MAKERERE UNIVERSITY
COLLEGE OF COMPUTING AND INFORMATION TECHNOLOGY

Ubiquitous Computing for Mobile Based Payments in Localised Intelligent Transportation Systems

By
CS23-4

DEPARTMENT OF COMPUTER SCIENCE

A Project Report submitted to the School of Computing and Informatics Technology For the Study Leading to a Project Proposal in Partial Fulfillment of the Requirements for the Award of the Degree of Bachelor of Science in Computer Science Of Makerere University

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July, 2023

Declaration

We Group CS23-4 do hereby declare that this Report is original and has never been published and/or submitted for any other degree award to any other University before.

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Dedication

We dedicate this report to our parents and guardians, whose unwavering and selfless support has been instrumental throughout our entire academic journey at this university.

Acknowledgement

We express our deep gratitude to our project supervisor, Mr. Ggaliwango Marvin. We are sincerely thankful for his continuous guidance and assistance, which have been instrumental in overcoming some of the challenges we encountered during this demanding study.

Furthermore, we extend our special appreciation to our friends and families for their enduring support during the rigorous moments and stressful periods throughout the research project. Their understanding and encouragement have been invaluable.

We would also like to acknowledge the school for providing us with the invaluable opportunity to work as a cohesive team. This experience has not only fostered our teamwork spirit but has also enhanced our communication skills. Additionally, we extend our gratitude to each member of the group for their unwavering team spirit and solidarity, contributing to the overall success of the project.

Abstract

The current system of ticketing and payment for parking at Makerere University in Kampala, Uganda, faces several challenges, such as frequent malfunction of the ticketing machines, fraud by the system employees, difficulty in locating a payment point for motorists, and hefty fines of 50000 Ugandan shillings for lost tickets. These challenges result in inconvenience, inefficiency, as well as revenue loss for both the system's managers as well as motorists using it. To overcome these challenges, we propose a low-cost secure and reliable system that consists of a mobile app that enables cashless digital prepayment of the parking fees using local popular payment platforms such as MTN mobile money. The app interacts with an embedded microcontroller at the gate that scans the QR codes and grants the motorist access to the premises. When the motorist wishes to exit, their QR code is scanned again by a different microcontroller which interacts with the server to deduct the motorist's due fees basing on time spent and grant them permission to exit. We describe the design and implementation of the app and the microcontroller, and examine its benefits as well as shortcomings. We argue that our system offers a more convenient, efficient, and transparent way of managing toll payments not just in the university context, but other premises with a similar payment system in place.

Keywords: Intelligent Transportation Systems, Ubiquitous Computing, Mobile Based Payments, QR code technology

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Chapter 1

Introduction

1.1 Background and motivation

Access to parking places is a challenge in many urban areas such as universities, shopping malls, hospitals, where there is a high demand for parking spaces and a limited number of them in availability[1] thus the need for automated ways of managing it.

Makerere University in collaboration with Kenya Airport Parking Services in 2014 put in a place a system of this nature. The system was set up to allow motorists to purchase tickets and make payments at any of the payment points within the university premises to ensure the smooth flow of traffic, reducing congestion, while generating revenue for the university[2].

This system has however suffered from several problems, such as frequent malfunction of the ticketing machines, fraud by the system employees who may sometimes take payments from motorists direct rather than having motorists pay at the paypoints within the university, difficulty in locating a payment point for motorists, and hefty fines for lost tickets. These problems have resulted in inconvenience, inefficiency, and occasional revenue losses for both the system's managers and motorists.

To address these problems, we present a novel system in the local context that comprises a mobile application that enables cashless digital prepayment of the parking fees using local popular payment platforms such as MTN mobile money and Airtel Money. The application also interacts with an ESP32 microcontroller, that's able to trigger and verify motorists' payments using QR code technology. Once motorists scan at the exit gate, they are charged dynamically basing on the time they have spent within the university premises.

According to a study by Centellegher et al.[3], mobile money platforms such as MTN mobile money have been widely adopted, with 548 million registered mobile money accounts in the region. These platforms have seen a 23% growth in transaction value, reaching 490 billion dollars. Another study also found that in Uganda, mobile money accounts are held by 43% of the population, compared to just 11% who have bank accounts[4] thus making them a viable option for our system.

Our work is also motivated by a growing trend of using mobile apps for parking payment in some cities around the world. Mobile applications offer several advantages over traditional methods of parking payment, such as convenience, flexibility, security, and cost-effectiveness, amongst others. A report by Grand View Research also indicates that the global mobile parking app market size was valued at USD 6.4 billion in 2020 and is expected to grow at a compound annual growth rate (CAGR) of 22.1% from 2021 to 2028[5]. Some examples of mobile parking applications include ParkMobile[6] developed and used in the United States and Flowbird developed in France[7]. Most of these applications are designed for developed countries with advanced infrastructure and technology, and there is a need for developing context-specific solutions that cater to the needs as well as limited resources in developing countries like Uganda.

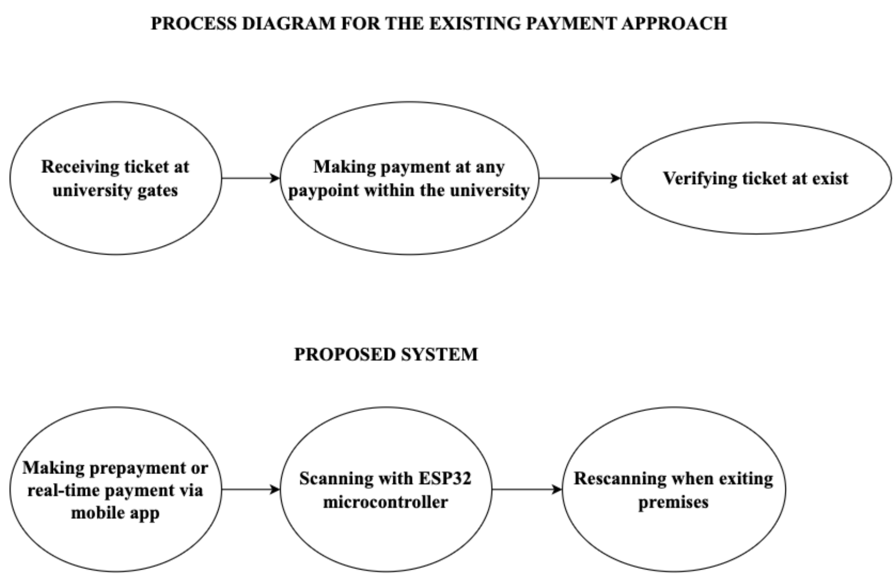


Figure 1.1: High level Process diagram comparing the existing and proposed system

1.2 Problem Statement

Managing access to parking places is a common challenge in many urban public places such as universities, malls where there is a high demand for parking spaces but limited availability[1]. The current system of ticketing and payment for parking at Makerere University in Kampala, Uganda was put in place to address the above challenge. From our interviews with Mr. Twinomusinguzi Julius, the project manager, we were able to determine that it has however suffered from several problems, such as frequent malfunction of the ticketing machines, fraud by the system employees, difficulty in locating a payment point for motorists, and hefty fines for lost tickets.

