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DELA AHETO  
USING PROXIMITY SENSORS TO AUTOMATE THE TOLLBOOTHS  
IN GHANA

Master of Science Thesis

Examiner: Prof. Kaisa Väänänen

Examiner and topic approved on

29th March, 2018

## ABSTRACT

**DELA AHETO:** Using proximity sensors to automate the tollbooths in Ghana  
Tampere University of technology  
Master of Science Thesis, 50 pages, 3 Appendix pages  
April 2018  
Master's Degree Programme in Information Technology  
Major: User Experience  
Examiner: Prof. Kaisa Väänänen

Keywords: Proximity Sensors, tollbooths, motorists, users, electronic toll collection, NFC, app, prototype, participants, mobile payments

Motorists come across tollbooths all over the country when they are moving from one place to the other. Tollbooths has become an important part of generating funds in Ghana to help maintain and construct other roads.

Inasmuch as these tollbooths help generate funds, they also create traffic jams because of the number of cars they have to process. Since the tollbooths are manned, it becomes difficult to serve each vehicle expeditiously. Some commercial drivers use that avenue to change their high denomination notes into small ones, so that they can get change for their respective passengers.

It has also become a worrying trend nowadays for the tollbooth personnel to give motorists fake receipts after the toll fees have been paid, which means that there is no record of the sort of the transaction, and hence, the toll does not go into the coffers of the state but to that of the tollbooth attendant.

The overall objective of this thesis is to design a user-friendly interface in the form of a mobile app which motorists are going to use to pay for the toll fees. To better understand the user requirements, interviews and questionnaires were used. A prototype of the proposed app was designed and tested with motorist as they are the main target group of this thesis.

## PREFACE

When I was applying to study in Tampere University of Technology (TUT), it seemed an impossible task at the time looking ahead of the challenges ahead. In retrospect, these past few years in TUT have provided a good learning environment and opportunity for me. What was a dream back when I started my degree program has now become a reality.

I would like to use this opportunity to thank all my teachers/professors, and the staff of TUT for their support over the years.

I would like to thank my supervisor, Kaisa Väänänen, for supervising my work and also for giving me ideas on how to approach my research topic. Special thanks to Anna-Mari Viitala, my student coordinator who was always available to answer questions related to school work.

My appreciation goes to Heli Väätäjä, Peter, Essel, and Olaiya for their outstanding support during the thesis, and to all my friends who supported me directly and indirectly, I say thank you.

Finally, my utmost gratitude goes to my family for their love and support during my degree in Finland. I would not have made it this far without their help.

Tampere, 10.04.2018

Dela Edinam Aheto

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## LIST OF SYMBOLS AND ABBREVIATIONS

App	An application/program that can be downloaded onto a user's mobile phone.
Database	A structured set of data that is stored on a computer
ETC	Electronic Toll Collection
HCI	Human-Computer Interaction
Interfaces	A medium through which a user communicates with a computer
ALPR	Automatic License Plate Recognition
Motorist	The driver of a car/vehicle
NFC	Near Field Communication
OCR	Optical Character Recognition
Prototype	An initial design of a product from which other designs are developed
RFID	Radio Frequency Identification
Toll Booths	A roadside kiosk where motorist or pedestrians pay to use a road
Users	People who would use a particular service or product
UX	User Experience

# 1. INTRODUCTION

Providing tolls on major roads in Ghana has been very important to generate financial capital. Besides the capital being used to develop roads in the country, they are also used for their maintenance. Ghanaians, and for that matter motorists, are to pay these tolls because, it goes in line with the principle that the person who benefits must pay [1]. Road users incur extra costs besides the fee they pay at the tolls, the most important being the waiting time and money because of the fuel wasted while waiting at the toll booths.

## 1.1 Background and Motivation

There are many vehicles on Ghanaian roads and a lot more are coming up by the day. There are also many toll booths spread across the country which motorists cannot avoid going through. It is not the presence of the toll booths which is causing the problem. The problem has to do with the enormous traffic jams it creates as a result of slow working personnel or too many vehicles to attend to especially at peak hours.

Most of the traffic jams occur as direct results of reckless driving, accidents, road constructions, just to mention a few. But the percentage of jams also created by these toll booths cannot be ignored. Majority of the working class have their workplaces far from their places of residence, and due to the inefficiency of the bus transport system in Ghana, workers would rather use their private cars which is faster and convenient as opposed to using public transport.

