Application of Fingerprint authentication to Fortify Child Safety in School Transport

Student ID: 152971

Mutuku Stercy Wanza

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School of Computing and Engineering Sciences

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Declaration and Approval

I declare that this work has not been previously submitted and approved for the award of a master's degree by this or any other University. To the best of my knowledge and belief, the work contains no material previously published or written by another person except where due reference is made in the work itself.

Mutuku Stercy Wanza

Stercy
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7th April 2024

Approval

This dissertation of Stercy Wanza Mutuku was reviewed and approved by the following:

Dr. Allan Omondi

Lecturer, School of Computing and Engineering Sciences,

Strathmore University.

Signature: ………………………… Digitally signed by Allan Omondi Date: 2024.04.07 16:47:45 -04'00'

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Abstract

Safety of school-going children has been a great concern to parents, school administrations and the transport team in the recent past. In urban areas like Nairobi where most parents are busy working and crime is fast increasing, the need for an efficient and safe transport for pupils cannot be underestimated.

Most current school transport systems use NFC cards or manual attendance records to keep track of the children picked in the morning or dropped after school. Using manual attendance is time consuming, especially where there are many students. NFC cards could also be lost or misplaced. This could be a security loophole if picked by someone else and manage to access the transport.

This research uses fingerprint authentication for both learners and staff where fingerprints are captured, and database queried to authenticate the learner or staff. The choice of technology is inspired by the fact that fingerprints are unique to every individual adult or child. The research used Rapid Application Development (RAD) methodology because it is more flexible in accommodating the changing nature of requirements which are not well defined in the initial stages. The requirements are implemented in the system in separate prototypes until the final prototype is developed. It also allows for fast user feedback and speeds up delivery. Learners' existing records will be used as input to the system and will be incorporated with the children fingerprint then stored in a database. Convenience sampling was used in the research to obtain simulated data.

Keywords: Biometrics, safety, fortification, school transport, Facial Emotion Recognition, Biometric Fingerprint scanner, Geofencing

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Table of Contents

List of Figures

List of Tables

Abbreviations/Acronyms

NFC	Near Field Communication
OOAD	Object Oriented Analysis and Design
OLTP	Online Transaction Processing
ORM	Object Relational Mapping
RAD	Rapid Application Development
RSA	Rivest, Shamir, Adleman
TAM	Technology Acceptance Model

Operational Definition of Terms

Biometric	A unique and more practical way of authenticating a person using biological characteristics such as fingerprint (Adeoye, 2010).
Bus	Any form of vehicle used by school to offer school transport to learners. Could be a bus, a van, a personal car etc recognized to offer transport for the school.
Fingerprint scanner	A biometric technology which identifies and authenticates school going children when boarding or exiting the school transport e.g., van or bus (Hamidi, 2019).
Flawless	Oxford Dictionary defines flawless as being Free from defects.
Fortify	To reinforce security to prevent loopholes (Chapman, 2021).
Geofencing	Defines geographic area of interest (Suyama & Inoue, 2016).

Chapter 1: Introduction

1.1 Background

School transport is an integral part in the education system. However, according to Nasimiyu M., (2018) it is not easy to manage the school transport system. In urban areas like Nairobi where most parents are busy working and crime is fast increasing, the need for efficient and safe transport for pupils cannot be underestimated. Parents value the safety of their children and that is why, parents who own personal cars, prefer to drop their children to schools to have surety that the children arrived in school and safely too. Other parents organize private means of transport to ensure safety for their children.

In busy towns, schools are located all over, even in the outskirts and it's therefore impractical to think about schooling in Nairobi without thinking about school transport. The issue of learners' safety on transit is paramount. Student identification Cards, manual registers and Global Positioning Systems (GPS) have been widely used in the past to ensure safety to learners during the transition. Manual registers however are prone to human error and can be easily altered. Research has been conducted over time to help improve safety to the learners. One recent research proposed the use of an IoT based school bus tracking system that generates a fixed QR code for each student that will be placed on a card that contains the student personal information (H. Gull, 2021). This research uses an innovative biometric-powered system combined with geofencing technology to offer utmost protection to children and thereby provide relief to parents and all other stakeholders. The implementation of fingerprint-biometrics technology in school transport systems births a new era in fortifying the security landscape of school transport system. Every learner has a unique fingerprint. According to Sharma et al., (2018) fingerprints start to develop from 6 weeks of an embryo and are fully developed by the 13th week. This means before a child is born, they have their fingerprints fully developed. Fingerprints can therefore be used when the child joins school and enrolls for the school transport. Fingerprints for the prototype were taken using biometric fingerprint scanners and location was set to give the coordinates for latitude and longitude to be used for geofencing.

Application of fingerprint biometric technology in school transport revolutionizes the conventional school transportation, creating a flawlessly streamlined and secure journey for students.

1.2 Problem Statement

The safety of young school going children during school transportation has sprouted a lot of concerns in the recent past. Safety is a major threat in big towns like Nairobi where there are all sorts of people with different crime intentions (Muindi et al., 2022). In the recent past, there has been tremendous rural to urban migration in search of jobs and in an attempt to alleviate poverty. When no jobs come forth, many people turn to all manner of crime. According to Selod and Shilpi (2021) abduction of young school going children is on the rise. The abductors then demand ransom for them to release the children else risking the children's lives. Other children have disappeared, never to be seen again with only a few who manage to be rescued. There have been several attempts to address this problem.

Wambayi (2016) and Sarosa et al. (2023) propose the use of Near Field Communication Cards to help track and notify a child when near the school transport. NFC cards can be lost, or a student can even carry it to another child and the system notifies the parent as though the child boarded or exited the school transport. The use of GPS is very good for live tracking of the school transport but must be used with complementary identification to ensure total safety of learners. Mahfouz K. et. Al., 2020 proposes that biometrics in school transport will track leaners as they exit the school bus or van hence solve the issue of learners being left behind in buses which could be dangerous for them due to extreme weather in Dubai.

This dissertation uses fingerprint scanner fitted at the entry or exit points of the school bus to keep track of the learners dropped or picked. Geofencing is used to prevent the driver from leaving the learner's geofence without picking or dropping them unless the learner is not among the kids being picked or dropped in that particular location that day. An alert is sent to the parent or guardian accordingly. This solution is beneficial to parents, the school itself, school administrators and even transport managers or providers. It ensures the safety of young learners whose future is unfolding.

1.3 Aim

This research aims at developing a secure child tracking system.

1.4 Research Questions

i. What are the challenges faced by the existing school transport systems?
ii. What technologies are used in the current school systems to ensure safety of learners?
iii. What is the impact of using fingerprint authentication at entry/exit points?
iv. Will the developed system ensure safety to learners?

1.5 Specific Objectives

i. To examine the challenges of the existing school transport systems.
ii. To review technologies used to ensure safety of learners during transition to or from school.
iii. To develop a safe system using fingerprint and geofencing technology.
iv. To test the efficacy of the developed system.

1.6 Justification

There has been a high rate of criminality in the recent past. Children have been disappearing some never to be seen again. According to the Labor and Social Protection Cabinet Secretary Florence Bore, 6,841 children were reported missing between July 2022 and May 2023. Well, this is a high number of children and many of them get lost to or from school. This means therefore, there is dire need to fortify the security of our children no matter what it takes.

Integration of Biometric technology in school transportation enhances child safety and reduces transportation risks in Kenyan schools. Children are assured of getting home more safely than in the past. If safety is fortified in school transport, it leads to increased school attendance rates, more subscription into the transport system and reduced absenteeism which leads to possible economic growth.

The system leads to a positive secure environment for learning, increased school attendance rates and reduced absenteeism which is key in improvement of academic performance hence the quality of education. The system prevents unauthorized access to buses or attempts to manipulate the system for personal gains.

1.7 Assumptions

i. A school transport aide or coordinator shall be available to ensure that each learner scans their fingerprints every time they board or alight the bus.
ii. Parents and/or guardians will give permissions and consent for the collection and use of biometric data for child identification purposes during the system deployment.
iii. It is assumed that reliable network connectivity, such as cellular data or Wi-Fi, will be available in the school transport.

1.8 Scope and Limitations

Scope

This research was carried out within the school sector focusing on safety of children on transit to or from school. It was constrained to schools within Nairobi County.

The system incorporated fingerprint biometric scanners capable of accurately identifying each child boarding and alighting from school transport. It then logs boarding and disembarking time, the locations, and dates for each child.

It integrated GPS technology to monitor the real-time location of the school bus and generates automated alerts and notifications to the necessary stakeholders such as parents and school staff regarding the child's boarding, disembarking or when the bus is approaching the drop off the learner.

The system also incorporated the use of Geofencing to ensure that once the bus or van gets to the premises of a learner and leaves without picking or dropping the learner then an alert is sent to the parent or guardian and the driver. The driver then responds accordingly.

However, the proposed system does not involve managing vehicle maintenance or the driver's behaviour such as adherence to traffic rules. It does not extend its attendance verification capabilities beyond the school bus environment, to areas within the school environment.

Limitations

Participants not willing to grant consent for use of their fingerprint data posed a challenge during the research. Comprehensive communication was done to assure the participants that their data would only be used for the purposes of the research only.

1.9 Risk Level

The level of risk involved in developing the system is generally low. Although handling biometric data possesses a high level of risk since it can be linked to a particular individual, encryption was put in place to mitigate this risk. There may also be moderate technical risks including software bugs, hardware issues, and interoperability issues. These are addressed through rigorous testing and monitoring or when they arise. Integrating the fingerprint authentication system with the existing school transport system may present some challenges. There may therefore be the risk of data loss during synchronization, compatibility issues, and potential disruptions during integration.

Chapter 2: Literature Review

2.1 Introduction

This chapter discusses the need for a safe school transport system in safeguarding the younger generation of school-going children. Section 2.2 presents theories that provide insights into the expected phenomenon of biometric identification and child safety in school transportation. This section is followed by Section 2.3 which reviews all related and published works done. Section 2.4 then outlines the software development framework for creating the system. Section 2.5 which discusses the software architecture or the components in totality that make up the system is closely followed by the conceptual framework which displays how variables relate to each other in a study.

2.2 Theoretical Framework

The theoretical framework describes the theories that explain the current situation or how the expected phenomenon (safety) can be achieved in school transport system. It also explains why schools or private transportation providers may choose to use biometric technology for learners' identification as opposed to other methods.

2.2.1 Evidential decision theory

The evidential decision theory focuses on choice-making considering the available options (Ahmed A. 2021). It advises one to take the action which increases the chance for the desired goal. The theory can be applied to enhance the system's decision-making processes (Stern R. 2017) where one is presented by more than one choice. Leveraging fingerprint biometric technology presents many advantages and is likely to lead towards achieving or near achieving of child safety during the transportation period.

The key advantage of this theory is allowing decision makers to consider all available evidence before making a choice. This helps in making sound and informed decisions.

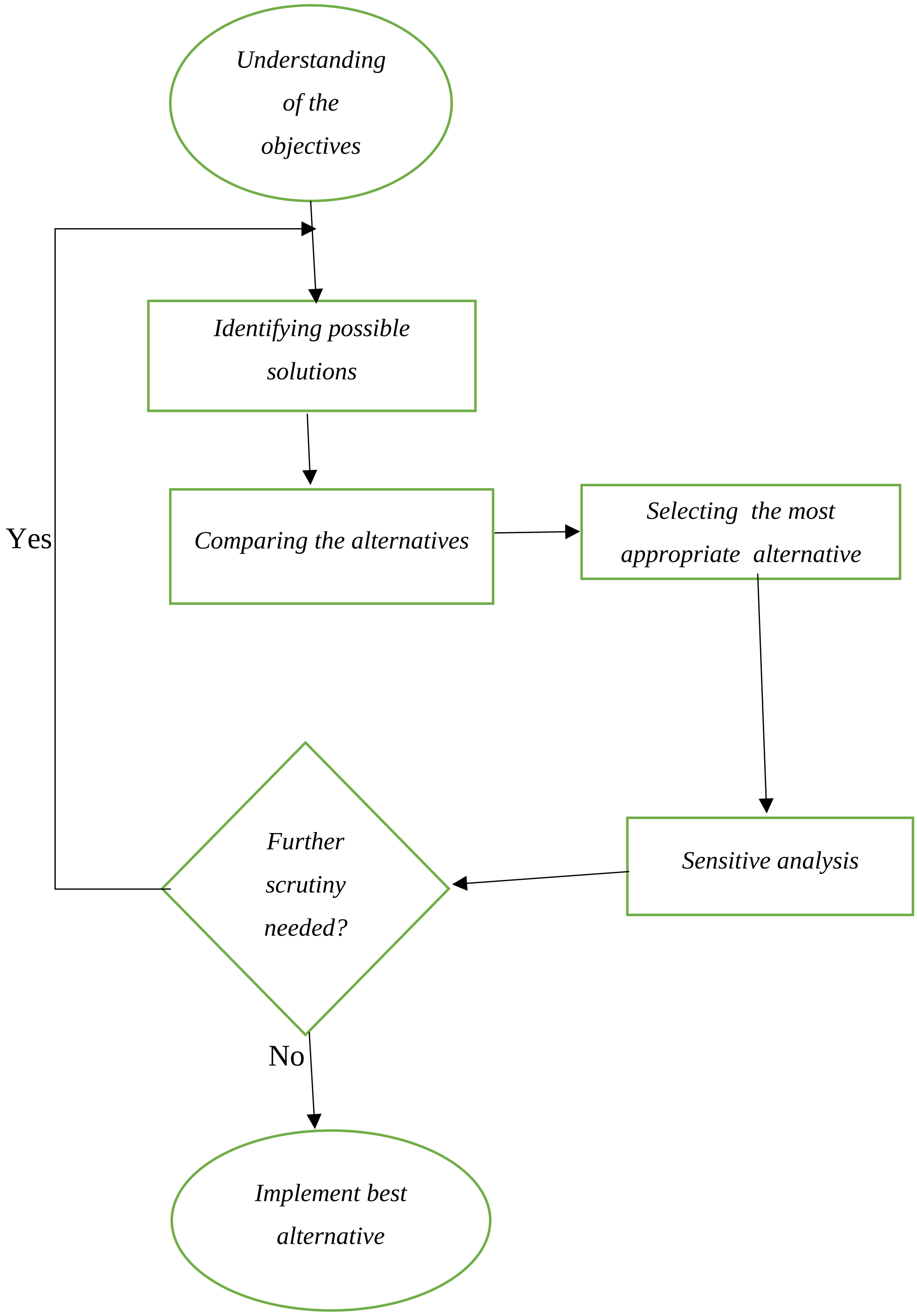


Figure 2.1: evidential decision theory

2.2.2 *Technology Acceptance Model theory*

According to Yuen, Cai, Qi & Wang (2021), Technology Acceptance Model (TAM) theory seeks to understand users adopt or embrace new technology. It argues that there are two determinants as to whether a computer system will be accepted by its potential users or not. The determinants are the anticipated benefits the system will bring forth and the ease of using it. TAM will help predict how and whether the involved stakeholders will embrace the system's benefits of accurate attendance tracking, real-time monitoring and how easy it is to use the system. Technology Acceptance model is very useful to organizations because it helps determine the attitude of users on a particular technology and thereby the possible barriers likely to be faced during adoption (Lezki, AYDIN & Fikret, 2015).