These problems result in inconvenience, inefficiency, and revenue loss for both the system's managers and motorists, thus there is a need for developing a cross platform system that can provide a simpler, and more transparent way of managing these payments in the university context.

1.3 Objectives

1.3.1 Main Objective

To design and implement a novel system that consists of a mobile application and an embedded microcontroller for cashless parking payment using QR code technology and local payment platforms such as MTN Mobile Money. This will provide a more convenient, efficient, and transparent way of managing toll payments in the university context, overcoming the problems and limitations of the current system of ticketing and payment.

1.3.2 Specific Objectives

The project's specific objectives include:

- To understand the existing payment approach used at Makerere University toll gates.
- To collect requirements for the digital parking payment system for motorists trying to access Makerere University.
- To design a system prototype for the proposed solution.
- To implement the proposed mobile application and validate whether it solves the highlighted problems within the current payment system.

1.4 Scope of the project

The challenges mentioned in the problem statement above affect various parking payment points in the country and even beyond Uganda's borders. However, for this project we focused on the Makerere University context. The team developed the mobile application, programmed the microcontroller to read the QR code values and open the gate. To demonstrate the gate-opening logic, we used a Servo Motor equipment

1.5 Significance of the project

In our project, we were able to develop a digital parking payment system. This system comprises a cross platform mobile application, and a low-cost ESP32 microcontroller for payment verification, eliminating the need for ticket usage when making the payments. This system we believe will address other challenges prevailing in the current system such as difficulty in accessing payment points, fraud by the gate attendants and the issue of hefty fines for ticket loss.

Chapter 2

Literature Review

2.1 Introduction

In this chapter we consider similar projects that have been done and how they relate to the project development and execution in relation to our project. We also look at their shortcomings and how they're addressed in our solution.

2.2 Ubiquitous Computing approaches

The domain of ubiquitous computing according to Michael Friedewalda and Oliver Raabe is concerned with countless small, wirelessly intercommunicating microprocessors, embedded into objects. Such techniques are applied in similar concepts, such as "the Internet of things".The main motive in these domains is assisting people and optimizing economic and social processes through the use of microprocessors and sensors.

These microprocessors are equipped with sensors enabling them to capture information about their current environment or process information and communicate over a network with other similar devices[8].

Ubiquitous computing systems consist of features such as:[8]

- The system is decentralised
- Computers are embedded in other devices
- Real-time information is readily available for users
- The system is able to adapt basing on current information.

This concept has a number of real world applications in domains such as retail, industrial production, health care and this is achieved through implementations such as tracking applications, wearable devices like smartwatches.

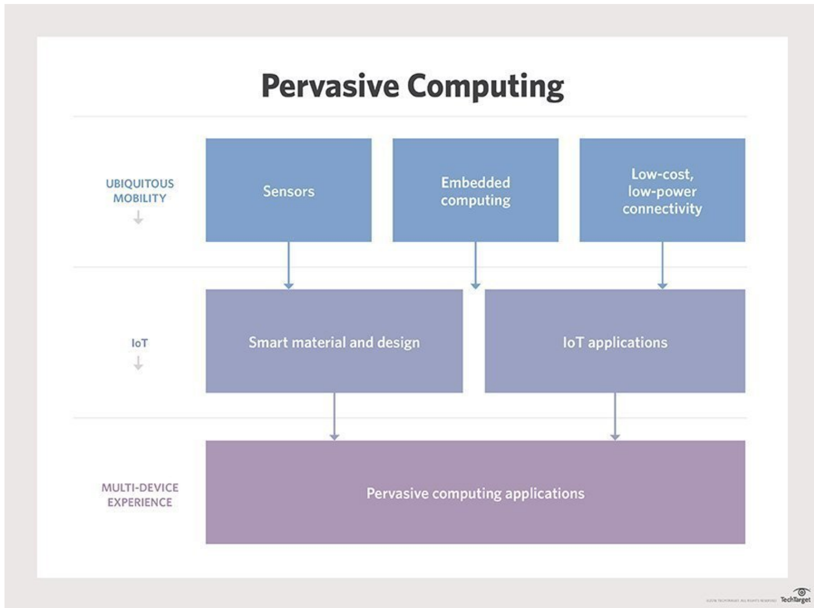


Figure 2.1: A sketch of a ubiquitous computing application

In this section looks at projects that have been done in the area of ubiquitous computing with an aim of addressing a challenge similar to ours. We also look at their shortcomings and how they're addressed in our project.

2.2.1 Use of RFID sensors

One approach that's based ubiquitous computing techniques is the use of an RFID system. This system has two main components:

- A transponder: This is the tag that holds information, found on the object to be identified
- A reader/interrogator: This device is able to capture data from the tag.It has a radio frequency module, control unit and coupling element for linking to the transponder. Additionally, an interface is added to pass on data captured from the transponder to a different system

Sabbir Ahmed et al. in 2019 also proposed a similar solution.Their proposed system would simplify toll payment through use of RFID tags placed on digitised license plates of all vehicles.Once the tag is scanned, and the motorist has a sufficient balance on their account, the vehicle is granted access[9].

Another study by Etqad Khan et al. in 2018 proposed a system similar to ours that would ease payment of toll fees using RFID tag that would be linked to motorists' personal accounts where would have a mobile e-wallet on which a

[h]

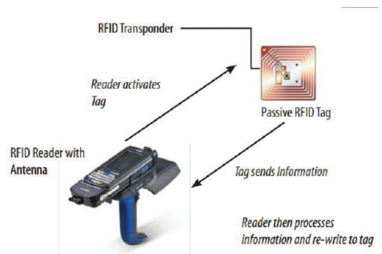


Figure 2.2: Components of an RFID system

given amount would be saved.The system also provides a mobile application to view their past payments[10].

Research Gap

These two identified studies are constrained in our project scopes context, because:

- Implementing such solutions would first off require digitisation of all vehicle license plate, an endeavour that has not yet been taken on by the government of Uganda.
- Long range RFID tags and scanners are costly to purchase which would be needed in this use case are costly ,and would thus the need for a low-cost solution that is also widely accessible such as via mobile.

2.2.2 Use of GPS Software and Cell Towers

Research on how this can be leveraged in easing toll parking fee payment has been done by others. In 2020, Danang Dismantoro, Istas Pratomo and Surya Sumpeno also proposed a mobile application that allowed payment of these fees via GPS software[11, 12]. The system was tested through simulations in Vissim software [13], which they believe was able to simulate the real world condition at tollgates. Cell phone towers and GPS technology are used to identify the motorist' s location and if the motorist happens to be within the toll's gate vicinity, the money is automatically deducted from their personal account.

Research Gaps

- No physical implementation of this system was realised
- The researchers acknowledge the need for a deeper feasibility study and the fact as it has some shortcomings.
- Some scenarios are unaccounted for such as if one is near a cell tower but does not necessarily intend to access the tollgate,they'll have their money deducted even without actually using the gate.