The main toll booths have about 4 to 5 lanes. The last lanes typically have the electronic payment system where the approaching vehicle has a prepaid card attached to the windshield so the bar automatically raises when the vehicle is in a considerable distance. Only this does not solve the underlying problem of the traffic jams altogether because the vehicle has to still be in a traffic jam for at least twenty-five minutes (depending on the time of day) before getting to the booth. These traffic congestions reduce the overall productivity of the workers stress, which further affects the economic stability of the country.



In other words, there is a relationship between transportation and productivity [2].

There have been calls from prominent people in the country to the government to increase road tolls because these people believe that the fees being collected at these booths are low.

The National Chairman of the Association of Road Contractors, Mr. Ebo Hutton, called for all the toll booths in Ghana to be automated so that the siphoning of the revenue will be reduced. According to a newspaper publication on 25<sup>th</sup> June 2013, about 9 million cedis (approx €2.25m) was unaccounted for by the companies tasked to collect the tolls<sup>1</sup>.

Since there are people manning these booths, it comes as no surprise that the revenue is stolen because it is that easy to do so. It is with this reason that the Ghana Highways Authority is set to introduce point of sale devices at the various booths to check thefts<sup>2</sup>.

The manual system as it is now means that the cash collected from the motorists are kept in the booth for some hours or even days before the agents tasked to collect them actually come for them. During this period, the booth is susceptible to robbery which will result in the state losing more money and which may also result in the loss of lives if the attack is deadly.

Armed robbers stormed one of such toll booths and made away with about GHC 45,000 (approx. 9,000euros), which was tolls collected over a period of 3 days<sup>3</sup>.

To prevent this from happening, more security personnel will be required to tighten security at the toll booths. This move can be seen as a further waste of resources in the long run since these additional personnel could have been assigned to different posts, also making the government incur Variable Operating Costs [3].

Thus, the problem statements of this thesis are;

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<sup>1</sup> <https://www.modernghana.com/news/471075/over-gh9m-collected-as-road-toll-unaccounted-forreport-rev.html>

<sup>2</sup> <https://www.myjoyonline.com/business/2017/December-27th/tolls-booths-to-get-point-of-sale-devices-to-check-theft.php>

<sup>3</sup> <https://www.primenewsghana.com/general-news/ghc45-000-stolen-from-tema-motorway-tollbooth.html>

1. Traffic congestions at the toll booths
2. Inefficient and ineffective ways of the toll collection.

With the influx of technology in our day to day activities, there is the need to employ its use to curb the problems and challenges facing the toll booth system in Ghana.

The thesis seeks to provide ways by which technology can be used to improve the toll collection.

## **1.2 Research Objectives and Methodology**

This thesis aims at understanding the user requirements involved in the interaction between motorists and the toll booth system. This is the core objective of the thesis since Human Computer Interaction (HCI) seeks to come up with ways in which human needs as it pertains to software and user interfaces can be well understood and used to solve the problem of customers' dissatisfaction

### **1.2.1 Objectives**

The main objective of this thesis is **to develop a user interface that will help motorists interact effectively and efficiently with the toll booths on Ghanaian roads.**

Additionally, various proximity sensors will be researched with the view of coming up with the most suitable one to help in the implementation of the Electronic Toll Collection.

### **1.2.2 Methodology**

The designing of the user interface is based on the User-Centered Design Methodologies which focuses on providing principles and guidelines by which software and hardware systems need to be designed to enhance the user experience of interacting with these systems, by taking into consideration the user requirements and needs.

To illustrate and visualize how the proposed system works, storyboards were created so that the idea is more understandable. Since the design process is iterative, a prototype was used so that changes could be made after testing.

Working towards the concept of eliminating the manually-run toll booths in Ghana, studies were conducted at various toll booths across the country, which brought about the idea of using proximity sensors to automate the toll booths. The purpose of this idea is;

- To help the state account for all the revenue accrued by the toll booths so that the current tolls need not be increased
- To eliminate the susceptibility of the booths being attacked
- To decongest the toll booths since the payment of the tolls will be done electronically

Motorists, passengers, and officers from government agencies were interviewed based on the storyboard and the prototype developed. These interviews were done so that the interviewees could express their views in interacting with the proposed system, as opposed to the current system. In other words, the main purpose of the study was to assess the User Experience of using the product. The efficiency and effectiveness of the system was assessed based on what the system is supposed to provide.