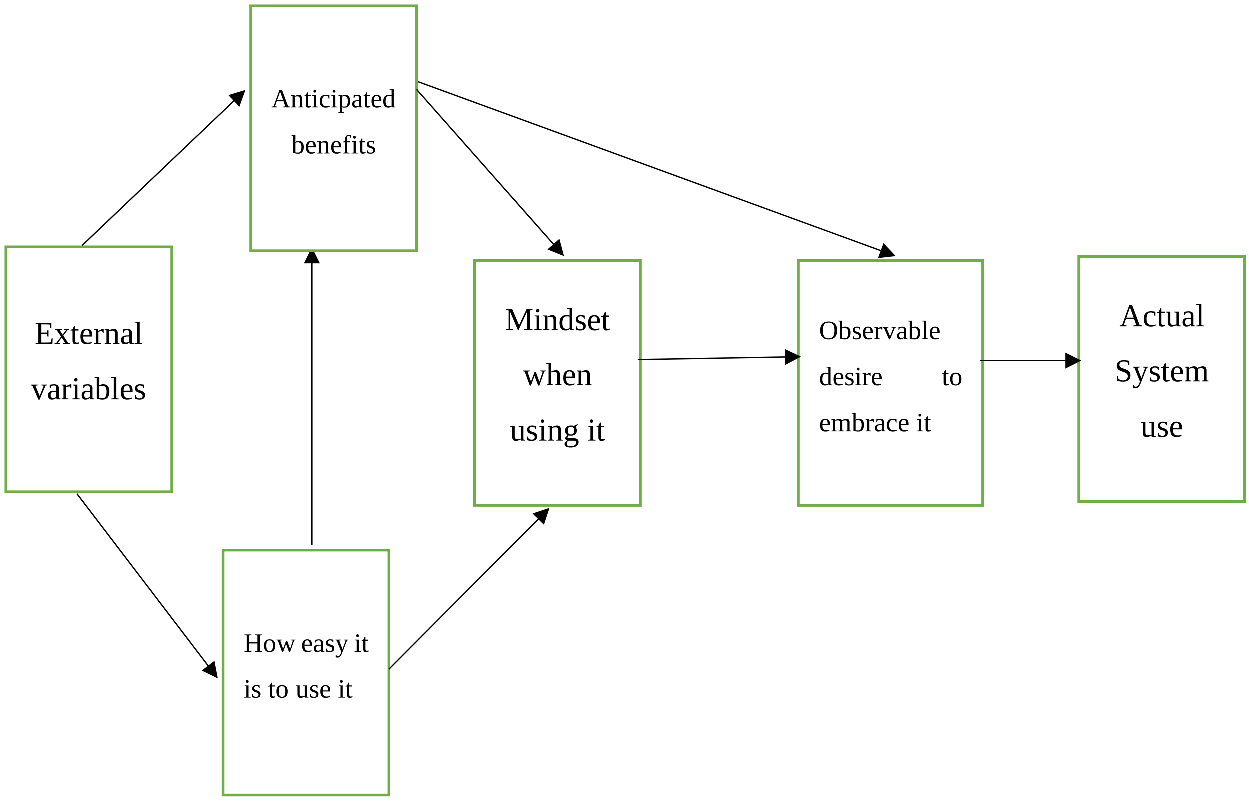


Figure 2.2: Technology Acceptance Model

2.3 How The System Works

The system works by using Fingerprint biometric technology to verify learners to access the school transport. The verification process shall involve a number of processes.

Learner Enrolment –

i. Learner enrolment by the school enrolment - Learners' fingerprints will be initially taken using a fingerprint scanner and enrolled into the system. This data will be associated with unique learner identification information such as their name.
ii. Learner enrolment by parent or guardian – Parents will have the right to update the learner's location which will be used for geofencing, contact person for the learner to pick, drop who can be called for the learner's welfare.

Fingerprint storage – The fingerprint data collected will be stored in safely in a centralized database.

Fingerprint Authentication – When a learner wants to board or alight from the school transport, they will place a finger on the fingerprint scanner mounted at the door. The system will capture the fingerprint and convert it into a unique digital representation which will be compared to the data stored in the database to find a match. When a matching information is found, the learner is allowed to enter or exit. When no matching information is found the system raises an alert and the unauthorised person is denied access.

Alerting – Once a learner is authenticated, the system notifies the necessary stakeholders such as the learner parents or guardian.

Logging – The system will then keep a record of learners' access of the school transport. This log information will be used for attendance tracking and security purposes.

2.4 Empirical Framework

One cannot fail to acknowledge how school transport has brought convenience for learners who commute daily to and from school. However, the issue of their safety while commuting has been the pricking thorn in the flesh for many parents. No matter how long it takes to address the problem, there can never be peace until efficiency and safety is guaranteed.

The Traffic Amendment Bill 2016 passed in 2017 dictated that the official color for all school buses in the country be yellow. This was in a bid to achieve safety for the Kenyan learner. According to the then Cabinet Secretary Dr. Fred Matiang'i, yellow color was ideal for ease of identification on roads thereby ensuring safety for learners.

2.4.1 Implementation of a framework for tracking school children while on transit

Wambayi, R. G. (2016) proposed the implementation of a framework for tracking school children on transit by using NFC Cards and Global positioning system to track and notify parents of their children's location. Wambayi's system leverages on the NFC technology in storing kid's details. Anytime the card is used, the respective parents are notified of the location the card is used with the assumption that it's the child who used it. The implementation of a framework for tracking school children while on transit has several advantages such as:

1. Monitoring attendance. Ensuring children are in the right bus and are picked and dropped in the right locations.
2. Safety. The main goal of the framework is to enhance the safety of learners. Monitoring the location will improve safety for learners.
3. Efficient routing. It provides optimal routes for the school transport thus reducing the travel time.

The implementation of the framework has also some disadvantages or weaknesses

1. Overreliance on technology. Depending too heavily on the tracking system can be chaotic in managing the transport system in case of a technical issue.
2. Data accuracy can be affected by the GPS signal strength.

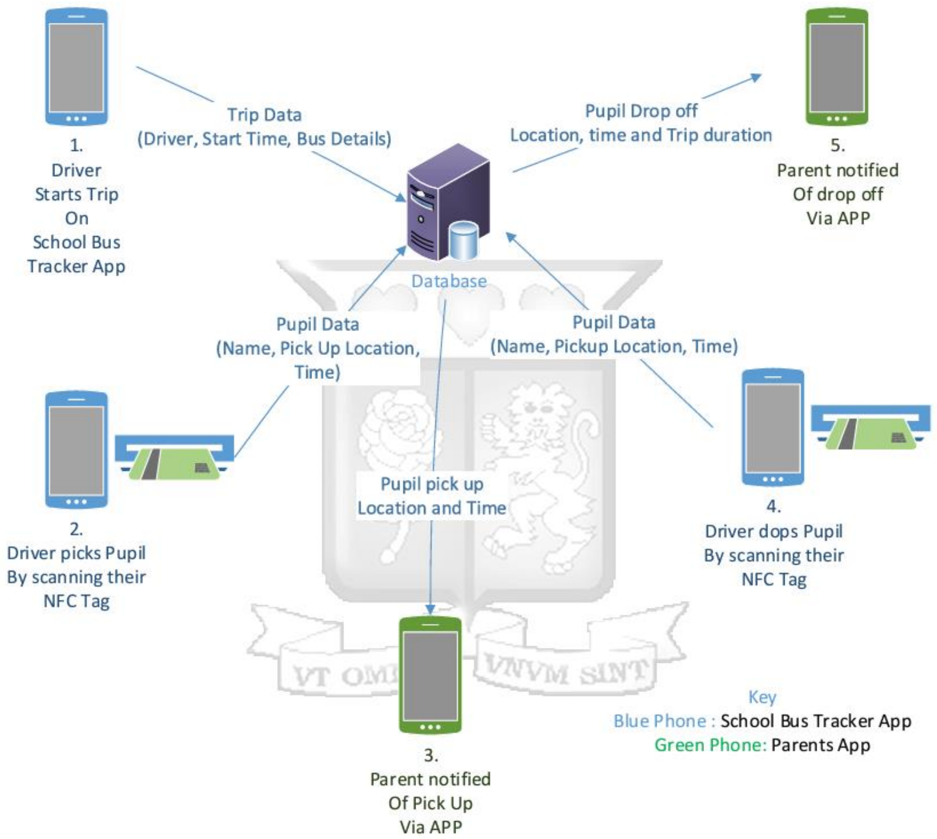


Figure 2.3: Implementation of a framework for tracking school children while on transit model

2.4.2 Design and implementation of school bus information and tracking system application

Another study is done for the Indonesian market by Sarosa M., Ningrum, M. & Mas'udia, P (2023). It suggests the use of a school bus monitoring system using localization and speed sensors using GPS data communication signal comparison. The argument is that this allows parents and school authorities to track school bus trips in real-time. The system uses GPS and communication devices using global system for mobile (GSM) to monitor the position of the bus in real time using a Smartphone application. It also uses the smartphone application to determine the estimated distance and time for the bus to arrive at a given destination. This provides a good model for the prediction of distance and arrival time of the bus and provides alerts to the parents. The system identifies the child by tapping the NFC cards on a smartphone on the school bus. This system has some advantages such as:

1. Improving safety of learners by monitoring their identify using NFC cards.
2. Monitoring live locations for the bus
3. Ensures timely communication is sent to all application users using the internet network.

Some gaps found include:

1. NFC cards can be lost and therefore be difficult to identify the learner.
2. Learners can exchange the NFC cards and use them to enter the bus which may pose a security threat.

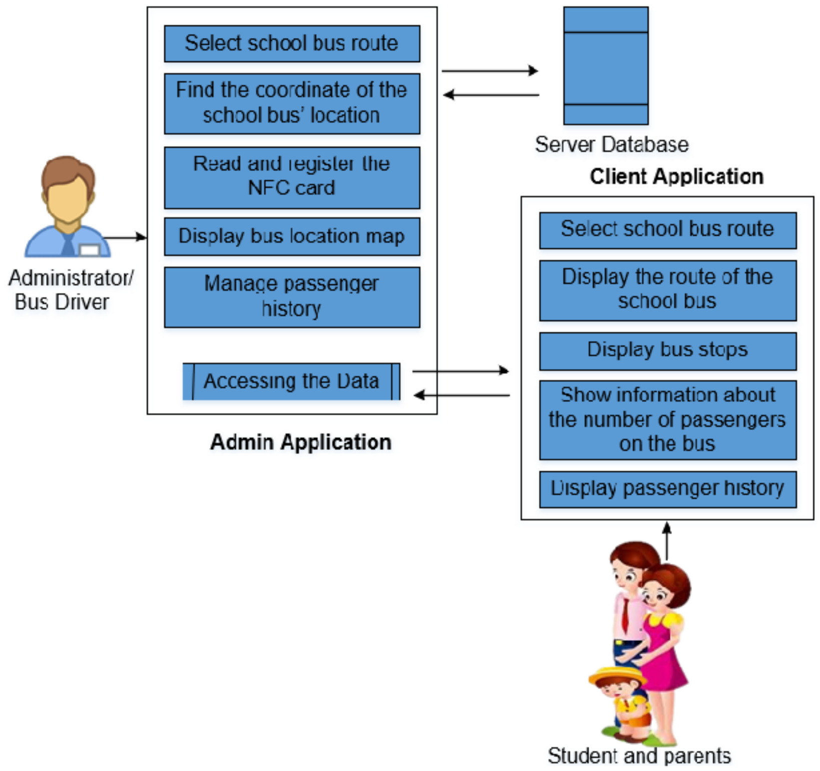


Figure 2.4: Design and implementation of school bus information and tracking system application framework.

2.4.3 Route Mapping and Biometric Attendance System in School Buses

Another study done for the Dubai market by Mahfouz K. et. Al., 2020 suggests an attendance approach using biometrics to ensure security in school going children. According to the scholars, the system comprises of the smart tablet, a microcontroller-based fingerprint sensor, an automated gate and a developed android application which will allow a learner to board or alight a bus when his or her fingerprint is recognized.

When it's time to drop the children off, the system generates a route based on the attended students and furthermore detects and alerts the bus driver if an attended student has not boarded/exited the bus. The system provides an advancement towards ensuring safety though its application is not for the Kenyan market. It also does not provide a key intelligent alerting model for all involved stakeholders for decision making if need be. This research had several advantages which include:

1. Improves safety of learners
2. Efficient routing based on the students who have boarded the bus or van.
3. Alerts the driver if a student who boarded in the morning is not picked in the evening.

The disadvantages of Route Mapping and Biometric Attendance System in School Buses include:

1. The research doesn't state what happens after a child is left behind. There is no way to raise alarm or inform the driver before leaving the school bus.
2. Route mapping using GPS can result to poor or inaccurate tracking in areas with poor network coverage.