2.3 Mobile Applications

In this section we discuss some of the mobile applications that have been developed to address the challenge of parking in urban areas. We also look at their shortcomings and how they're addressed in our project.

2.3.1 ParkMobile

Parkmobile is a leading mobile application launched in 2009 in the United States of America that allows motorists to find and pay for parking on their phone. This application is currently used in approximately used in three thousand locations in North America, and also has garnered over 43 million users processing over 113 million parking transactions in 2022.

It offers various features and benefits for its users, such as making prepayments and reserving parking points at any given location. It also offers a rewards program that allows users to earn points for every parking transaction and redeem them for discounts or free parking. Parkmobile also supports Google and Apple Pay for a faster and more secure payment process. [6] The project has had good traction since it was launched and in 2022 it generated 9.1 million dollars in revenue , with an average revenue per employee of 52,906 dollars. Parkmobile was acquired by EasyPark Group, a Swedish company that provides smart parking and mobility solutions, in June 2021.

2.3.2 FlowBird

The Flowbird parking app is a cloud-based platform developed in France that allows users to pay for parking in three simple steps and access different parking solutions to meet their personal needs. It offers similar features to the ParkMobile application previously discussed such as mobile-based payments, statistics of available parking places, etc[7].

2.3.3 Research Gap

The main shortcoming of these applications is the fact that they were built and are currently only used in developed countries. As of this writing there exists no equivalent mobile application to enable parking and toll fee payments in Uganda. This is the gap that our project aims to address.

2.4 Makerere University Automated Payment System

This is the existing system in place and was the main case study of our research. The project was commenced in 2014 by Makerere University in collaboration with Kenya Airport Parking Services[2] . From our interviews with Mr. Twinomusinguzi Julius, the current manager of the existing system we learned that the system costs approximately 1.5 billion shillings to set up. It consists of a ticketing machine that issues tickets to motorists, as well as various payment points where payments are made and human labour to receive money, give change and manage the systems in case of breakdown. Some of the challenges in this system include:

- Frequent malfunction of the ticketing machines. This occurs due to their wear and tear over time. As previously mentioned, this equipment is costly not just to purchase but maintain as well.
- Fraud by the system employees. A common way this occurs is when a motorist instead of paying at the point, they're granted access by the gate attendants, who then retain the money for themselves. From our interviews, we also determined that students who are exempt from paying the parking fees upon proving their status, sometimes pay the gate attendants to be granted access in case they don't have their student IDs with them. This can be addressed by having a system that automatically detects students and grants them access without the need for human intervention.
- Difficulty in locating a payment point for motorists. The university is large about 300 acres with payment points placed at different points around it. For people visiting the area for the first time, locating these points can be a challenge thus the need for a more convenient way of making payments.
- Hefty fines for lost tickets as motorists who misplace their tickets are required to pay a fine of 50,000 Uganda Shillings. From our interviews we were informed that a high fee was set because with a lower fee, some motorists park for long periods and intentionally lose their tickets to pay a fine that's lower than their actual parking bill.

2.5 Uganda National Roads Authority Express Highway

Figure 2.3: Toll gate at Kampala Entebbe Express Highway

The Uganda National Roads Authority in 2022 launched the Kampala Entebbe Express Highway, a Ugandan government project worth approximately 450 million dollars developed to help ease transport flow in Kampala city. Access to the highway is via the tollgates where motorists can make both cash and digital cashless payments. For cashless payments, motorists use an UPESI card.[14]. A motorist purchases an UPESI card that they then load a given amount of money and upon arrival at the tollgate, they swipe the card. The fee is then deducted from the card and the motorist is then granted access.

The main gap with the approach is motorists often resort to only using the cash payments that result in delays and other issues because they find it easier than purchasing an UPESI card. Additionally, the process of loading money onto the card is unnecessarily long.

2.6 Our Contribution

Alot of work has been done by other researchers to address the issue of digital payments for toll / parking fees. Many of these solutions leverage RFID technology as an alternative to the physical cash payments.This would however require purchasing costly scanners and tags, thus the need for a similar but cheaper solution. Additionally, the existing mobile applications meant to help address this issue are only available in developed countries, and as of this writing, no system has been developed in Uganda. The biggest benefits to our proposed system:

- Designing and implementing a cross platform mobile applicaton and an embedded microcontroller that interact using QR codes to facilitate parking access and payment. The mobile app is developed using the Flutter framework guaranteeing its accesibility to various mobile platforms i.e Android, iOS. More details on this are discussed in the presentation of results section.
- Using low cost microcontrollers(ESP-32), we were able to program them with a camera module to be able to read and capture QR-code values, and interact with a server to verify motorists payments. This we believe is a cheaper alternative to use of RFID tags.
- Leveraging all local payment platforms e.g MTN mobile money, Airtel Money thus various providers are all catered for.

Chapter 3

Methodology

3.1 Introduction

This chapter discusses the techniques that were used to achieve the objective of the proposal. It covers the approaches used for data collection, design, final implementation, and system testing. The results from the data gathering and other steps of our methodology are presented and discussed in the next chapter.

3.2 Data Gathering and Elicitation

The team collected relevant and appropriate data to determine the requirements of the proposed system. This was done through questionnaires, interviews and physical observation[15].

3.2.1 Questionnaires

Questionnaires contain open or closed ended questions given to a selection respondents to solicit information on a selected research topic[16]. Google forms [17] were be used to create online questionnaires that were shared through social media and emails to targeted stakeholders. Advantages of online questionnaires are that they are relatively easy and quick to distribute. It is also quicker to receive responses and the data can be collected directly for analysis. The survey questions for this research are available in the report appendix. The questionnaires were distributed to a total of 52 respondents from various categories of users of the current system. Details on the respondents are shown discussed in the next chapter on System Analsysis and Design.

3.2.2 Interviews

An interview is a one on one planned conversation with a person with an aim of attaining information. Researchers had interactions with owners of the system currently in place as well as a selection of the motorists in order to get first-hand information on issues faced. This helped us in better defining the system requirements of the project. The interviews also enabled the researchers to establish relationship with potential respondents as well as owners of the current system and therefore gain their corporation, yielding highest response rates in the survey research. The researchers conducted 2 interviews with Mr. Twinomusinguzi Julius the project manager of the current system in place, and from these we were able to better understand the current system and its challenges. The interview questions are available in the report appendix.

3.2.3 Observation

Observation involves spending time with stakeholders and keenly monitoring their activities. Researchers took a physically closer look at what takes place during the daily activities of motorists trying to access the university and the challenges they face and will entail systematic noting and monitoring of events, behaviors of the motorists as they go on with their activities.

3.3 Data Analysis

This was done to remove inconsistencies in the data collected, as well as sieve out useful data that will be used to improve the system requirements.

3.4 System Design

For the system design, context diagrams were created and used to define the scope of the project and its environment as well as the entities who will interact with it.Additionally, there were detailed processes of how the system works. [18].

3.4.1 Process Modelling

Here, data flow diagrams were used to demonstrate the processes and entities that interact with the system.

