers, bus operators and transport authorities to employ a passenger security and safety system

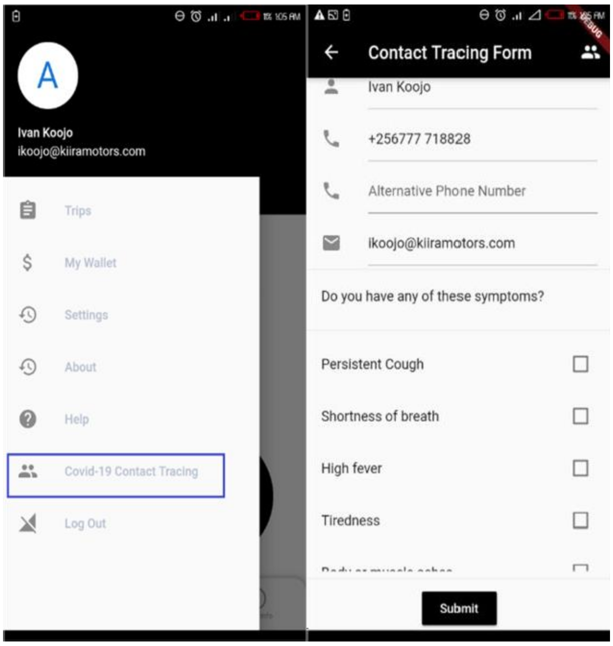


Fig. 12.Screenshot showing navigation to the contact tracing screen of the designed mobile application

for buses by leveraging a combination of existing technologies and thus improve security, accountability, planning and automate time-consuming tasks like contact tracing records and temperature measurement.

ACKNOWLEDGMENT

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Output 2: Poster Presentation

A Passenger Security System for Mass Transit Electric Buses: A Case Study of the Kayoola EVS Bus

Ivan Koojo, Dr. Dina Machuve, Dr. Silas Mirau, Simon Peter Miyingo

Nelson Mandela African Institution of Science and Technology. P.O. Box 447, Arusha Tanzania

Emails: koojoi@nm-aist.ac.tz, dina.machuve@nm-aist.ac.tz, silas.mirau@nm-aist.ac.tz, simon.miyingo@kiiramotors.com

CENIT@EA

KIIRA MOTORS

INTRODUCTION

- Kiira Motors Corporation established in 2011 to champion the development of the Ugandan automotive value chain.
- The company aims to attain its core value; customer satisfaction on the Kayoola EVS Bus which is the its Market entry product through a security system

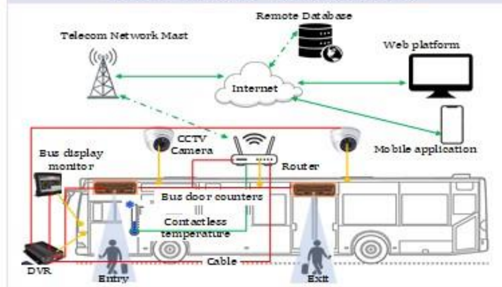
PROBLEM STATEMENT

- Rampant passenger insecurity and loss of passenger property on commuter taxis and buses
- Spread of contagious diseases like COVID-19 poses subtle health risks to the.
- Passenger counting, management and accountability for transporters is an uphill task

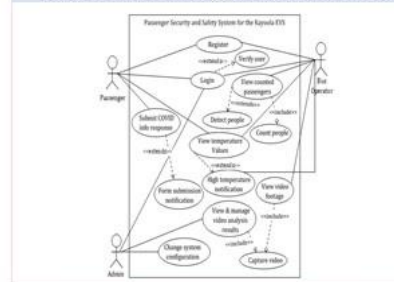
OBJECTIVES

- To identify and establish system requirements of the passenger security system.
- To develop the modules of the passenger security system
- To test and validate the modules of the passenger security system.

PROPOSED SOLUTION



SYSTEM REQUIREMENTS



DEVELOPED SYSTEM