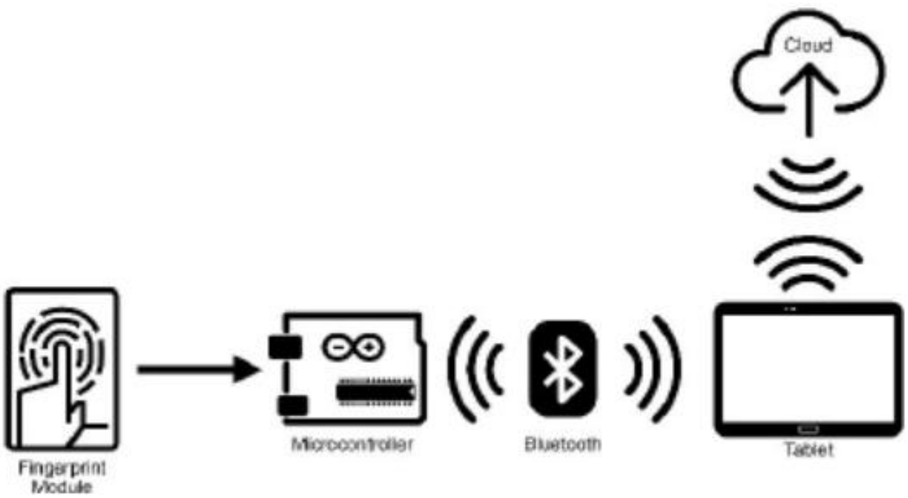


Figure 2.5 Route Mapping and Biometric Attendance System in School Buses

2.5 Existing Algorithms

2.5.1 RSA Encryption Algorithm for Data Security

RSA encryption algorithm will be used to ensure data security and privacy since it uses public and private keys for secure data transmission and storage. Biometric data, attendance records, and sensitive information will be encrypted using RSA to prevent unauthorized access and data breaches.

2.5.2 Dynamic Time Warping (DTW) Algorithm for Attendance Matching

The Dynamic Time Warping (DTW) algorithm will be utilized to match biometric attendance records with existing student profiles. DTW is effective for comparing sequences with variations in timing or speed. It can accurately match attendance data even if children's boarding and disembarking times vary slightly due to real-world conditions.

2.6 Dissemination and Utilization of Results

The target consumers of the findings are schools which comprise of the administration, parents, school transport director among other stakeholders. The dissemination of the research findings will be done through presentations at professional meetings with school administrators and/or other relevant stakeholders. This will ensure quick dissemination and receiving of direct feedback which can be used for future addition of features or improvement.

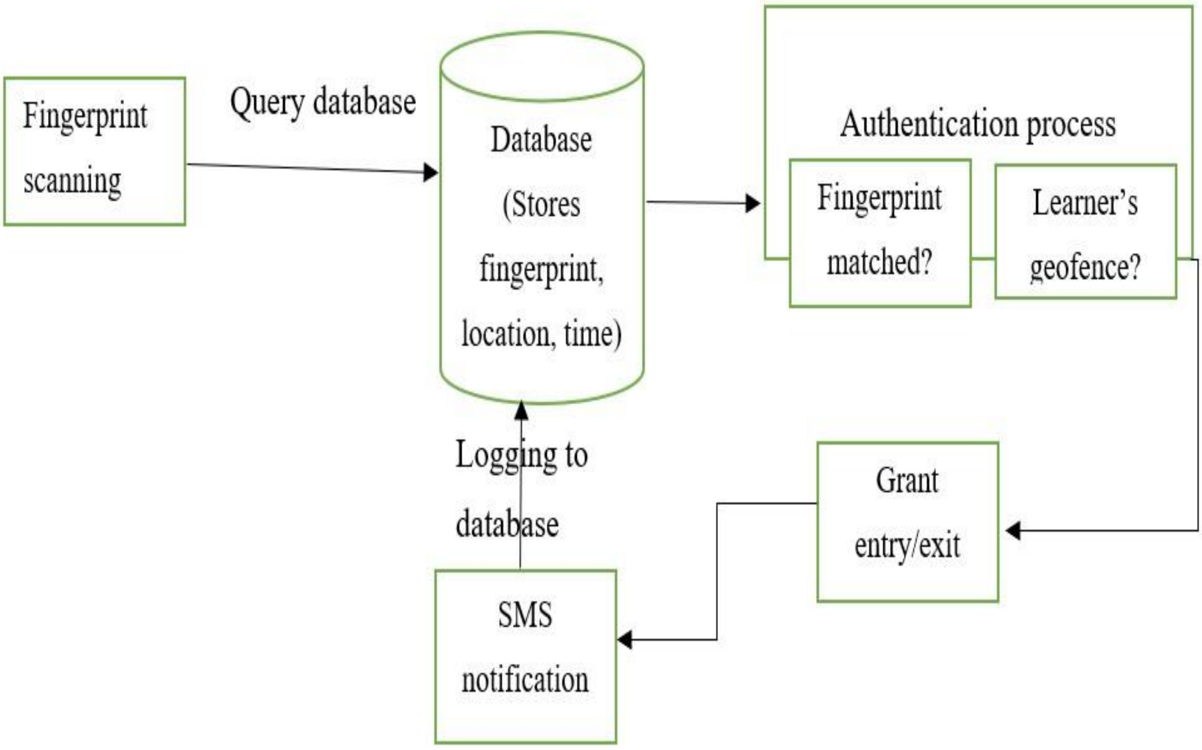
Utilization of the results will be by targeted schools those with offering school transport to learners and who may be interested in incorporating a system that can enhance safety to learners during transportation.

2.7 Conceptualization

The fingerprint capture process will utilize optical fingerprint sensors that will capture the minutiae points on an individual's fingertip. Learners will be guided on proper finger placement and cleanliness. To ensure high-quality fingerprints, Multiple fingerprints will be taken for each person to enhance accuracy. The system will then select the highest quality. The captured fingerprints will be transformed into biometric templates then securely stored in the database server. The database server will index the stored biometric templates for efficient retrieval during the authentication process. This indexing will allow for quick and accurate matching when a user attempts to authenticate their identity. When a user attempts to authenticate by placing their finger on the scanner, the captured fingerprint is converted into a template, and matching done. The database server compares this template with the stored templates to find a match. It then uses a predefined threshold to assess the similarity between the captured fingerprint template and the stored templates. If a match is found, the learner is accepted or else rejected.

The database server maintains logs of authentication attempts, including successful and unsuccessful ones. This information is crucial for system administrators to monitor the system to ensure safety.

2.7 Conceptual Framework



NB: Arrow directions show the flow of actions.

Figure 2.6: Conceptual framework

Chapter 3: Research Methodology

3.0 Introduction

This chapter addresses the Object-Oriented Analysis and Design and its advantages and focuses on the RAD methodology because of its incremental nature of development where requirements are not well defined from the beginning. It also addresses the software Development Framework and research design used. It also discusses methods of data collection, hypothesis testing and Data Analysis Methods, Reliability and validity of the system and ethical considerations.

3.1 RAD methodology

The system was developed using Rapid Application Development methodology because it allows for iteration and incremental nature of development. RAD is very flexible and can be used where the user requirements are not so well defined from the beginning. It is a good methodology for developing the first prototypes of a system.

RAD is also good as it allows for gradual improvement of the system leading to an excellent system.

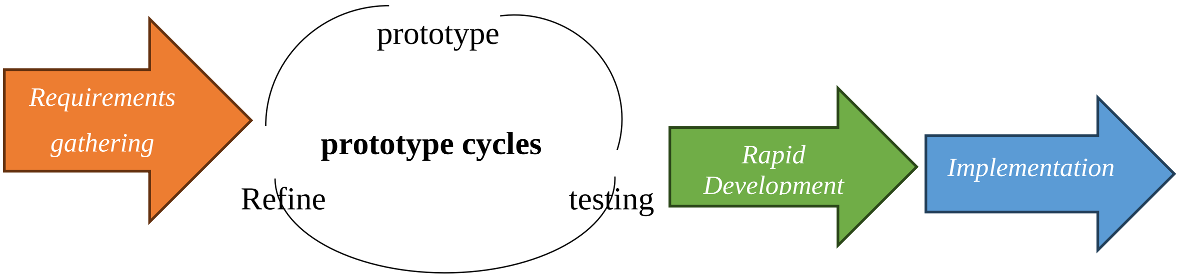


Figure 3.1: Stages of Rapid Development Methodology

3.2 Object-Oriented Analysis and Design

This research applies an Object-Oriented Analysis and Design (OOAD) because of its many advantages. Among them;

3.2.1 Several components

This proposed system involves several components such as the Registration module, login module, Enrolment module, location module, fingerprint module, capturing module, Matching module, management of the database server, alerting of the necessary stakeholders among others which is achieved using the Object-Oriented Analysis and Design.

3.2.2 Modularity and Reusability

Object-Oriented Analysis and Design allowed for breaking down the complex software into smaller self-contained but interconnected modules each module having a specific function.

3.2.3 Clear definition of object relationship

OOAD defined the kind of relationships that exist between the different components of the system. The learner for example has a relationship with the location and with the parent.

3.3 Software Development Framework

The Software Development Framework for creating the fingerprint biometric system includes a pre-established set of libraries and tools such as Java and the PHP framework which were used to streamline the software development process.

3.4 Research Design

The research employed the Quasi-Experimental Research Design as it allowed for the measurement of the effect of fingerprint biometric technology and geofencing on the safety of school going learners on the school transport.

3.4.1 Type of Research

The research incorporated Applied Research. This is because the research applied fingerprint Biometric and geofencing technology in the school transport settings to enhance safety of learners as they board and exit the school transport.

3.4.2 Type of Research Data

The type of research data used was:

1. Primary data – Fingerprint data was collected from a few willing individuals to test the system.
2. Mixed methods – This research used mixed methods to help the researcher gain comprehensive knowledge of the problem and how to address it well. IThhe researcher held lengthy conversation with the bus driver to gauge his opinions and perceptions of the application of fingerprint biometric technology in school transport.

3.4.3 Experiment Procedure

Technique 1: Using biometrics technology in school transport.

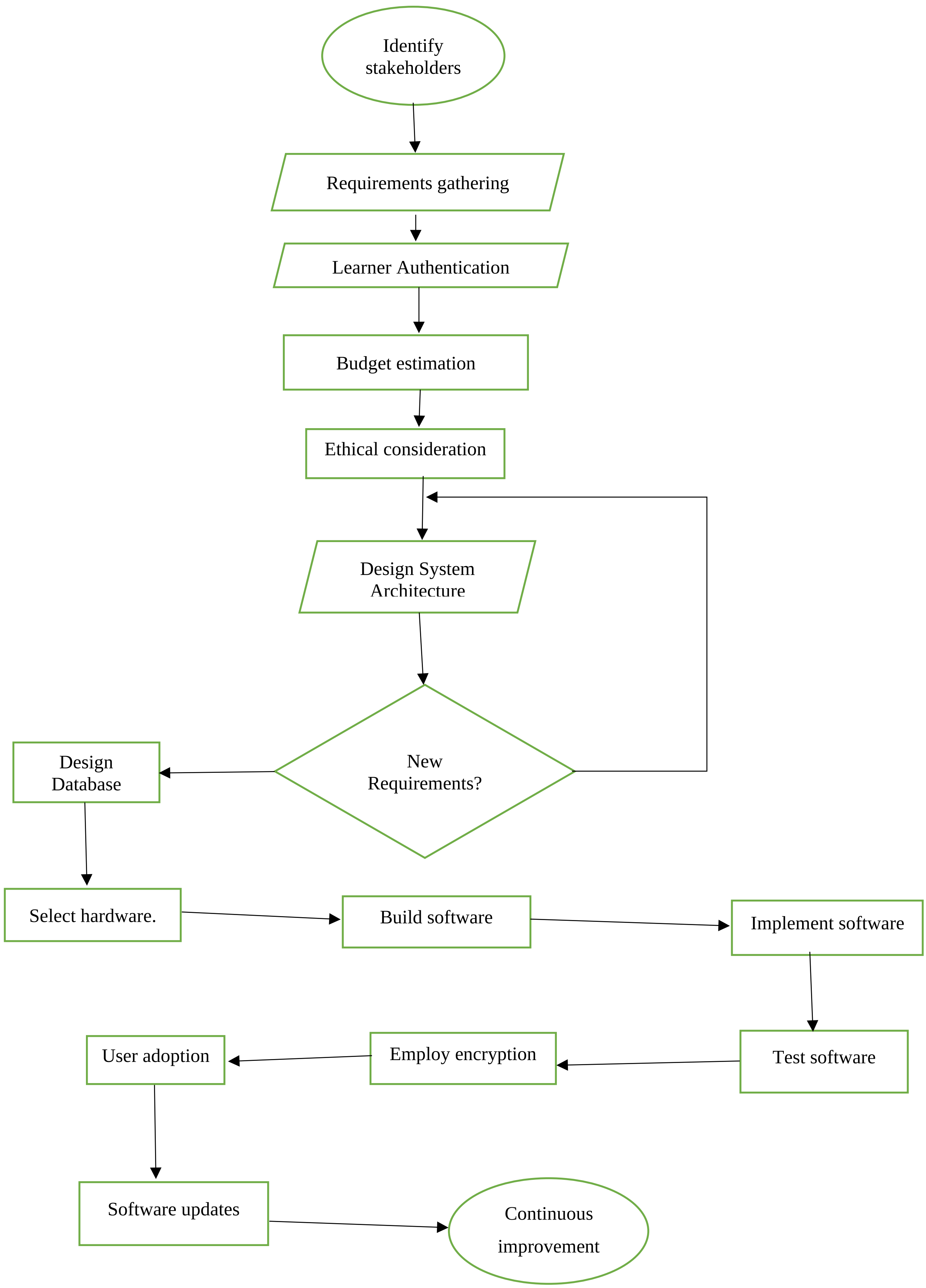


Figure 3.2: Experiment procedure

Technique 2: Using manual registers and learners' NFC cards to monitor safety.

Step 1. Identify all stakeholders which will be affected by the system.

Step 2. Identify specific objectives the system will do e.g., enhancing learner identification.

Step 3. Estimate the budget.

Step 4. Evaluate ethical considerations.

Step 5. Design the system architecture.

Step 6. Create user interface.

Step 7. Select hardware components e.g., NFC readers, RFID scanners, communication devices.

Step 8. Integrate the hardware components to the system.

Step 9. Create database and enter learner information e.g. learner NFC cards, contact details etc.

Step 10. Develop training programs for the school driver, learners, parents etc.

Step 11. User adoption

Step 12. Testing.

Step 13. Deployment of the system

Step 14. Ongoing monitoring

Step 15. Continuous improvement.

From the above results technique 1. Using biometrics technology in school transport is better in enhancing learner security because:

1. Fingerprints are unique to every learner.
2. They cannot be lost they are everyone's' biological characteristics.
3. It takes less time than manually checking learners' IDs and registers.
4. It provides reduced physical storage e.g. manual registers.

3.4.4 Experiment Test Data

To test the biometric algorithm, the researcher collected fingerprint data for a few available individuals. Fingerprints are unique to every person and if they work with a few individuals they would work for the learners.

The researcher used their own fingerprint and for a few others willing individuals to test and store the captured fingerprint data safely in a database.