3.4.2 Data Modelling

Entity relationship modelling was done to identify the entities as well as their relationship how they interact with each other. This was achieved by use modelling entity relationships. The researchers used a top down approach to identify the entities interacting with the system.

3.5 System Implementation

At this stage the team built the E-Tolls application.A number of tools and technologies were used and these are defined below:

3.5.1 Software tools

- Android Studio & Xcode: This is where the mobile application was developed.
- Arduino IDE: This was used to write the code for the microcontroller.
- Flutter mobile framework: This will be used to write the cross-platform code for the application
- DigitalOcean: This will be used to host the remote server.
- Silicon Pay: This will be used to process payments which are computed dynamically basing on the time one has spent within the premises

3.5.2 Hardware tools

- ESP32 microcontroller
- Servo motor to demonstrate the opening and closing of the gate
- Camera to be used to scan QR codes
- Wi-FI GSM module to enable internet connection of the microcontroller
- FTDI connector to enable connection of the microcontroller to the computer

3.6 System Testing and Validation

Here, the system is deployed and executed to assess its functionality. The system was deployed on a server and released as a prototype for user testing and validation. The purpose of validation was to ensure that the system performs precisely as intended in a consistent and efficient manner.

To validate the system, various methods were employed, including testing the prototype with invalid data and assessing how it handles exceptions. The android application was deployed to Firebase app distribution and shared with selected internal testers to try out and share feedback on the application. The feedback was used to improve the application and fix any existing issues.

3.7 Conclusion

In conclusion, this chapter has outlined the procedures followed in the creation of the E-Tolls Mobile Application. The system we believe will be able to meet not just the requirements of the users but also the objectives of the project.

Chapter 4

System Analysis and Design

4.1 Overview of the System

This chapter consists of the general introduction, the study of the existing system, requirement specification and system design. The study of the existing system includes main findings from interviews, requirements specifications include functional, non-functional requirements, software and hardware requirements. System design comprises modelling the solution basing on findings from the interviews.

4.2 System study

The data gathered using the selected data collection techniques enabled the system developers to garner information which was studied to realise the weaknesses of the existing systems and how the new system would be designed in a better way.

4.3 Study of the existing system

Our case study as previously mentioned was the Makerere University Parking System. We conducted two interviews with the project manager who informed us all the details of the current system and its shortcomings. Some details however such as average revenue garnered by the system,etc. were not shared with us for confidentiality purposes.

4.4 System Analysis

4.4.1 Data Analysis

The charts below provide a summary of some of the main findings from the survey we conducted.

Breakdown of the users of the existing and proposed system

Our analysis found that the main users of the system are fall into two categories, each with its own subcategories. These are:

- Frequent users: This comprises users students, lecturers and university staff who are the main users of the system.
- Occasional users: This comprises visitors to the university or ordinary passers-by who wish to use the system quickly perhaps a shortcut to avoid traffic, or a brief visit to the university, among other reasons

The system therefore ought to have a way to discern between these two categories, and frequent users are not expected to make payments every time they use the system. To achieve this, we have built our system in such a way that registered users can register with their student or university credentials, and the system can then verify their status via email and allow them to use the system without making payments. The occasional users can then be charged for each use of the system.

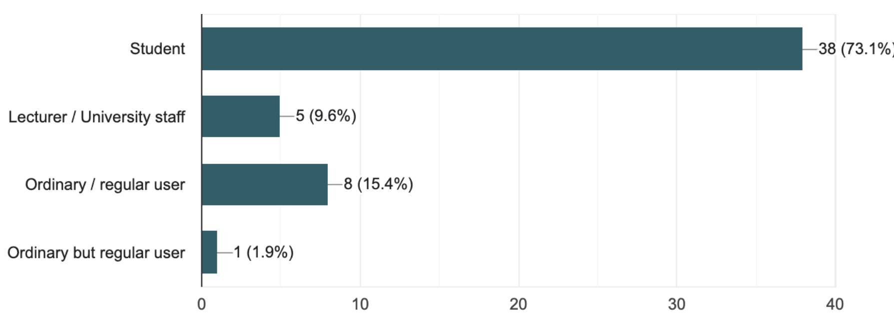


Figure 4.1: Breakdown of intended users of the system

Analysis of frequency of usage of the current system

We were also able to analyse the frequency of usage of the current system. We found that the majority of our respondents use the system on a daily basis, with a few using it on a weekly basis. This is expected since the main users of the system are students, lecturers and university staff who are expected to be at the university on a daily basis. The occasional users are expected to be a minority.

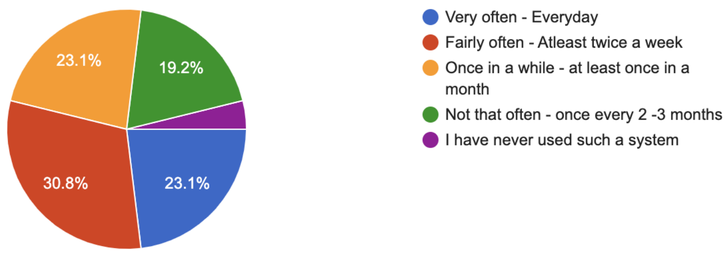


Figure 4.2: Respondents' frequency of usage of the current system

Level of satisfaction with existing system

We also sought to find out how satisfied our respondents were with the existing system. We found that the majority of our respondents were either not satisfied or fairly satisfied with the existing system, with a few being satisfied with it. This is expected since the existing system has a number of shortcomings which we have already highlighted.

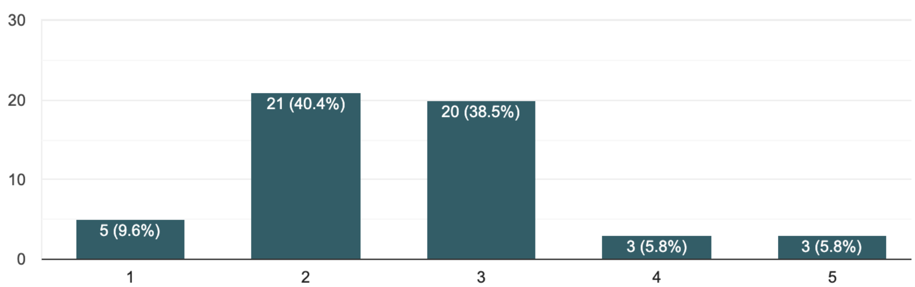


Figure 4.3: Respondents' level of satisfaction with the existing system on a scale of 1 to 5

Familiarity with local mobile payment platforms

We believe one of the benefits of our proposed system is that we leverage local mobile money platforms such as MTN Mobile Money and Airtel Money. We therefore sought to find out how familiar our respondents were with these platforms. We found that the majority of our respondents were familiar with these platforms, with a few not being familiar with them. This is expected since mobile money is a popular payment platform in Uganda.