### **1.3 Structure of the Thesis**

The Introduction chapter explains the background and the motivation behind the research. It explains why there is the growing need to implement ETC's in Ghana based on the problem statements mentioned.

Chapter 2 talks about the various technologies that will help in the implementation of the ETC. The first part covers the Automatic License Plate Recognition and how it works. RFID is covered in the second part. The third part talks about some vehicle detection technologies in the market. The chapter is concluded with details about Near Field Communication.

Chapter 3 involves Mobile Payments, the approaches to how mobile payments can be implemented, factors that hinder or promote the use of mobile payments, and finally some user studies on the use of mobile payments.

Chapter 4 is the Research Process which talks about the various data collection techniques used in this thesis, the demographics of the users and their background.

Chapter 5 is the design and implementation chapter. In this chapter, a general overview of the proposed system is given as well as how the current system works. It also documents ways that can be employed to solve the problem statements as mentioned in the introductory chapter.

Chapter 6 documents the Results of the research process done in chapter 4.

Chapter 7 is the final chapter of the thesis which houses the challenges to the design and implementation of the proposed system, what is left to be done or what can be done to further improve upon the proposed system. Conclusion summarizes the research and closes the curtain on the research topic.

## 2. TECHNOLOGICAL OVERVIEW

This chapter encompasses the various technologies employed in this thesis. It is divided into four main parts.

Part one explains the use of ALPR which is a very important element because this technology will be used to allocate the toll fee for different vehicles. RFID, which can also be used to implement an ETC (in the case of Salik) is discussed into details in the second part. Part three covers the vehicle detection technologies.

Finally, the last part gives insight to the use of the NFC technology.

### 2.1 Automatic License Plate Recognition (ALPR)

With the inception of high-quality cameras, many developed countries have employed the use of ALPR to help manage traffic, track down stolen vehicles and also for automatic toll systems [4]. ALPR is a surveillance system that retrieves data from the license plate of vehicles by capturing the images of the license plates [4]. The increase in the number of vehicles in recent years has made the adoption of ALPR important since there is delay in the processing time if humans were doing the monitoring and capturing of the license plates [4].

In [5], the ALPR process is divided into four main segments;

**Image Acquisition:** This stage involves the capturing of the image where the license plate is located by using computerized camera and sufficient amount of light.

**Number Plate Extraction:** This is the stage where the actual number plate is extracted from the image acquired. It is the most critical of all the stages since the subsequent stages rely on this stage. Different vehicles have different positioning for their license plate which poses a problem with ALPR, among other problems.

[6] proposed the use of Sobel edge detection, together with morphological operators to help in the accurate extraction of the number plate.

Morphological operators are used on the captured image to extract the plate area. A rectangular-shaped morphological operator is used for this purpose. When the plate area is detected, the coordinates of the bottom right and top left are extracted. The coordinates are then used to extract the plate area from the original image.

In Sobel edge detection, there are two masks that identify the vertical and horizontal edges of the number plate.

**Character Segmentation:** It is the process where each character in the image captured is individually isolated from the rest of the characters. These isolated characters are then labelled using Connected Component Labelling (CCL) to help identify them for further use.

**Character Recognition:** In [4], character recognition is done by matching the characters from the character segmentation with values stored in a template. This is called template matching. All the alphabets (A-Z), and numbers (0-9) are stored in a template. The labelled characters are then run through the template (containing 37 data elements) to get the best match possible that corresponds to the characters on the number plate.

## 2.2 Radio Frequency Identification (RFID)

RFID is a wireless technology that is used primarily to identify or track objects, animals or people with the help of tags or transponders. RFID is basically made of 3 components; the tag that has the information (for example an ID of a book or an employee) embedded in it to which it is attached or implanted, the reader that powers the tag and reads the information stored on the tag, and finally the database that processes the information [7].

RFID tags can be either passive or active. Passive RFID tags receive power from the readers which means that it does not require its own power source. They only transmit when they receive enough power from the reader. This characteristic makes passive tags

cheaper to procure. Its main disadvantage is that it has a shorter range capacity compared to active RFID tags which require a battery to function [8]

## **2.2.1 Some Application Areas of RFIDs**

### ***2.2.1.1 Vehicle Identification System***

[8] employs the use of RFID tags to give traffic operators, police, etc., the ability to record stolen vehicles whilst also providing the authorities with easy access to updated records. The paper uses passive tags in the form of stickers which will be put on the vehicle's windshield so that the reader can read the information from the tag whilst the vehicle is still moving.