3.4.5 Experiment Test Bed

The development environment of the system includes:

1. The android operating system – The development environment will run on all android devices.
2. The integrated Development Environments used were Android studio for mobile application development and Visual Studio code for the web application.
3. RAM – The system runs in any android device with a RAM of 8GB or more .
4. Network bandwidth – The system needs a stable and high-speed internet network.

3.4.6 System and Algorithm Testing Technique

The entire system was tested using the following steps:

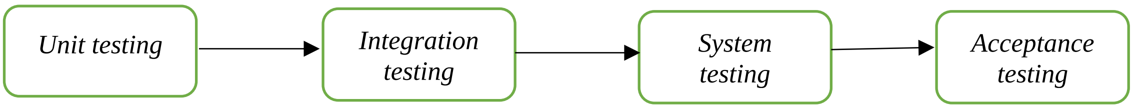


Figure 3.3: Steps of System and Algorithm Testing

- Unit testing – Each individual module was tested during development e.g. fingerprint module testing.
- Integration testing – Components were gradually integrated then tested together as a unit e.g. the fingerprint biometrics testing.
- System testing – Testing of the entire system was done.
- Acceptance testing – The complete system was tested to ensure that it returns the expected results.

The system was validated through testing of the suggested solution (using biometrics and geofencing) to ascertain that it solves the problem as seen by the stakeholders (school and parents).

3.4.7 System Modules and System Functionality (Deliverables)

The developed system has the following modules:

1. Fingerprint authentication module: This is used to authenticate learners by matching the captured fingerprints with the one stored in the database.
2. Online Transaction Processing (OLTP) Allows for real time transactions such as real time learner authentication using biometric data.
3. Database management module: Stores and manages learner information. It also allows for retrieval and management of the data. This module uses both Online Transaction Processing and Online Analytical Processing for real time transaction of data and analysis of the learners' information.
4. User interface module: This is an interface the system provides for the users like the driver, school administration etc to interact with the system. The interface also allows for authentication of learners.
5. Communication module: This module manages communication between the system and all involved stakeholders. It sends alerts to parents concerning their children' pick-up or drop-off details. It uses OLTP for real-time alerting.
6. Security and access control module: It enforces data security and controls permissions accordingly. It uses OLTP for real time access and control of the private information.

3.5 Data Collection Methods

This involves the processes used in gathering data to solve the problem of learners' insecurity on transit to or from school.

3.5.1 Method to be used to Gather the Functional and Non-Functional Requirements

The following methods were used to gather data for the system.

Convenience Sampling was used to collect fingerprint data. Participants were chosen based on their availability and willingness. Since fingerprints are unique to everyone, for the initial stages, the system used fingerprints from a few willing participants to develop a prototype for the system. Biometric data for learners will be used during deployment of the system with school. This means that there is no sample size needed to collect fingerprints to carry out the research.

3.5.2 Population Description and case study description

The target population for the research is private schools in Nairobi County. The case study for the research was St. Bakhita school Sabaki. A prototype was used to demonstrate that the system ensured safety to learners as intended and alerted the necessary stakeholders accordingly.

Data for the prototype was taken from willing participants only. This data was then used as simulated data for the prototype.

Individuals who expressed discomfort or unwillingness to have their data used for testing were excluded from participating in the simulation.

Actual implementation of the system will use real data of learners whose parents will have signed the consent forms. Those who will express discomfort with it or fail to sign the consent forms will be excluded.

3.5.3 Sampling Distribution

Younger learners need the solution more than elder ones because they are not yet able to protect themselves in case of a tragedy. They are also easy to sway because of their tender age.

3.5.4 Operationalization of Abstract Variables

Subjective assessments were used to measure abstract variables.

- Open-ended questions were used to measure satisfaction with the system. This is because they provide detailed feedback than just to rate their satisfaction in a scale.
- Net promoter score to measure satisfaction by assessing the likelihood of recommending the system to use by others depends on whether the system meets the objectives.

3.6 Hypothesis Formulation

H_1: Application of biometrics technology with geofencing fortifies safety to learners compared to other safety measures.

3.7 Data Analysis Methods

Descriptive statistics were employed to summarize the characteristics of the simulated data, providing insights into key features and trends of the system.

Comparative analyses were conducted to assess how well the prototype performs in simulated scenarios compared to expectations.

Inferential statistics:

The research used inferential statistics to make conclusions and generalization about how effective the system is even when applied to the whole population of learners (Bhandari, 2023). It also evaluated the relationships between the different solutions offered for the problem.

3.8 Reliability and Validity

The system yielded the same results when another research was done following the steps outlined in the research. The system consistently provided accurate authentication results for different test data.

The system is therefore valid since it produces the expected results any time learners need to be authenticated.

3.9 Ethical Considerations

The following ethical principles will be applied in the research.

1) **Honesty** – Truthful findings about the research were provided.

2) **Objectivity** – Employment of unbiased data collection and analysis was key. The system avoided preconceived notions and only focused to the objectives.
3) **Integrity** – The researcher honestly reported the findings and avoided data fabrication.
4) **Carefulness** – Data collected was encrypted to prevent unauthorised access. Measures were put in place to avoid careless errors and negligence.
5) **Transparency** – All the methods used in the research, the assumptions and analyses were provided.
6) **Accountability** – Justification for what was done and why, was provided. There was accountability for choices and decisions made.
7) **Intellectual Property** – Proper citation and acknowledgement of other peoples' work was given where necessary.
8) **Confidentiality -** Learners' private information was protected and not shared with anyone else. The data was used only for purposes of this research. Proper encryption methods were used to ensure privacy and security of the data.
9) **Competence** – Professional competence and expertise was maintained.
10) **Legality** – Compliance with all relevant laws and regulations including data protection laws, child safety regulations, and ethical guidelines were considered.

Chapter 4: System Analysis, Architecture and Design

4.1 Introduction

This chapter deals with the analysis, design, and general architecture of the proposed system. It explains the components of the developed system, the interactions between the different components and the interactions between the users and the developed system. The functional and nonfunctional system requirements are also discussed. A detailed understanding of the system design demonstrating the interaction between the target users and the main components of the system was illustrated using Use Case diagrams, Entity Relationship diagrams and Class diagrams.

4.2 System Analysis

This section analyses the requirements of the system in order to achieve the objectives outlined in section 1.5 of this document. The requirements gathered are divided into two categories: the functional requirement and nonfunctional requirements.

4.2.1 Functional Requirements

Functional Requirements define functions of the system or its components. They are demonstrated by the features of the system that enable it to perform one or all the tasks or goals intended for it to achieve. These include;

i. **Create account**

   The system allows a user to create the school account and specify the level of the school. The user who creates the school account automatically becomes the school admin. The school can have different system administrators depending on the level i.e. whether kindergarten, primary level or junior secondary level. Alternatively, the school can just decide to have one admin for all the levels. The system provides an interface for all necessary details to be entered. The admin is able to create all the other users and assign them the initial credentials they will use to access the system.

ii. **Login**

   All the users, including the school administrator will be authenticated using their username and password. Only then will they be allowed to access the system.

iii. **View users**

The system should allow the school admin to view all the system users the school has this includes staff, parents and students.

iv. **Edit user**

The system allows the school admin to edit a user.

v. **Delete user**

The school admin will have the right to remove or delete a staff member from the system once they leave the school.

vi. **Add bus**

The school admin can add a bus to the system. Adding a bus will involve entering all the required details such as the bus name, number plate etc.

vii. **Remove bus**

The system allows a bus to be removed from the database. A bus can be deleted if it is no longer in operation.

viii. **Add location**

The system will allow the school admin to add location and map it to a particular learner. This is the location that will be used for geofence during pickup or drop off of the learner.

ix. **Remove location**

The admin can remove a location from the system if no student is mapped to it. Alternatively, once a student leaves the school and is deleted from the database, she is deleted together with all linked information among them the location.

x. **Add zone**

The school admin can also add a new zone into the system and link it to a particular location. A location can belong to only one zone at a time.

xi. **Edit zone**

The system will allow the school admin to edit a zone.

xii. **Delete zone**

A zone will be deleted if there are no longer learners being picked up or dropped there.

xiii. **Create roles**

The system allows the school admin to create roles to the different users accordingly.

xiv. **Assign permissions**

The school admin is able to assign different permissions to the system users according to their roles.

xv. **View roles**

The admin is able to view the roles of all system users.

xvi. **Edit permissions**

The system allows the school admin to edit permissions depending on need for example if a user changes roles.

xvii. **Import files**

When creating the accounts for the different system users, the school admin can either import a file and the users will be created or can add users one by one.

xviii. **Scan fingerprint**

Learners shall be required to scan their fingerprints as they enter or alight the bus for them to be authenticated.

xix. **Logout**

System users can logout of the system at anytime.

4.2.2 Non-Functional Requirements

These are requirements that do not affect the way the system operates yet they are part of the system to enhance quality. The non-functional requirements of the system are;

i. Security – The system should allow access to only authorized users. Also data will be encrypted to ensure privacy of data and prevent unauthorized access.

ii. User friendly – The user interface should be easy to use.

iii. Performance – The system should be able to authenticate a learner within two seconds so as to save on time and give a better user experience.

iv. Reliability – The system should be reliable, and handling of downtime planned well. This is to ensure that the system should be up and running whenever needed.

v. Integrity – Data in the system should not be altered in anyway by authorized personnel.

vi. Scalability - As the number of students increases, the system should be able to scale to accommodate growth with minimal changes if necessary.

4.3 System Design

This section is an in-depth explanation of the major components of the system, their interactions, and how data flows in the system.

4.3.1 Use case Diagram

A use case diagram is a system design tool that illustrates the interactions between users and a system (Fauzan R., 2019). It helps users to understand the functional requirements of the system by illustrating the various ways in which users can interact with it.

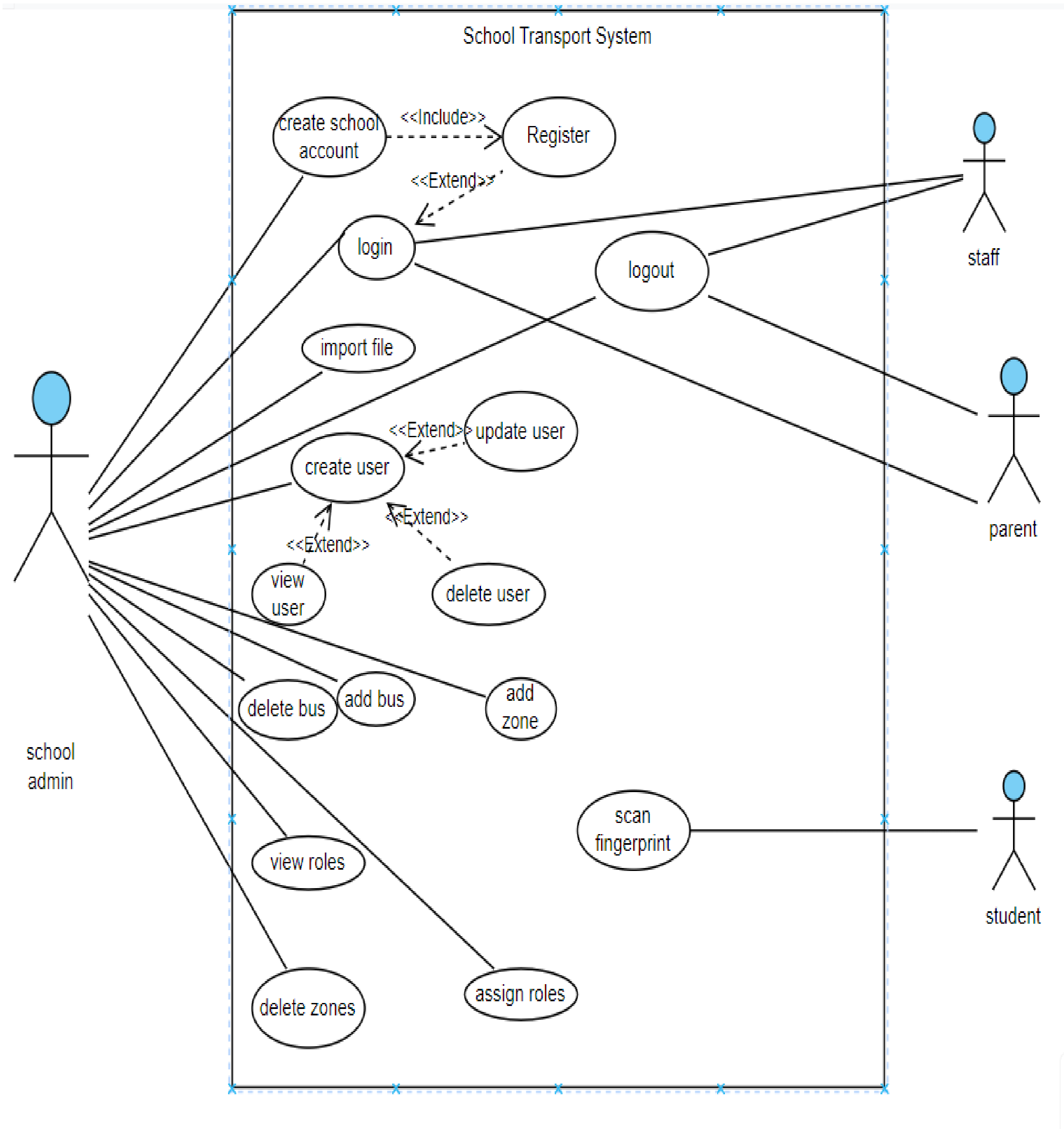


Figure 4.1: Use Case Diagram

4.3.2 Class Diagram

A class diagram is a UML diagram describing the structure of a system by showing all the system's classes, attributes, operations and the relationships that exist between the classes. Class diagrams presents a high-level view of the system thereby making it easier for the system to be well understood even by people who are not developers.