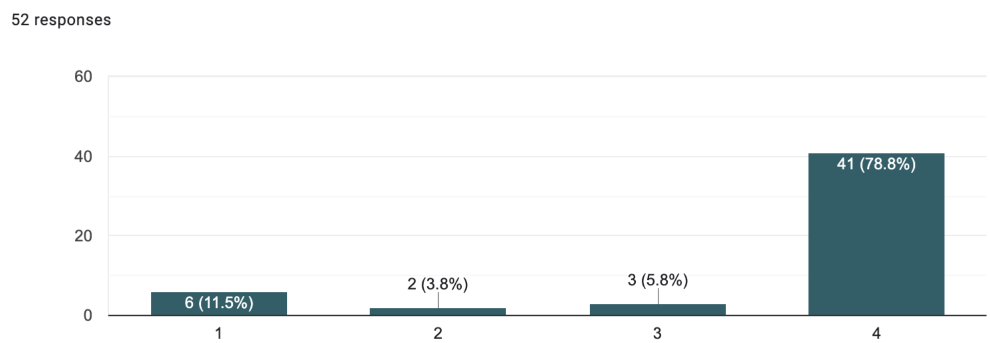


Figure 4.4: Respondents' familiarity with mobile money platforms on a scale of 1 to 5

Likelihood of using the proposed system

We also sought to find out how likely our respondents were to use the proposed system. We found that the majority of our respondents were very likely to use the proposed system, with a few being somewhat likely to use it. This is expected since the proposed system is expected to be more convenient than the existing system.

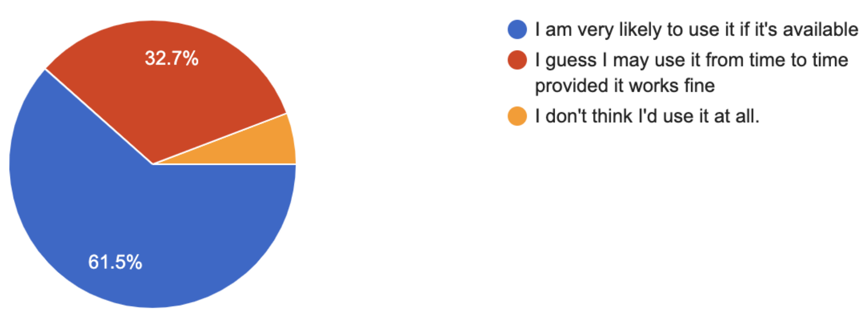


Figure 4.5: Respondents' likelihood of using the proposed system

4.4.2 Requirements Specification

In order to come up with the end user requirements for the new system, data was collected through interviews with both the project manager of the current system at Makerere University and a survey shared with motorists who use the gates.

The collected data was then analysed in order to come up with the requirements of the new system. This section included the requirements of the new system divided into user requirements and system requirements.

User Requirements

This encompasses the requirements of the system from the user's point of view.

The users identified are gate attendants who can also double as administrators of the system as well as motorists who use the gates. The motorists are split into two further categories: regular users and occasional users.

- **Gate attendants / Administrators**: Manages the ETolls System
- **Motorists**: Uses the ETolls System to make their payment

Functional Requirements

This is to do with the services that the system will provide to the users. The system will be able to:

- Allow new users(motorists) to register for the system
- Allow registered users to log in to the system
- Allow exempt individuals to get access to the premises without payment
- Allow users to make payments for parking
- Allow users to view their payment history
- Allow users to view their parking history
- Allow the system administrator to add or delete users

Non-Functional Requirements

These are requirements that are not directly related to the functionality of the system but are important for the system to work properly. These include:

- The system should allow for easy registration of users
- The system should support various payment platforms such as MTN Mobile Money, Airtel Money
- The system should be secure

- The system verifies all user inputs and users must be notified in case of error

4.4.3 System Design

This section defines the physical architectural design and the logical design (showing processes, sub processes and entties) of the system required to satisfy the specified requirements.

Architectural Design

An architecture diagram is a representation of elements that comprise a given system[19].

The system will comprise a mobile application as well as remote server hosted on the cloud. The mobile application will be used by the motorists to make payments and view their payment history. The remote server will be used to store the data of the users and their payment history. The final component is the microcontroller which will be used to control the gates and communicate with the remote server, guiding on when a user has began their journey within the premises, and flagging when it ends such that the server can make charges basing on time spent within the premises.

For demonstration purposes, the system will be demonstrated using a microcontroller and a servo motor to demonstrate the logic of opening and closing of gates

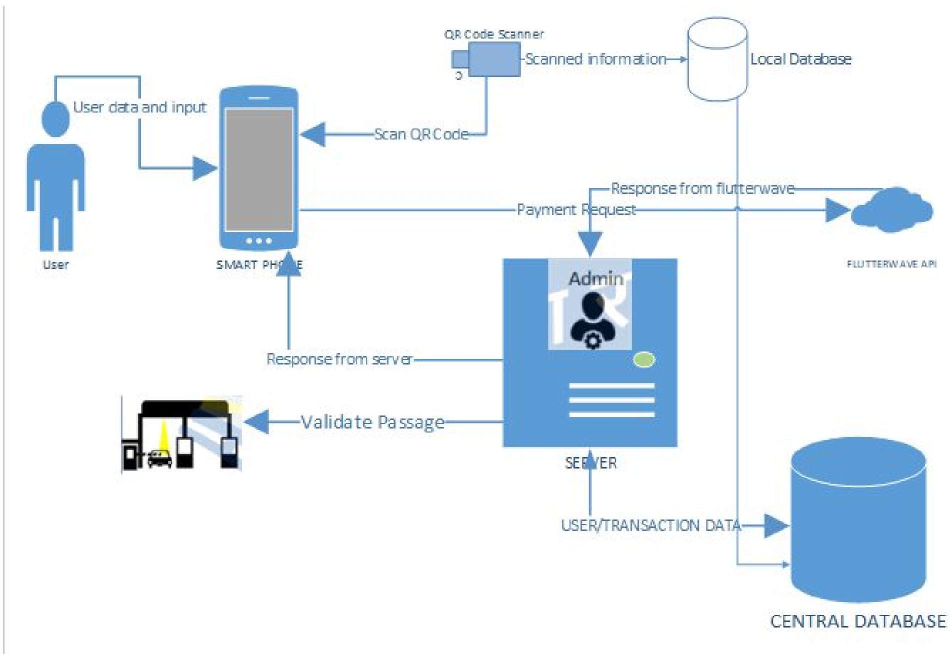


Figure 4.6: System Architecture diagram for E-Tolls System

Use case diagram

A use case diagram is a graphical representation of a given user's possible interactions with a system. It gives broad view of a system and the different types of users and use cases within that system [20]. Screenshots of the mobile applivation for this use case are also included in the presentation of results section. Below is a use case diagram for our proposed system:

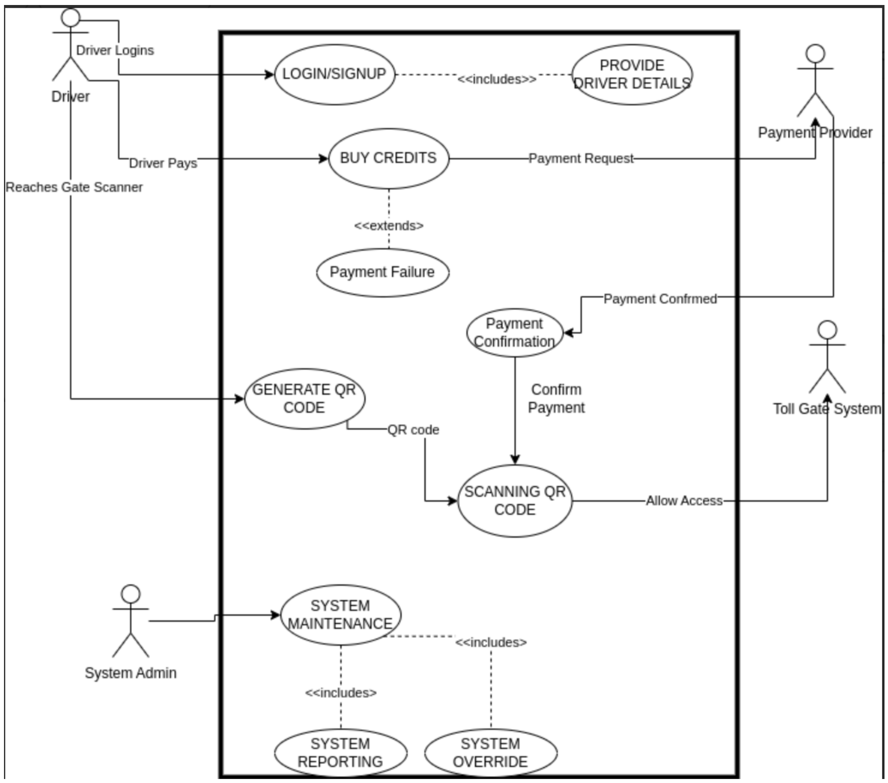


Figure 4.7: Use Case diagram for E-Tolls System

Entity Relationship Diagram

An entity relationship diagram (ERD), also known as an entity relationship model, is a graphical representation that depicts relationships among people, objects, places, concepts or events within a system. The diagram below shows the entities and their relationships in our system[21].

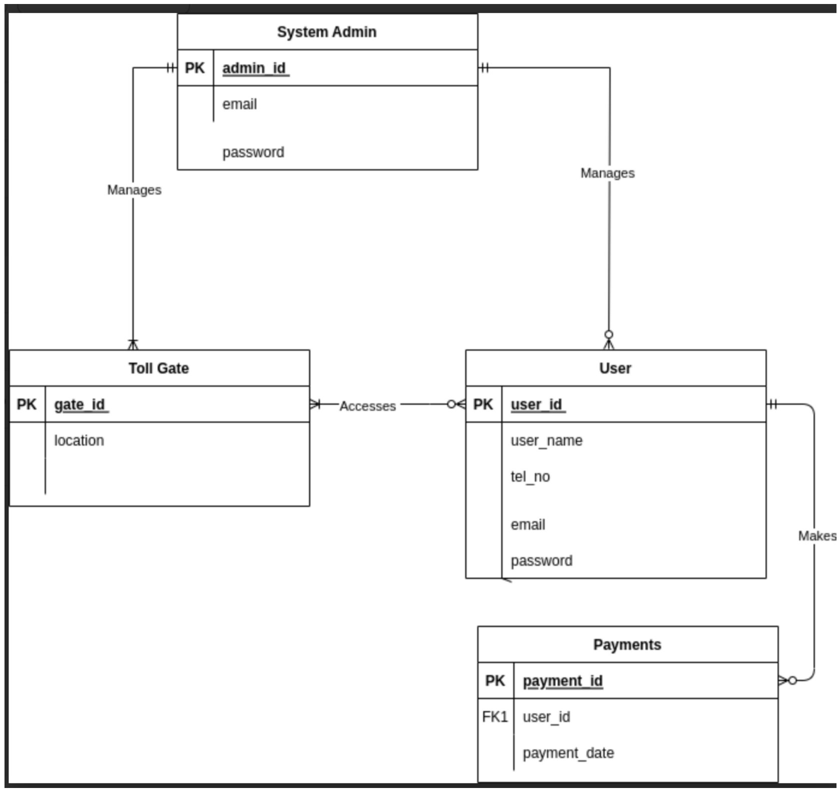


Figure 4.8: Entity Relationship Diagram for E-Tolls System

Flow chart

The flow chart represents the dynamic behavior of the objects and classes that have been identified as part of the system. The flow chart helped us describe the plan in order to perform the different tasks. It showed what was done when the decision was made and when to go to each process as a result. The flow chart helped us build a step-by-step picture of the processes of our system.

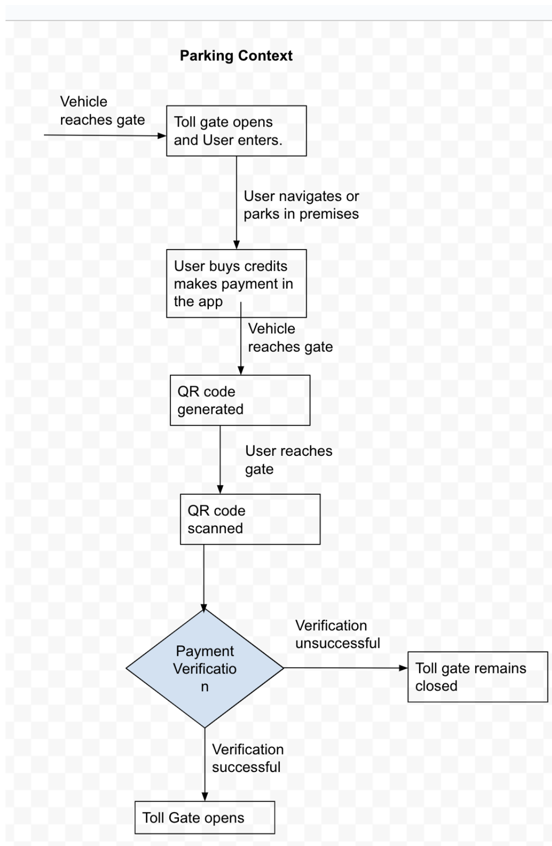


Figure 4.9: System Architecture diagram for E-Tolls System

Context Diagram

A context diagram provides a visual representation of how external elements interact with a system, such as a project or a software system. It clarifies the interfaces and boundaries of the project or process at hand, and shows the project's interactions with other systems and users[22].

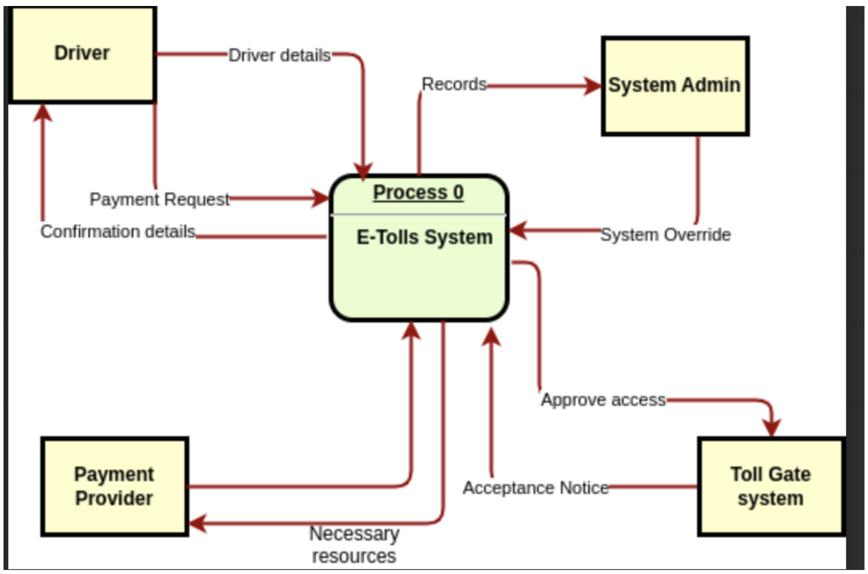


Figure 4.10: Context Diagram for E-Tolls System

Chapter 5

Presentation of Results

5.1 Introduction

This chapter shows screenshots of the system interface, connections of the hardware equipment and other details the programming environment that was used to develop the system.

5.2 Implementing the system

5.2.1 Programming Tools

The system was implemented using the following programming tools:

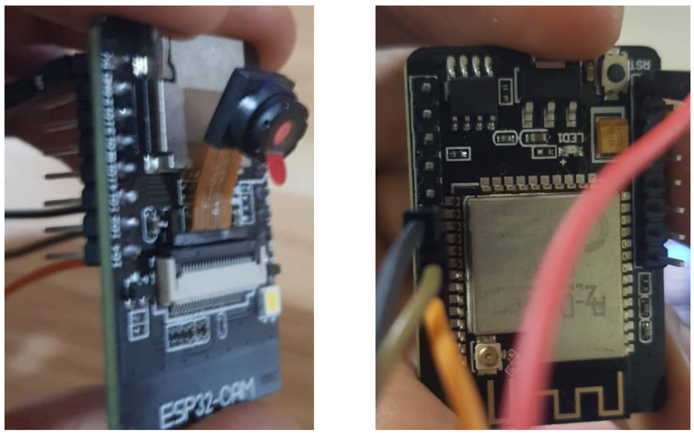
- **Android Studio**: This is the official IDE for Android development. It was used in the development of the mobile application.
- **Arduino IDE**: This is the official IDE for Arduino development. It was used in the development of the microcontroller code.
- **Digital Ocean**: This is a cloud hosting service. It was used to host the remote server.
- **Flutter**: This is a cross-platform UI toolkit developed by Google. It is used to develop the mobile application.
- **Firebase**: This is a mobile and web application development platform developed by Google. It is used to handle user authentication.
- **Silicon Pay**: This is the payment gateway the researchers opted for due to its support for all local payment platforms
- **ESP32 Microcontroller**: This is a microcontroller developed by Espressif Systems. It is used to receive data from the mobile application and send

it to the remote server.

- **Servo Motor**: This consists of a DC motor, gearbox, and a control circuit. It has a simple lever that can be attached to it and used to demonstrate the opening and closing of the gate upon verification of payment.
- **FTDI connector**: This is a USB to serial adapter that is used to program the ESP32 microcontroller.

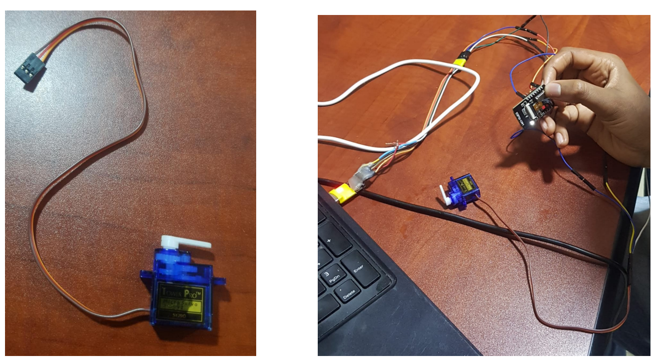
5.2.2 Embedded Systems Equipment

The following equipment was used in the development of the system:



(a) (b)

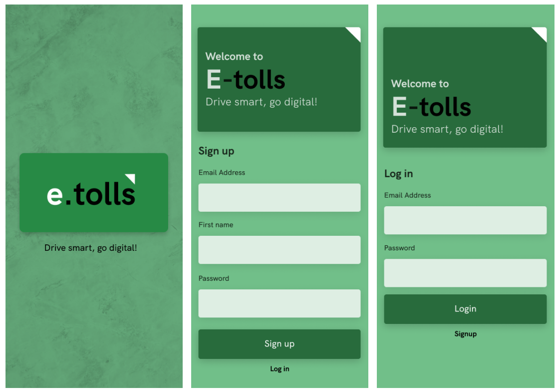
Figure 5.1: ESP32 microntroller used to scan the user QR codes



(a) (b)

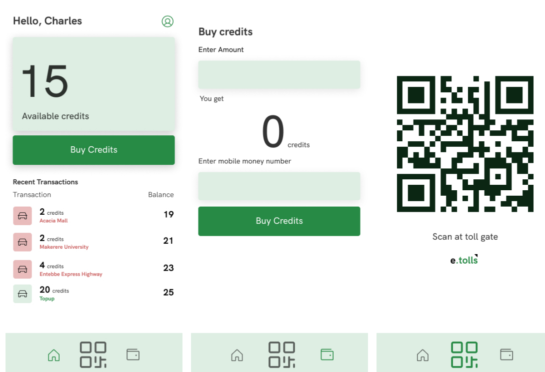
Figure 5.2: Left is a servo motor used to demonstrate closing and opening logic and Right is the complete connection of the equipment

5.2.3 Screenshots of the mobile application in order of use



(a) (b) (c)

Figure 5.3: Login and Sign Up Screens of the mobile application



(a) (b) (c)

Figure 5.4: Home Payment Screens of the mobile application

5.2.4 Silicon Pay Administrator dashboard

THe payment gateway Silicon Pay also provides a web based dashboard which one can use to monitor transactions made through the system. The dashboard is shown below:

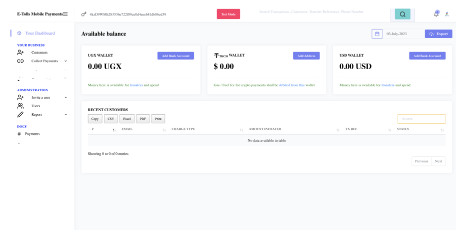


Figure 5.5: Web based admin dashboard to view all transactions

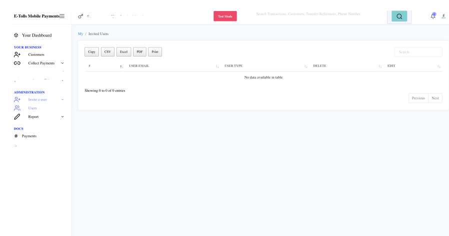


Figure 5.6: Table to hold summary of customers data that can be exported as CSV/PDF

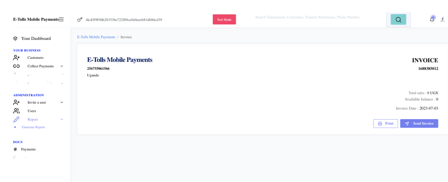


Figure 5.7: General Report of transactions made in a given period of time

Chapter 6

Limitations, Recommendations and Conclusion

6.1 Introduction

This chapter discusses the challenges encountered during the implementation of the project, its current limitations and possible future works.