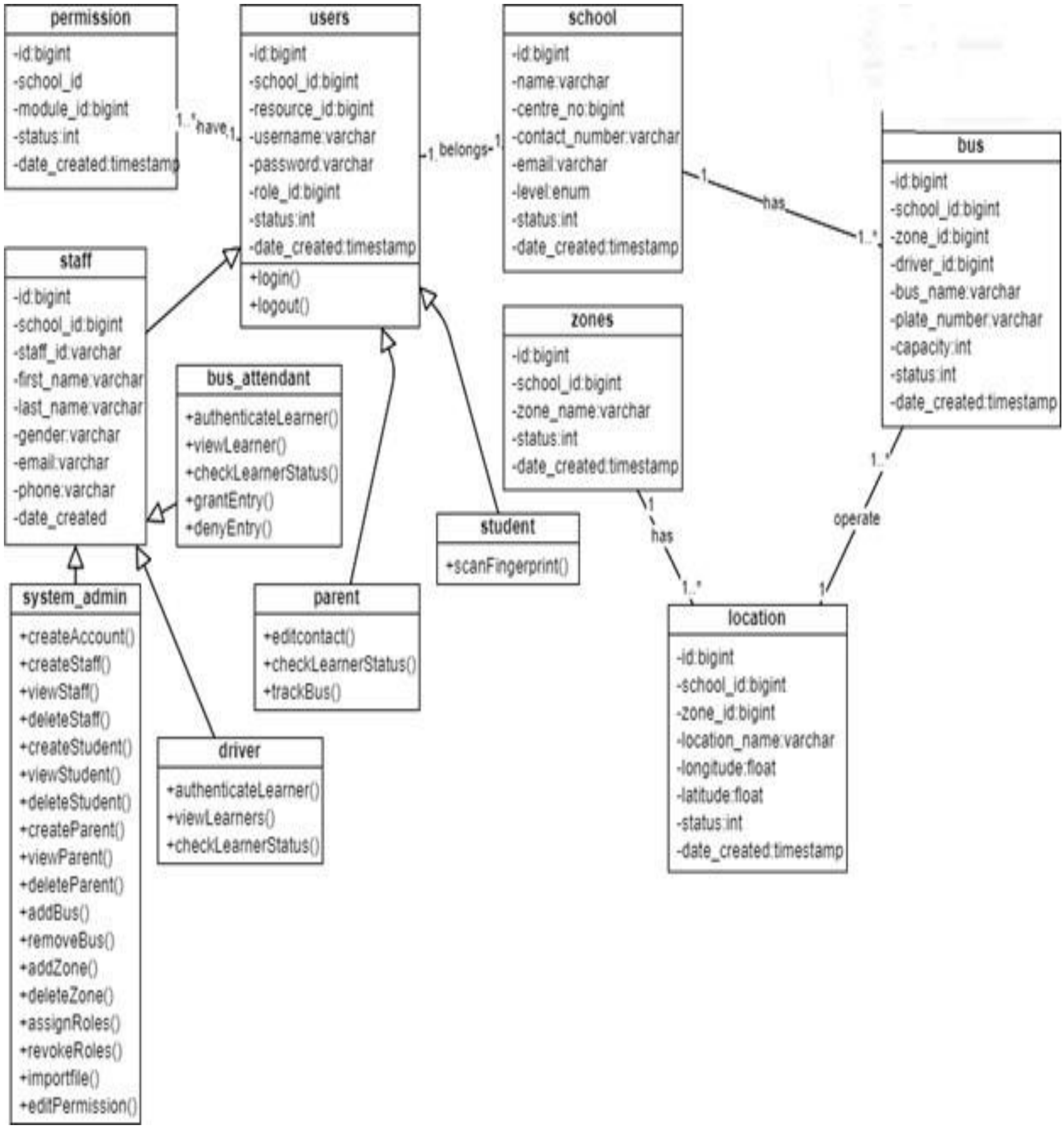


Figure 4.2: Class Diagram

4.3.3 Database schema

A database schema is a structure defining how data is organized in a relational database (Delplanque J., 2018). A relational database is one where data is logically structured or stored in tables(relations). Database schema represents the storage of data in the database and gives the relationships between the tables.

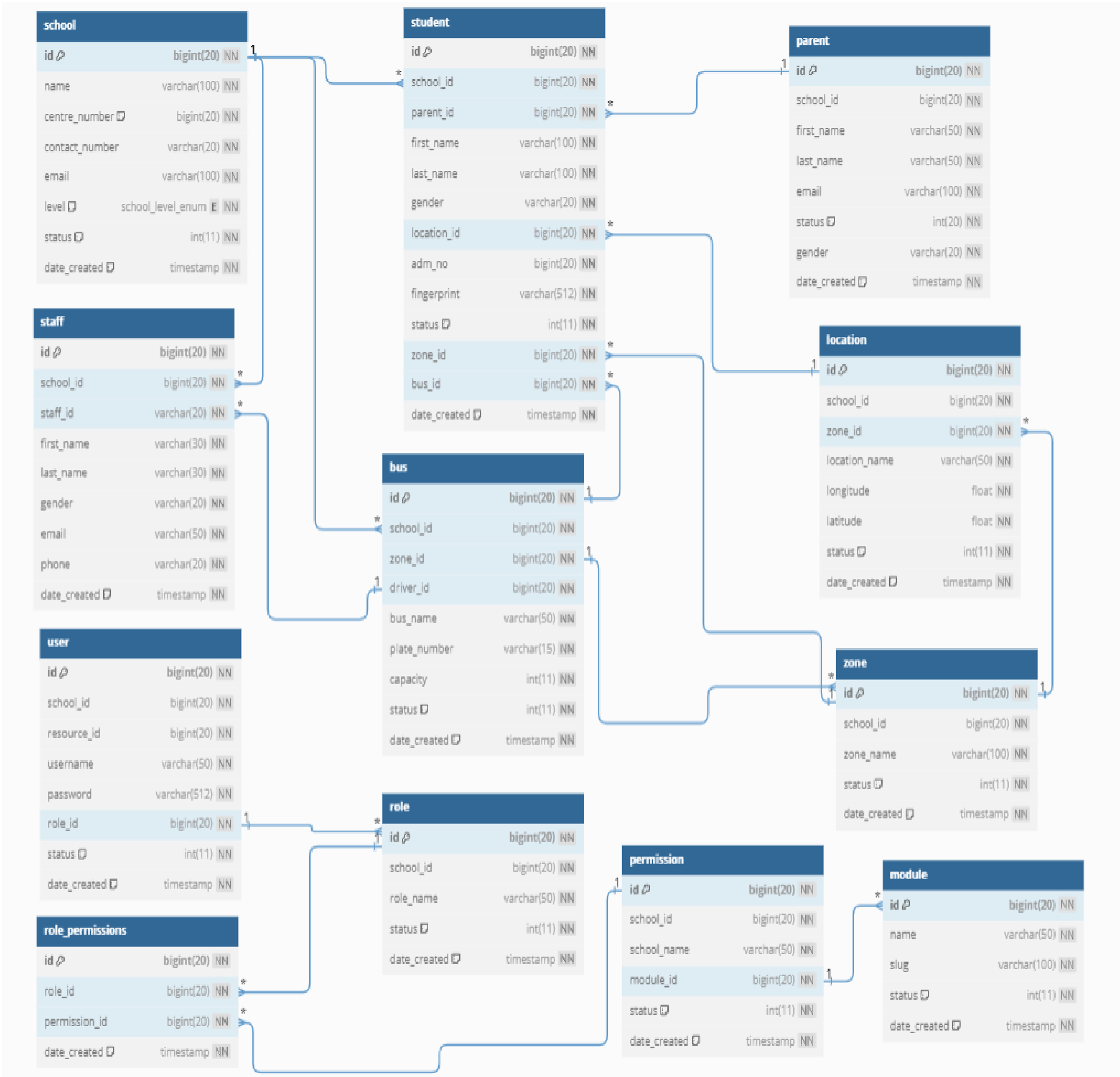


Figure 4.3: Database Schema

4.3.4 Sequence Diagram

Figure 4.3 below shows the sequence diagram of the system. A sequence diagram is a high-level diagram which captures exchange-based behaviour with reference to a sequence of messages between actors (Laosen & Nantajeewarawat, 2018). It shows the sequence of messages passed between objects in a defined interaction. Sequence diagrams are very helpful for understanding real-time specifications and complex use cases as they emphasize the time-based ordering of the activity that takes place among a set of objects.

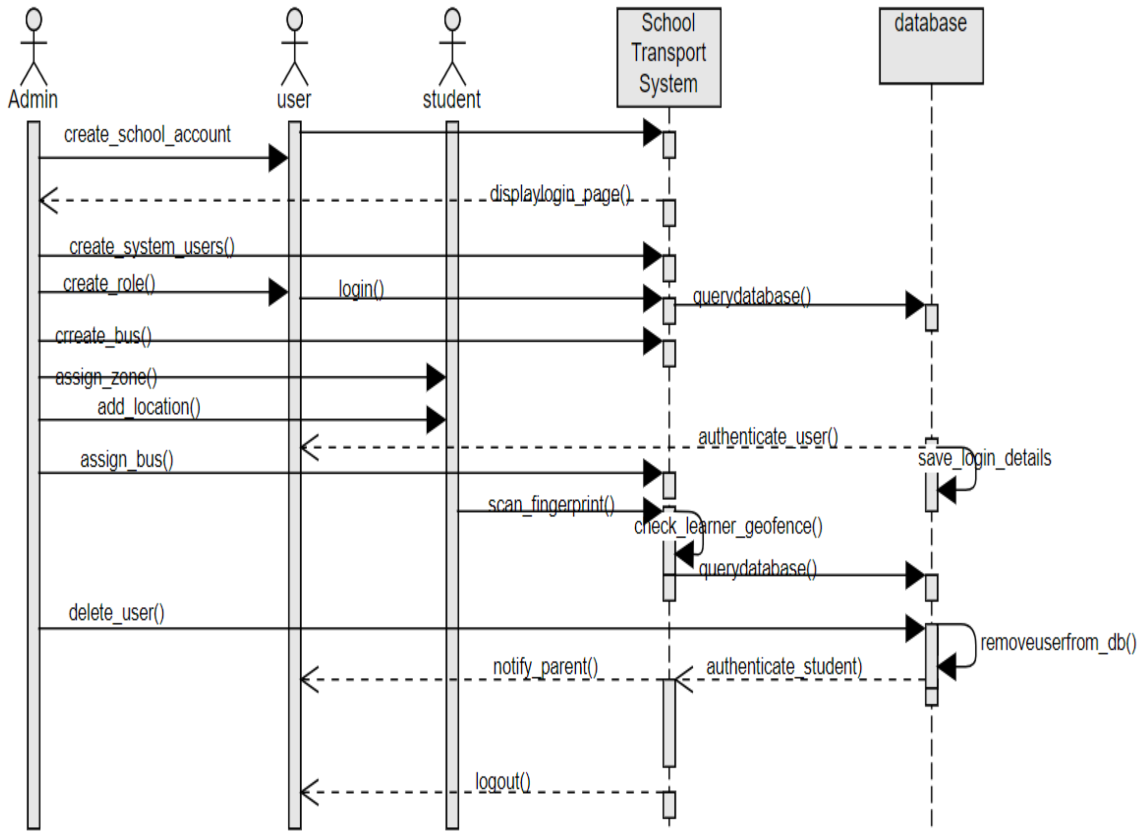


Figure 4.4: Sequence Diagram

4.3.5 Wireframes

A system wireframe is a design for interacting with the system or for visualization of how the system functions (Roth et al., 2017). The wireframe however may display fewer features than what the entire system provides (de Lange et al., 2020)**.**

4.3.5.1 Registration wireframe

The registration page allows a user to create the school account and feed all the information requested in the form. The user who creates the school account automatically becomes the school administrator.

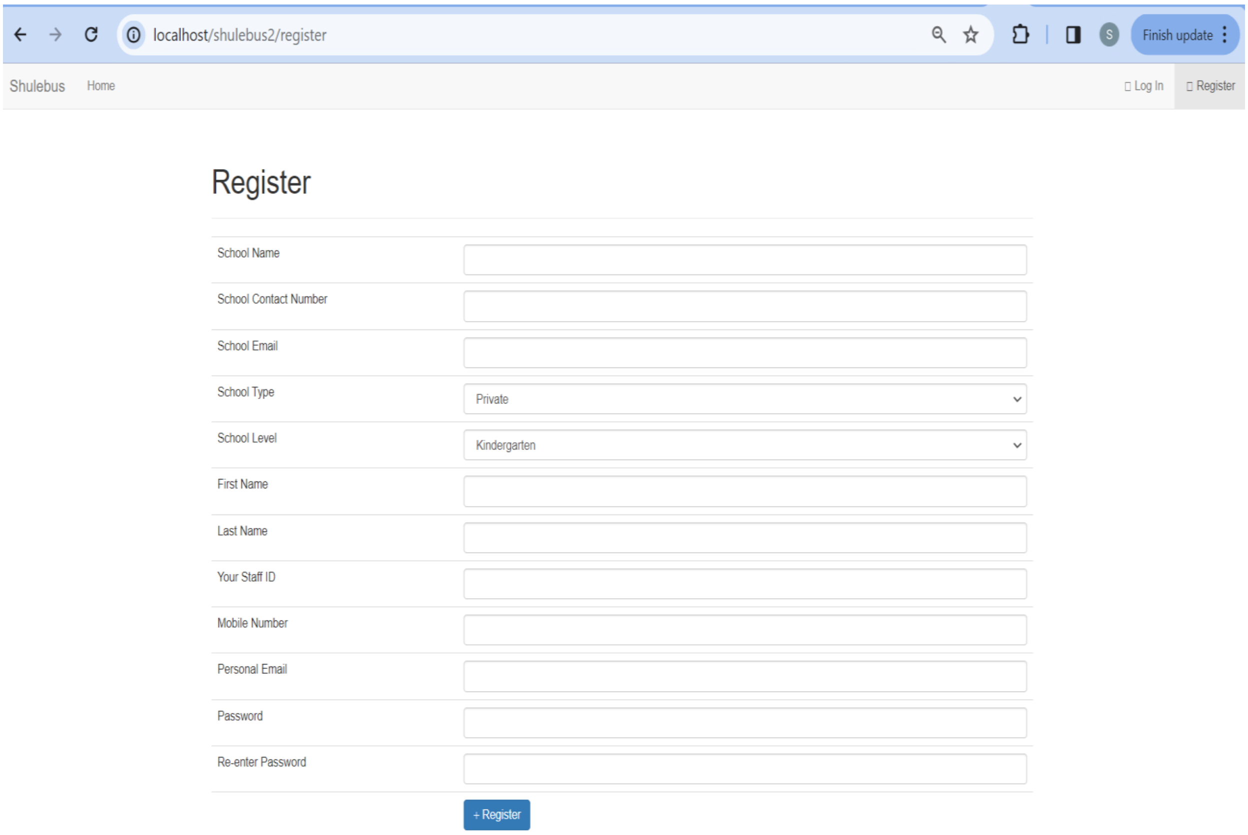


Figure 4.5: Registration wireframe

4.3.5.2 Login Wireframe

The login page contains a form that allows users to login to the system with their correct credentials i.e. their username and password.

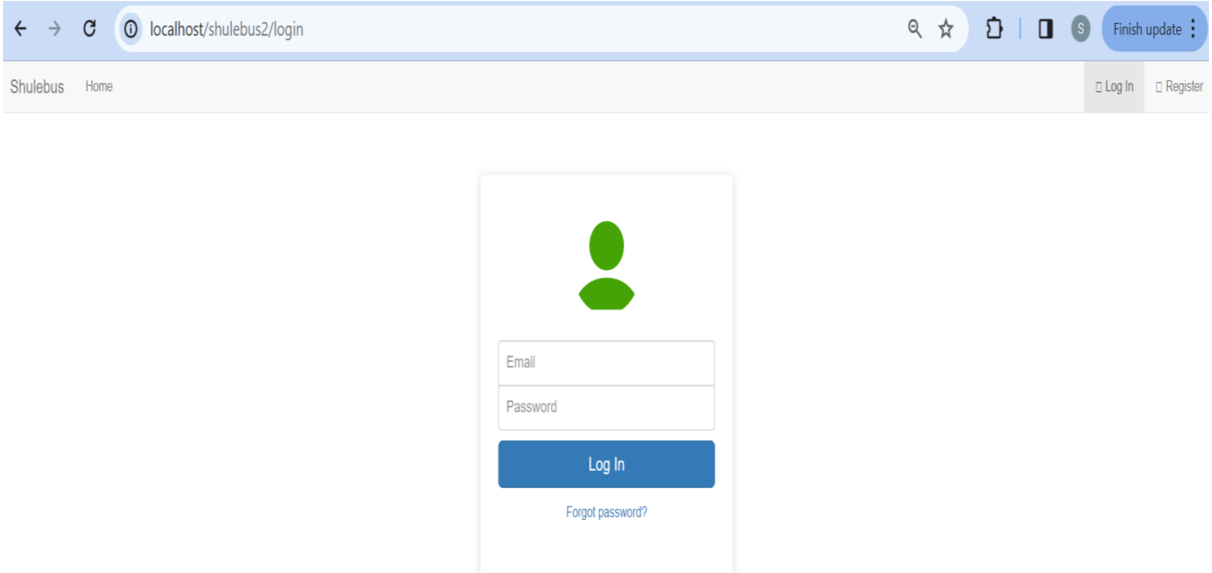


Figure 4.6: Login wireframe

4.3.5.3 Locations wireframe

The locations page contains a form where a user can enter location and map it to a particular zone. Figure 4.7 below shows locations wireframe.

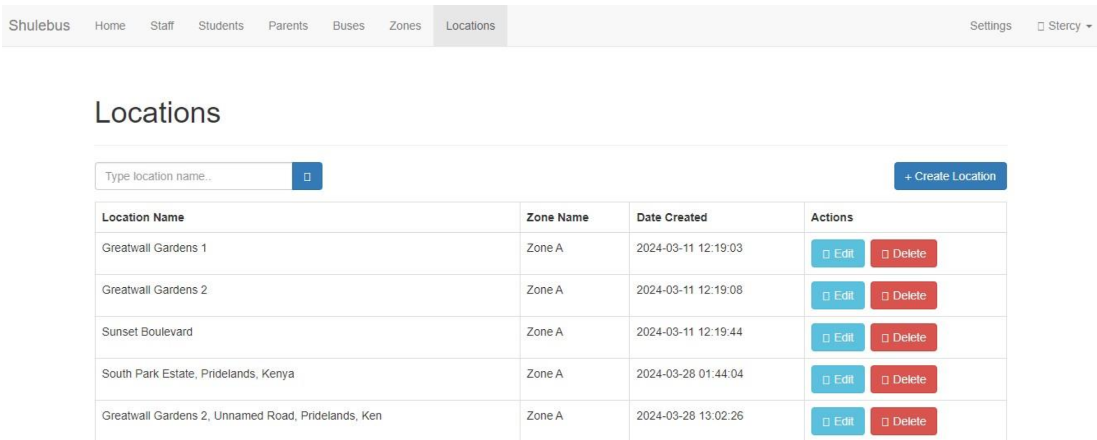


Figure 4.7: Locations Wireframe

4.3.5.4 *Creating Locations Wireframe*

As the user types the location suggestions for the locations are provided and longitude and latitude for the selected location are stored.

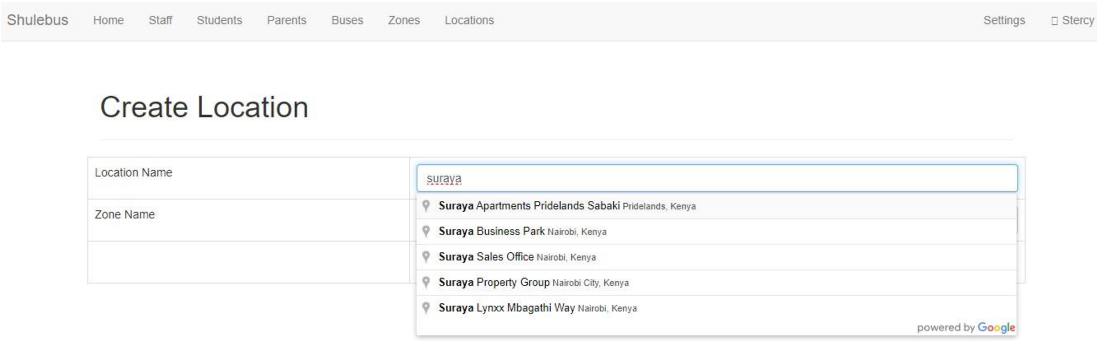


Figure 4.8: Creating Locations Wireframe

4.3.5.5 *Zones Wireframe*

The zones page allows users to view the registered zones.

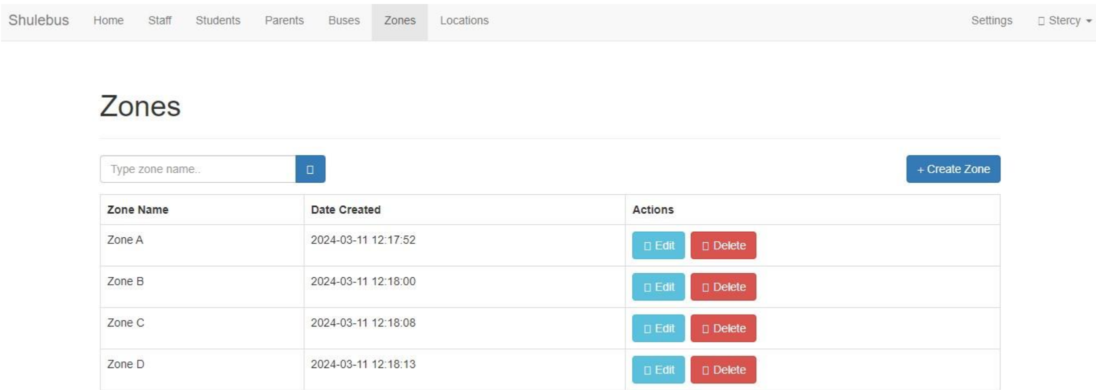


Figure 4.9: Zones Wireframe

4.3.5.6 *search Locations Wireframe*

Searching locations is under the locations page and allows users to search for a specified location.

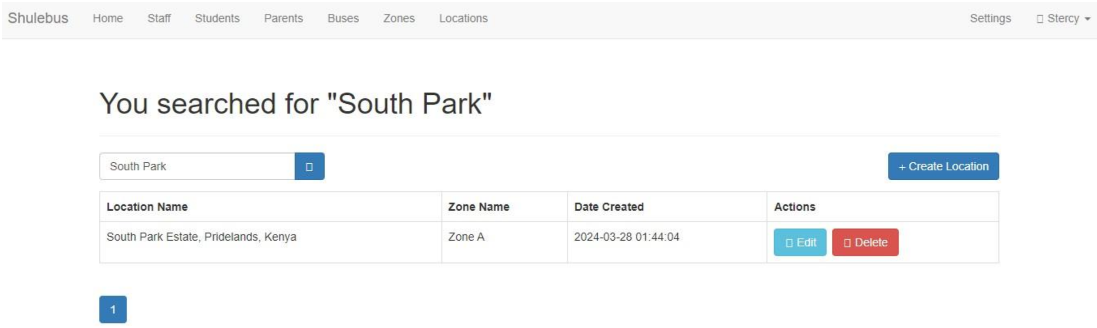


Figure 4.10: Search Location Wireframe

4.3.5.7 *Buses Wireframe*

The buses page allows a user to view buses.

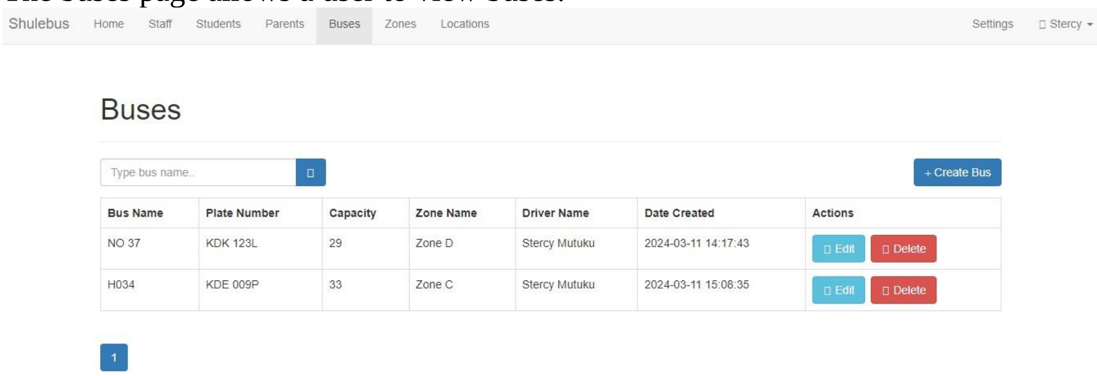


Figure 4.11: Buses Wireframe

4.3.5.8 *Create Bus Wireframe*

Create bus creates or adds a new bus to the database.

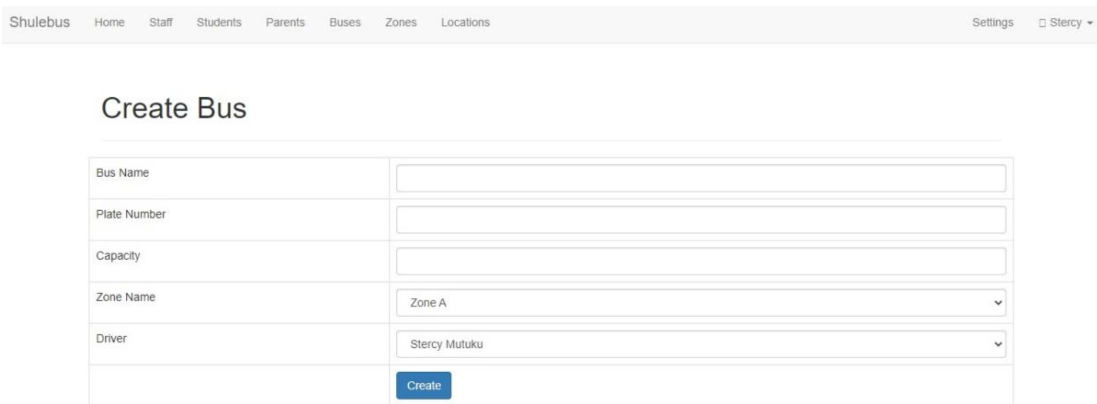


Figure 4.12: Create Bus Wireframe

Chapter 5: System Implementation and Testing

5.1 Introduction

System Implementation describes how the system design was implemented to a working prototype. The whole system comprises of three parts; an android application which is used to verify that the learner is picked and dropped at the right location and send an alert where necessary, a web application for back-office operations by the management and a relational database. Testing of the prototype includes functional and usability tests to ascertain that the system accomplishes the objectives stated chapter one.

5.2 System Development Environment

The system development environment outlines the characteristics of the hardware and software components that were used to develop the prototypes of the system. The specifications were as shown below.

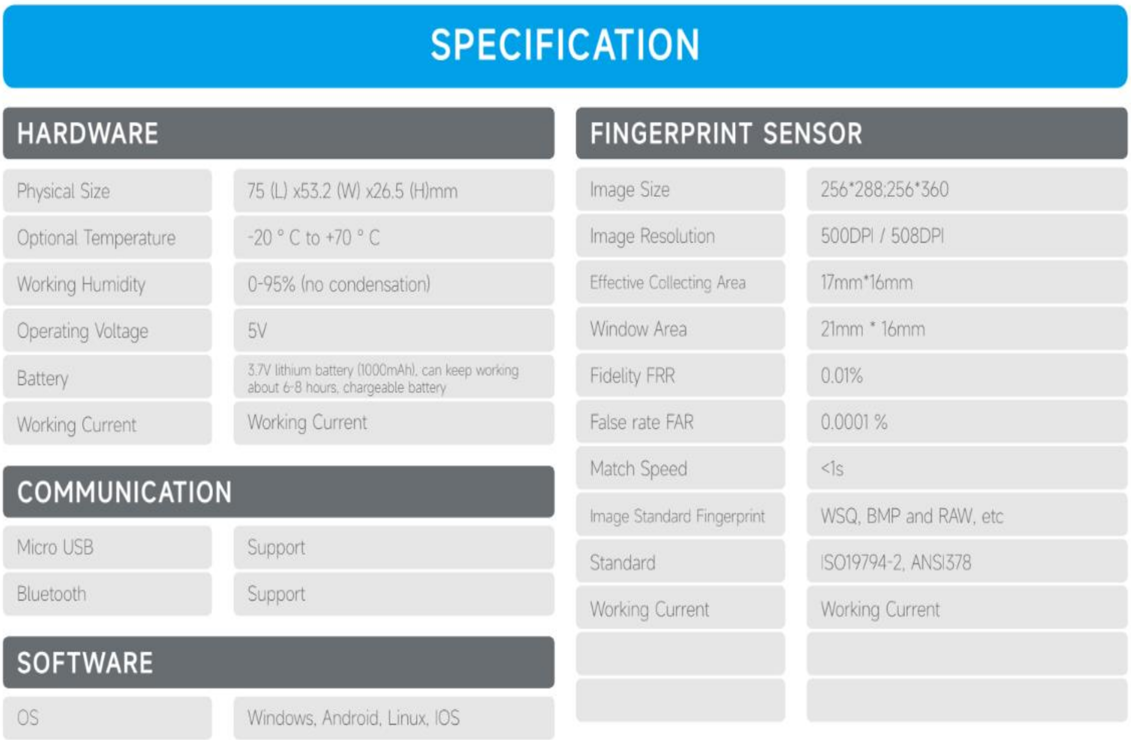
5.2.1 Hardware Requirements

Table 5.1 below shows the hardware requirements for creating a safe school transport system using fingerprint technology and geofencing.