6.2 Limitations and Future Works

The system currently does not account for some scenarios such as the following:

- Cases where there is no internet connection: This is especially as the ESP32 requires an internet conncetion to verify the payment status of the user.
- Considering some categories of individuals are exempt from payment basing on their credentials, some users may misuse this and gain access without making payments, using credentials of exempt individuals.
- Non-smartphone users: The system currently only accounts for users with smartphones with iOS and Android Operating Systems. There is need to extend the system to also cater for non-smartphone users.
- The developed system is only limited to a demonstration stage, and no real-world implementation with real toll gate barriers and equipment has been done.

The application was also not deployed to any application stores as these require official paid accounts which the researchers were not in position to acquire due to financial constraints.

Finally, implementation of the project was limited to a simple demonstration. Full implementation of the project would require using the ESP32 with a real toll gate barrier and other additional equipment which was outside the scope of the project but is a potential future work.

Future works on the project can be done to handle the scenarios listed above. The project if built in a real world setting, can also be scaled to various places such as malls and hospitals.

6.3 Other Challenges

The researchers encountered a variety of challenges during the implementation of the project. These challenges are discussed below.

- During the interviews, the researchers were not granted some information about the current system for confidentiality purposes. Information such as the detailed costs of the current system, revenue generated by the current system, and the number of tickets issued per day were not disclosed.
- Execution of the project was also dependent on funding to purchase equipment such as the microcontroller and servo motors which can easily be damaged by power surges.
- Majority of the respondents were regular(daily) users of the system and most especially students, leading to some bias in the information gathered. The researchers did not receive a significant number of responses from individuals within the occasional users category as well as university staff.

6.4 Conclusion

In conclusion, the research's primary objective was to a great extent. An initiative of this nature is worth investing in and taking to the next level of having it publicly available as it would address so many shortcomings in the system currently in place that would benefit various groups in the Makerere University community from students, lecturers and other staff while also generating revenue for the university.

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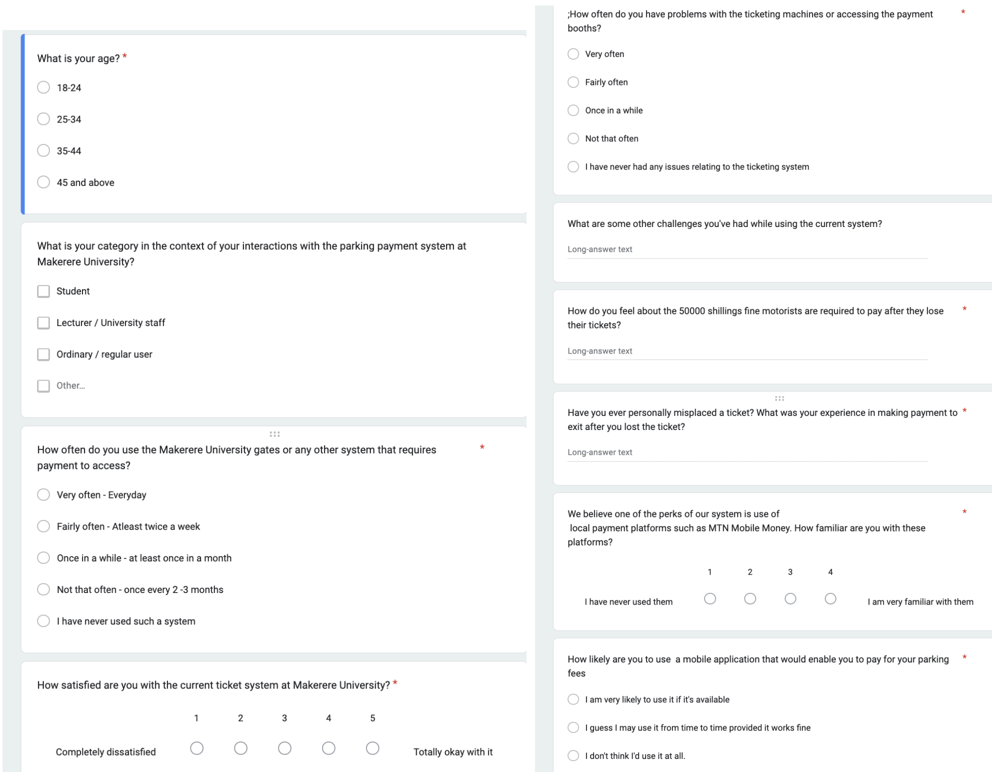
Appendices

The source code for the system and Latex files for this report can be found here

Survey Questions: Motorists


What is your age? *

18-24

25-34

35-44

45 and above

What is your category in the context of your interactions with the parking payment system at Makerere University?

Student

Lecturer / University staff

Ordinary / regular user

Other...

How often do you use the Makerere University gates or any other system that requires payment to access? *

Very often - Everyday

Fairly often - Atleast twice a week

Once in a while - at least once in a month

Not that often - once every 2 -3 months

I have never used such a system

How satisfied are you with the current ticket system at Makerere University? *

	1	2	3	4	5	
Completely dissatisfied	○	○	○	○	○	Totally okay with it

;How often do you have problems with the ticketing machines or accessing the payment booths? *

Very often

Fairly often

Once in a while

Not that often

I have never had any issues relating to the ticketing system

What are some other challenges you've had while using the current system?

Long-answer text

How do you feel about the 50000 shillings fine motorists are required to pay after they lose their tickets? *

Long-answer text

Have you ever personally misplaced a ticket? What was your experience in making payment to exit after you lost the ticket? *

Long-answer text

We believe one of the perks of our system is use of local payment platforms such as MTN Mobile Money. How familiar are you with these platforms? *

	1	2	3	4	
I have never used them	○	○	○	○	I am very familiar with them

How likely are you to use a mobile application that would enable you to pay for your parking fees *

I am very likely to use it if it's available

I guess I may use it from time to time provided it works fine

I don't think I'd use it at all.

(a) (b)

Figure 1: Survey questions shared with respondents

Figure 2: The researchers also conducted in person interviews with motorists and the project manager at the toll gate

Interview Questions: Toll Operator / Project Manager

- What was the motivation behind putting in place this system?
- What challenges do you normally face when managing these gates?
- What are some solutions you've put in place to alleviate the challenges you've had?
- Do you believe cashless payments would ease your organisation's work?