Table 1: Hardware Requirements

Hardware	Description
Laptop: Lenovo 82R7, 12th Gen intel® CORE i7 – 1255U, 16GB RAM and 512GB SSD	Used for development of the mobile and web application
Wireless fingerprint scanner:	For capturing learner’s fingerprint

Wireless fingerprint Scanner specifications



SPECIFICATION

HARDWARE	
Physical Size	75 (L) x53.2 (W) x26.5 (H)mm
Optional Temperature	-20 ° C to +70 ° C
Working Humidity	0-95% (no condensation)
Operating Voltage	5V
Battery	3.7V lithium battery (1000mAh), can keep working about 6-8 hours, chargeable battery
Working Current	Working Current

COMMUNICATION	
Micro USB	Support
Bluetooth	Support

SOFTWARE	
OS	Windows, Android, Linux, IOS

FINGERPRINT SENSOR	
Image Size	256*288;256*360
Image Resolution	500DPI / 508DPI
Effective Collecting Area	17mm*16mm
Window Area	21mm * 16mm
Fidelity FRR	0.01%
False rate FAR	0.0001 %
Match Speed	<1s
Image Standard Fingerprint	WSQ, BMP and RAW, etc
Standard	ISO19794-2, ANSI378
Working Current	Working Current

Figure 5.1: Wireless Fingerprint Scanner Specifications

5.2.2 Software Requirements

Table 5.2 below outlines the software requirements used in developing the prototype of the system.

Table 2: Software Requirements

Software	Description
Android Studio	The integrated development environment used for the mobile application.
Operating system	Windows 11
Microsoft word	Used in documenting the dissertation
firebase	Relays the processed data in real-time
Visual Studio Code	1.85.2

HTML	Used for creating and structuring the web application
PHP	For backend scripting
CSS	Used for styling the web application
JavaScript	For creating an interactive web page
Java	Used for developing the mobile application
Chrome browser	Running the web application
MySQL Database Management System	Database management
Apache	Web Server

5.3 Test Cases

Testing was carried out on the system to assess if it met the functional requirements stated in section 4.2.

5.3.1 Functional Testing

The system was tested based on the functional requirements to establish whether all desired functionality was achieved.

Table 3: Functional Testing

No	Test	Expected Results
1	Registration	A user should be able to register a school.
2	Creating Admin Account	The user who creates the school account becomes the school admin after entering his personal details.
3	Login	Once a user is created, they should be able to login.
4	Creating staff	The admin should be able to create a staff.
5	Creating student	The school admin should be able to enrol a student, view them or remove them.
6	Creating parent	The school admin should be able to create a parent and link them to the respective student.

7	Creating bus	The school admin should be able to add a bus or remove a bus once it stops operating.
8	Creating zone	The school admin should be able to create a zone, edit it or remove it based on the location.
9	Assign roles	The school admin should be able to assign roles to the staff.
10	Assign permissions	The school admin should be able to grant or revoke permissions depending on the current role of a staff.
11	logout	A user should be able to logout

5.3.2 Compatibility Testing

Compatibility was done for most browsers to ascertain that the system was compatible with most of them. Table 5.4 below displays the web browser compatibility test results.

Table 4: Compatibility Testing

Browser	Compatibility
Chrome	Compatible
Microsoft edge	Compatible
Mozilla Firefox	Compatible

5.3.3 Unit Testing

Each unit in the web app and the mobile application was tested by running the code which allowed viewing the results at each stage of the code. Registration module was tested for successful registration of users. The login module was tested for successful login. Wrong credentials were supplied to test if unauthorised user could access the system. The create users module was tested for successful creation of different users. The location module was tested to ensure it returned the anticipated coordinates for longitude and latitude using the Google places API. Fingerprint module was tested to ensure successful returning of a byte array of the captured fingerprint data which is converted into a base 64 string for storage in the database. Vehicle module was tested for successful addition and deletion of buses. Enrolment module was tested for successful enrolment of learners. Capturing module was tested for successful capturing of learner’s fingerprint for authentication when picking or dropping them.

Matching module was tested for successful matching the captured fingerprint against the enrolled fingerprint.

5.3.4 Integration Testing

Components were integrated then tested together as a unit. Interoperability between the different components of the system was tested to ascertain that the components worked as anticipated.

5.3.5 User Testing

User testing was done by a few willing individuals to ascertain that the system met the functional requirements. The tests confirmed the functionality and of the system.

5.4 Test Results

Table 5: Test Results

No	Test	Expected Results	Achieved Results
1	Registration	A user should be able to register a school.	Registration done successfully
2	Creating Admin Account	The user who creates the school account becomes the school admin after entering his personal details.	Admin account was created successfully
3	Login	Once a user is created, they should be able to login.	Users logged into the system successfully
4	Creating staff	The admin should be able to create a staff.	Staff was created successfully, could be viewed, or deleted.
5	Creating student	The school admin should be able to enrol a student, view them or remove them.	Student was created successfully, could be viewed, or deleted
6	Creating parent	The school admin should be able to create a parent and link them to the respective student.	Parent was created successfully, could be viewed or deleted

7	Creating bus	The school admin should be able to add a bus or remove a bus once it stops operating.	Adding or removing of bus was done successfully.
8	Creating zone	The school admin should be able to create a zone, edit it or remove it based on the location.	Zones were created successfully.
9	Assign roles	The school admin should be able to assign roles to the staff.	Roles assigned successfully.
10	Assign permissions	The school admin should be able to grant or revoke permissions depending on the current role of a staff.	Granting or revoking of permissions was done successfully.
11	logout	A user should be able to logout	A user logged out successfully.

5.5 Implementation

System implementation involves putting the new system into operation. The web application displays data stored in the database. There are two major categories of users in the system: the system administrators and normal users. Here are some algorithms.

5.5.1 Algorithm 1: Enrol Fingerprint Template

This algorithm facilitates the enrolment of fingerprint data by sending it to the web server via an HTTP POST request and handling server responses and errors appropriately.

The Progress Dialog Initialization creates and displays a progress dialog (progressDialog) to indicate that the enrolment process is in progress. Request Initialization creates a StringRequest object (stringRequest) using Volley library to make an HTTP POST request to the enrolment API endpoint (URL+"EnrollFingerprint"). It also defines response and error listeners to handle server responses and errors appropriately. The request is added to a request queue (requestQueue) for execution. A retry policy is set for the request, allowing it to retry on timeout. Upon receiving a response from the server, the onResponse method is called. The response is logged, and the progress dialog is dismissed. The response data is parsed as a JSON object, and a message from the server is displayed as a toast message. The getStudents method is called to update the list of enrolled students after a successful enrolment. Error handling is implemented in the onErrorResponse method, where the progress dialog is dismissed upon encountering an error. A HashMap is used to construct a set of parameters (params) to be sent with the request.

It includes the student ID, the size of the fingerprint data, and the fingerprint data itself encoded as a Base64 string.

```
private void EnrollTemplate(final byte[] fingerData) {
    final ProgressDialog progressDialog = new ProgressDialog(this);
    progressDialog.setIndeterminate(true);
    progressDialog.setMessage("Enrolling...");
    progressDialog.show();

    StringRequest stringRequest = new StringRequest(Request.Method.POST,
URL+"EnrollFingerprint",
            new com.android.volley.Response.Listener<String>() {
                @Override
                public void onResponse(String response) {
                    Log.d("Response",response);
                    progressDialog.dismiss();

                    try {
                        JSONObject jObj = new JSONObject(response);
                        String message = jObj.getString("message");

Toast.makeText(MainActivity.this,message,Toast.LENGTH_LONG).show();

                        getStudents();

                    } catch (JSONException e) {
                        e.printStackTrace();
                    }
```

```
            }
        },
        new com.android.volley.Response.ErrorListener() {
            @Override
            public void onErrorResponse(VolleyError error) {
                progressDialog.dismiss();
            }
        }) {
    @Override
    protected Map<String, String> getParams() throws AuthFailureError {
        Map<String, String> params = new HashMap<>();
        // the GET parameters:
        params.put("id", String.valueOf(student_id));
        params.put("size", String.valueOf(fingerData.length));
        params.put("data", Base64.encodeToString(fingerData, 0, fingerData.length,
Base64.NO_WRAP));

        return params;
    }
  };

  //Creating a Request Queue
  RequestQueue requestQueue = Volley.newRequestQueue(MainActivity.this);
  //change the retry timeout
  stringRequest.setRetryPolicy(new
DefaultRetryPolicy(DefaultRetryPolicy.DEFAULT_TIMEOUT_MS * 100,
        0, DefaultRetryPolicy.DEFAULT_BACKOFF_MULT));
  //Adding request to the queue
  requestQueue.add(stringRequest);

}
```

Figure 5.2: Algorithm 1 - Enrol Fingerprint Template

5.5.2 Algorithm 2: Match Template

This algorithm serves to authenticate captured fingerprint data against enrolled fingerprint data stored on the database, and take appropriate actions based on the authentication result. The Volley library is used for making API requests. A progress dialog (progressDialog) is initialized to indicate that authentication is in progress. A StringRequest object (stringRequest) is created using Volley library. This object defines an HTTP POST request to the fingerprint authentication API endpoint (URL+"auth"). The request is added to a request queue (requestQueue) for execution. A retry policy for the request is also specified. After receiving a response from the server, the onResponse method is called. The response is logged, and the progress dialog is dismissed. The response data is parsed, and if the operation is successful (code == 1), the fingerprint data of enrolled students is retrieved from the response. For each enrolled student, their fingerprint data is decoded from Base64 to a byte array, and a matching score is calculated against the captured fingerprint data (capturedData). This is done using the fingerprint SDK supplied by the device vendor. If the matching score is above a certain threshold (50), authentication is considered successful, and further actions such as retrieving student details and sending notifications are performed. If no match is found for any enrolled student, an appropriate message is displayed to the driver. Finally, the btnCapture is programmatically clicked to initiate another capture attempt. Error handling is implemented in the onErrorResponse method, where the progress dialog is dismissed upon encountering an error.

```
private void MatchTemplate(final byte[] capturedData) {

    final ProgressDialog progressDialog = new ProgressDialog(this);
    progressDialog.setIndeterminate(true);
    progressDialog.setMessage("Authenticating...");
    progressDialog.show();

    StringRequest stringRequest = new StringRequest(Request.Method.POST,
URL+"auth",
            new com.android.volley.Response.Listener<String>() {
                @Override
                public void onResponse(String response) {
```

```
                Log.d("Auth Response",response);
                progressDialog.dismiss();

                try {
                    JSONObject jObj = new JSONObject(response);
                    String message = jObj.getString("message");
                    int code = jObj.getInt("code");
                    final JSONArray jsonArray = jObj.getJSONArray("data");

                    if (code == 1) {
                        for(int i = 0; i < jsonArray.length(); i++) {
                            JSONObject jsonObject = jsonArray.getJSONObject(i);

                            final String studentFingerPrint = jsonObject.getString("data");

                            byte[] byteData = Base64.decode(studentFingerPrint,
Base64.DEFAULT);

                            boolean authStatus = false;

                            int score = fingerSDK.matchTemplate(capturedData, byteData);

                            if (score >= 50) {
                                AddStatusList("SUCCESS. Match Score:" +
String.valueOf(score));
                                getStudentDetails(jsonObject.getString("student_id"));
                                authStatus = true;
                            }
                            if (!authStatus) {
                               AddStatusList("Match Failed");
                                Toast.makeText(context,"Unable to identify
student!",Toast.LENGTH_LONG).show();
                            }
```

```
                        btnCapture.performClick();
                    }


                } else{
                    Toast.makeText(MainActivity.this,"Unable to process
request",Toast.LENGTH_LONG).show();
                }
            } catch (Exception e) {
                e.printStackTrace();
            }


        }
    },
    new com.android.volley.Response.ErrorListener() {
        @Override
        public void onErrorResponse(VolleyError error) {
            progressDialog.dismiss();
        }
    }) {
  @Override
  protected Map<String, String> getParams() throws AuthFailureError {
      Map<String, String> params = new HashMap<>();
      return params;
  }
};

//Creating a Request Queue
RequestQueue requestQueue = Volley.newRequestQueue(MainActivity.this);
//change the retry timeout
stringRequest.setRetryPolicy(new
DefaultRetryPolicy(DefaultRetryPolicy.DEFAULT_TIMEOUT_MS * 100,
        0, DefaultRetryPolicy.DEFAULT_BACKOFF_MULT));
//Adding request to the queue
requestQueue.add(stringRequest);
```

```
}
```

Figure 5.3: Algorithm 2 - Match Template

5.5.3 Algorithm 3: Google Places API

Included within the <head>

```
<script src="https://polyfill.io/v3/polyfill.min.js?features=default"></script>
<script type="module" src="../libs/js/./places.js"></script>
```

Included within the <body>

```
<script

src="https://maps.googleapis.com/maps/api/js?key=<KEY>&callback=initAutocom
plete&libraries=places&v=weekly"
      defer>
</script>
```

The src attribute specifies the source (URL) of the script to be loaded.

The script source is https://maps.googleapis.com/maps/api/js?key=<API KEY>&callback=initAutocomplete&libraries=places&v=weekly. This URL points to the Google Maps JavaScript API. The API key is necessary for authentication and regulating access when using the Google Maps API. The initAutocomplete is called once the Maps API is ready for use. The libraries specify additional libraries to load along with the Google Maps API. Here it is set to places, which loads the Places Library, allowing the use of features related to place search and details.

The v parameter specifies the version of the Google Maps JavaScript API to load. Here the v is set to weekly. It loads the latest weekly version of the API. The defer attribute allows the browser to continue parsing and loading other elements on the page while the script is being fetched. This can help improve page loading performance.

5.5.4 Initializing Places Api and Autocomplete Input Field

This code initializes a Google Places Autocomplete search box on the location name input field with id (location_input). It restricts the autocomplete results to locations within Kenya. When a user selects a place from the autocomplete suggestions or types in a location and presses enter, the latitude and longitude of the selected place are retrieved and populated into specified input fields (latitude and longitude).

```
function initPlaces() {

  // Create the search box and link it to the UI element.
  const input = document.getElementById("location_input");

  //restrict places to Kenya
  var options = {
    componentRestrictions: { country: 'ke' }
  };
  const searchBox = new google.maps.places.Autocomplete(input, options);

  var latitudeInput = document.getElementById('latitude');
  var longitudeInput = document.getElementById('longitude');

  searchBox.addListener('place_changed', function (event) {
    var place = searchBox.getPlace();

    if (place.hasOwnProperty('place_id')) {
      if (!place.geometry) {
        window.alert("The returned place contains no geometry");
        return;
      }
      latitudeInput.value = place.geometry.location.lat();
      longitudeInput.value = place.geometry.location.lng();
    } else {
      service.textSearch({
        query: place.name
      }, function (results, status) {
        if (status == google.maps.places.PlacesServiceStatus.OK) {
          latitudeInput.value = results[0].geometry.location.lat();
```

```
                longitudeInput.value = results[0].geometry.location.lng();
            }
        });
    }
  });
}

window.initAutocomplete = initPlaces;
```

Figure 5.4: Algorithm 3 - Initializing Places Api and Autocomplete Input Field

5.5.5 Algorithm 4: Geofencing

This query retrieves information about a specific student and their location while calculating the distance between their location and a given set of latitude and longitude coordinates. It then selects the closest location within a certain distance threshold.

```
SELECT student.*,

    6371 * 2 * ASIN(SQRT(POWER(SIN(($current_lat - location.latitude) * pi()/180 / 2), 2)

    + COS($current_lat * pi()/180 ) * COS(location.latitude * pi()/180)


    * POWER(SIN(($current_lng - location.longitude) * pi()/180 / 2), 2) )) as distance,

location.latitude,location.longitude FROM `student` LEFT JOIN location ON location.id = student.location_id

WHERE student.id = $student_id AND location.status = 1 GROUP BY location.id HAVING distance < 0.3

ORDER BY distance ASC LIMIT 0,1
```

Figure 5.5: Algorithm 4 - Geofencing

This SQL query retrieves information about a student and calculates the distance between their location and a given set of latitude and longitude coordinates ($current_lat and $current_lng). Geofencing uses the Haversine formular to get the latitudes and longitudes. The Haversine formular calculates the shortest distance between two points on the surface of a sphere, given their coordinates. It's commonly used to compute distances between two points on the Earth's surface, making it useful for applications such as geographical positioning systems (GPS) and location-based services (Basyir et al., 2017).

The Haversine formula is utilized here to calculate the distance between the specified latitude and longitude coordinates and the latitude and longitude coordinates of the student's location in the database.

5.5.6 The Haversine Formula

The Haversine formula calculates the shortest distance d between two points on the surface of a sphere given their latitudes lat_1 and lat_2 and longitudes lon_1 and lon_2. The formula is as follows:

$$d = 2 \cdot R \cdot \mathrm{asin}\left(\sqrt{\mathrm{hav}(\Delta\mathrm{lat}) + \cos(\mathrm{lat}_1) \cdot \cos(\mathrm{lat}_2) \cdot \mathrm{hav}(\Delta\mathrm{lon})}\right)$$

Where:

- R is the radius of the sphere (typically the Earth's radius, which is approximately 6371 kilometers or 3956 miles).
- $\mathrm{hav}(\theta)$ represents the haversine function, defined as $\mathrm{hav}(\theta) = \sin^2\left(\frac{\theta}{2}\right)$.
- $\Delta\mathrm{lat} = \mathrm{lat}_2 - \mathrm{lat}_1$ is the difference in latitude between the two points, in radians.
- $\Delta\mathrm{lon} = \mathrm{lon}_2 - \mathrm{lon}_1$ is the difference in longitude between the two points, in radians.

This formula provides an accurate calculation of distances over short distances, but its accuracy diminishes over longer distances due to the Earth's curvature not being perfectly spherical.

Figure 5.6: The Haversine Formula

Chapter 6: Discussions

6.1 Introduction

This chapter discusses the research findings based on the developed system to ascertain whether the objectives set at the beginning of the research were accomplished. The researcher's aim was to develop a system that could allow for enrolment of learners, use fingerprint technology to authenticate the learners and use geofencing technology to send a notification when the school bus leaves a learner's geofence without dropping or dropping them, yet their status is set as active. The study was built on four objectives. The core objective is to develop a safe school transport system using fingerprint and geofencing technology.

6.2 Review of the Research Objectives

Fingerprint and geofencing technology have the potential to revolutionize the way school transport is tackled in Nairobi and its outskirts. A review of the research objectives highlights their relevance and importance in addressing the challenges faced by learners and parents as they use the existing school transport systems. It was found that there is no single existing school transport system that could guarantee the inability to refute responsibility when something goes wrong regarding a learner. There was a need therefore to develop a more secure system for authentication of learners using their genetic characteristics which are unique for each person.

Some researchers have used other technologies to address the challenge of learner safety to and from school. These include the use of manual registers to counter check learners' names, NFC cards to detect when they are near or aboard the school bus and when they leave and use of fingerprint biometric. All these methods have in the past been used to address the challenges of insecurity. However, the combination of fingerprint technology and geofence leads to the achievement of the safety goal as stated in objective 3.

6.3 System assessment

The developed system requires users to have access to the internet in order to use the features. The benefits and drawbacks of using the developed system are discussed below.

6.3.1 *Advantages of the developed system*

i. The application is compatible with most of the browsers such as Google chrome, Microsoft edge and Mozilla Firefox.
ii. The security threat of learners on transit is eliminated. Safety of learners is achieved.
iii. The school can accurately track student during pick-up and drop-off.
iv. Geofencing is important to the school as administrators can receive alerts if vehicles deviate from pre-defined routes.
v. Administrators and parents can receive instant notifications if a learner fails to board or alight the school bus at the designated location facilitating prompt action to ensure learner safety.
vi. Parents can receive automated notifications regarding pick-up and drop-off of learners.

6.3.2 *Disadvantages of the Developed System*

i. System relies on internet connection to function.
ii. School administrator does a lot of tasks and may be overwhelmed.

Chapter 7: Conclusion and Recommendations

7.1 Conclusion

The development of a safer school transport system using fingerprint technology and geofencing technology has demonstrated significant improvement of safety among learners while on transit to and from school. The system can help not only St. Bakhita School Sabaki but also other schools within Nairobi to curb the issue of insecurity of learners during pick up or drop-off from school. The developed system allows each parent to track the school bus and send appropriate notifications regarding their children. Each user is given the minimum permissions that allow them to perform their tasks. This ensures that the system is secure, and the system keeps logs of all activities.

7.2 Recommendations

Based on the results of the study, the researcher recommends:

i. The use of machine learning to predict if more parents would be willing to enrol their children for the school transport or not.

ii. Integration of the school transport system with existing school management software to streamline administrative processes, such as learner enrolment, scheduling, and communication with parents.

iii. Conducting periodic assessments to allow for the identification of potential vulnerabilities or areas for improvement.

iv. Users be informed about the importance of safeguarding their login details as sharing them they may lead to unauthorised access into the system.

v. School admin should only grant necessary permissions to the right staff.

7.3 Future Works

More research could be done on how:

i. The system would verify those who pick up the learners during drop off.

ii. Machine learning could be used to help in route optimization and weather analysis then notify parents accordingly.

iii. Developing predictive analytics models could help to anticipate demand for school transport services based on historical data.

iv. To integrate the transport system with student information systems to streamline data management.

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Appendix A: Timeline of Activities

Table 6: Timeline of activities

	Task	Comments	Start	End	Dur	%	2023				2024					
							Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
	Proposal/Dissertation timelines		9/1/23	6/28/24	213											
1	Proposal submission		9/1/23	9/13/23	9											
2	proposal defence		9/25/23	10/2/23	6											
3	correcting of proposals		10/2/23	10/31/23	21											
4	submission of proposals for ethical clearance		10/2/23	10/31/23	21											
5	Submission of Dissertation to Graduate Studies office for examination		3/18/24	3/29/24	10											
6	Documents dispached to examiners		4/2/24	4/2/24	1											
7	Examiners return the assessed documents and reports		4/23/24	4/23/24	1											
8	Final oral defence		4/30/24	5/10/24	9											
9	Submission of Dissertation correction forms, certification of final version of Dissertation forms and the final bound copies of OGS as well as the electronic copies		5/29/24	5/29/24	1											
10	Graduation		6/28/24	6/28/24	1											

APPENDIX B: Consent Form and Data Collection Tools

Parental Notification and Consent Form for the use of Biometric Data

RE: Notification of intention to process pupils' biometric information and consent form

Dear Parent/Guardian,

I am writing to notify you of the school's wishes to use information about your child as part of an automated (i.e., electronically operated) recognition system. The purpose of this system isto reinforce safety of the learners at pick-up and drop-off locations. The information from your child that we wish to use is referred to as 'biometric information'.

Biometric information and how it will be used

Biometric information is information about a person's physical or behavioural characteristics that can be used to identify them, e.g., their fingerprint. The school would like to collect and use the following biometric information from your child:

- Fingerprint to use the transport system.

The school would like to use this information for the purpose of providing your child with a secure environment while on transit to or from school. The learners will only access the bus after their fingerprints are scanned and verified.

For parents that have provided consent

Please confirm that you have read and understood the following terms:

- I authorise the school to use my child's biometric information for the purpose specifiedabove until either they leave the school or cease to use the system.
- I understand that I can withdraw my consent at any time.
- I understand that, if I wish to withdraw my consent, I must do so in writing and submitthis to the school.
- I understand that once my child ceases to use the biometric system, the school willsecurely delete my child's biometric information.

I confirm that I have read and understood the terms above ☐

Name of child:	
Name of parent:	
Signature:	
Date:	

Appendix C: Similarity Index Report

ORIGINALITY REPORT

14%	12%	3%	8%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	www.coursehero.com Internet Source	2%
2	ijeecs.iaescore.com Internet Source	1%
3	www.ajman.ac.ae Internet Source	1%
4	Submitted to Caledonian College of Engineering Student Paper	1%
5	github.com Internet Source	1%
6	Submitted to University of Chichester Student Paper	<1%
7	Submitted to Daystar University Student Paper	<1%
8	developers.google.com Internet Source	<1%
9	fdocuments.in Internet Source	<1%

10	www.slideshare.net Internet Source	<1 %
11	eprints.utar.edu.my Internet Source	<1 %
12	Submitted to University of Witwatersrand Student Paper	<1 %
13	docobook.com Internet Source	<1 %
14	pastebin.com Internet Source	<1 %
15	Submitted to Swinburne University of Technology Student Paper	<1 %
16	Submitted to George Bush High School Student Paper	<1 %
17	speedypaper.x10.mx Internet Source	<1 %
18	Submitted to University of Ulster Student Paper	<1 %
19	jakir.me Internet Source	<1 %
20	www.javatips.net Internet Source	<1 %

Appendix D: Ethical Clearance

Strathmore
UNIVERSITY

15th January 2024

Mrs Mutuku Stercy,
stercy.mutuku@strathmore.edu

Dear Mrs Mutuku,

RE: Application of Fingerprint Authentication to Fortify Child Safety in School Transport

This is to inform you that SU-ISERC has reviewed and **approved** your above **SU-masters** research proposal. Your application reference number is **SU-ISERC1937/23.** The approval period is from **22nd January 2024 to 21st January 2025.**

This approval is subject to compliance with the following requirements:

i. Only approved documents including (informed consents, study instruments, MTA) will be used.
ii. All changes including (amendments, deviations, and violations) are submitted for review and approval by SU-ISERC.
iii. Death and life-threatening problems and serious adverse events or unexpected adverse events whether related or unrelated to the study must be reported to SU-ISERC within 72 hours of notification.
iv. Any changes anticipated or otherwise that may increase the risks or affected safety or welfare of study participants and others or affect the integrity of the research must be reported to SU-ISERC within 72 hours.
v. Clearance for the export of biological specimens must be obtained from relevant institutions.
vi. Submission of a request for renewal of approval at least 60 days prior to the expiry of the approval period. Attach a comprehensive progress report to support the renewal.
vii. Submission of an executive summary report within 90 days of completion of the study to SU-ISERC.

Before commencing your study, you will be expected to obtain a research license from National Commission for Science, Technology, and Innovation (NACOSTI) https://research-portal.nacosti.go.ke/ and obtain other clearances needed.

Yours sincerely,

Mr Ambrose Rachier,
Chairperson; SU-ISERC

STRATHMORE UNIVERSITY INSTITUTIONAL SCIENTIFIC AND ETHICAL REVIEW COMMITTEE
(SU-ISERC)
22-Jan-2024
Email:ethicsreview@strathmore.edu
P.O BOX 59857-00200
NAIROBI-KENYA

Ole Sangale Rd, Madaraka Estate. PO Box 59857-00200, Nairobi, Kenya. Tel +254 (0)703 034000
Email admissions@strathmore.edu www.strathmore.edu

Appendix E: NACOSTI Licence

REPUBLIC OF KENYA

NATIONAL COMMISSION FOR SCIENCE,TECHNOLOGY & INNOVATION

Ref No: **261832**

Date of Issue: **02/February/2024**

RESEARCH LICENSE

This is to Certify that Ms.. Stercy Wanza Mutuku of Strathmore University, has been licensed to conduct research as per the provision of the Science, Technology and Innovation Act, 2013 (Rev.2014) in Nairobi on the topic: Application of Fingerprint authentication to Fortify Child Safety in School Transport for the period ending : 02/February/2025.

License No: **NACOSTI/P/24/32705**

261832

Applicant Identification Number

Director General
NATIONAL COMMISSION FOR SCIENCE,TECHNOLOGY & INNOVATION

Verification QR Code

NOTE: This is a computer generated License. To verify the authenticity of this document, Scan the QR Code using QR scanner application.

See overleaf for conditions

Appendix F: Study Tools

Interview Questions

Researcher's name: **Stercy Wanza Mutuku**

The objective is to gather feedback, Requirements, and suggestions regarding the new system to enhance child safety during school transport.

Title of Research: Application of Fingerprint authentication to Fortify Child Safety in School Transport

Interview Questions

1. What are the current safety measures in place for learners during pick up or drop off using the school transport means?
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2. Are there any concerns or issues you have encountered with the existing safety measures?
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3. What are your expectations from the new system?
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4. Are there any specific concerns or reservations you may have about using fingerprint authentication or geofencing?
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5. What are your opinions and concerns regarding data security?
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6. Are there any specific requirements or preferences you would like implemented in the new system?
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7. How would you like the training program to be?
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8. Provide any additional feedback, suggestions, or concerns not previously provided.
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Thank you for your time and input.