RFID tags are capable of storing 1 kilobyte of data which can store the identification number of the vehicle. In this regard, the vehicle's license plate would be its identity (ID). This ID can be entered via a computer, together with the model of the car, the owner, and others.

An android app was developed which was integrated with the RFID tag. The traffic operators for example will have the android app installed on their mobile devices. All the information from the vehicle's tag appears on the app after the reader reads it. So if the vehicle was stolen or is wanted by the police, appropriate action would be taken [8].

### ***2.2.1.2 Library Management System***

The RFID technology has been used extensively in library management systems. Singapore was the first country to implement a library management system with RFIDs when it was deployed in the Rockefeller University in 1999 [9]. Libraries in schools, universities, and other institutions now prefer to use RFID tags instead of barcodes because of its added advantages [10];

- With barcodes, only one code can be scanned at a time, whereas the RFID reader can read multiple tags at a time making the scanning process faster.

- The RFID reader can read tags no matter where the tags are placed. The reader can read tags through plastic, wood, paper, and other non-metallic objects. Whereas the barcode must be placed outside the object, RFID tags can be implanted or embedded in the object.
- RFID tags have a bigger storage capacity as compared to barcodes meaning that the tags can store more data than barcodes.
- The data content on the tags are password-protected so the data cannot be easily altered.

Using RFIDs in the library management system ensures that quick inventory of books is taken. As mentioned in the advantages, since the reader can read multiple tags, it facilitates the quick gathering of information about the various books in the library for efficient inventory which saves time and energy the library staff would have used.

The tags can also be used as an anti-theft technology to deter people from stealing books or taking the books outside the library if they have not been properly checked-out. The readers are placed at the doors of the library so if the books have not been properly checked-out, the alarm goes off [10].

#### ***2.2.1.3 Usage in Healthcare***

The RFID European Lab has been researching various aspects to which RFID technology would be used. The technology can be used to improve the tracking of medical personnel, patients, equipment and drugs, and to facilitate the positive identification of drugs and patients. It is of no surprise that hospitals are the main buyers of the technology [11].

#### ***2.2.1.4 Electronic Toll Collection***

Notwithstanding all the application areas mentioned above, the most important application area in respect to this thesis is using RFID tags as a medium to pay for toll fees at toll booths.

In Dubai, tolls are paid automatically, which means that there is no need to stop at respective toll booths to effect payment. The fees are charged whilst the vehicle is still in motion.



Dubai's Electronic Toll System, which is called Salik, meaning "clear and moving" in Arabic, consists of seven toll gates in the city of Dubai. Salik was designed to be as free-flowing as possible.

All patrons of Salik need to be registered. After registration, an RFID tag is given to be put on the windshield of the vehicle. A prepaid account is allocated to each user with some amount of prepaid credit on it. So anytime the vehicle with that tag crosses a toll gate, the fee is automatically deducted from the user's prepaid account. The transaction goes on while the vehicle is in motion so the driver need not slow down or stop<sup>4</sup>.

## 2.3 Proximity Sensors

A proximity sensor is a sensor that detects objects that come close to it.

There are various types of sensors for different application areas. Motion sensors are installed in schools, shopping malls, etc., to detect the movement of people to open doors or to turn on the lights in the hallways. There are also different sensors/detectors that are capable of detecting the presence of vehicles on roads.

Infrared detectors, ultrasonic detectors, inductive loop detectors, are all devices that can be used to detect vehicles.

Like any other technology or device, these detectors come with their advantages and disadvantages. Installing some of these detectors can be difficult and expensive whilst some may not be able to detect vehicles when it is dark or when the weather is bad. These are some of the pros and cons of the mentioned detectors listed below.

Device	Advantages	Disadvantages
Infrared Detector	-Works both during day and night -Can be mounted on the side of the road or overhead	-Sensitive to weather changes
Ultrasonic Detector	-Has higher sensing distance -Can be mounted above the road	-Prone to high wind speeds

<sup>4</sup> <http://whatson.ae/dubai/2017/08/salik-heres-everything-need-know/>

		-Has be to mounted perpendicular to the target
Inductive Loop detector	-The detector is safe and secure since it is buried in the ground	-Difficult to install and must be reinstalled when the road is repaved -
Banner	-Can be used to trigger the opening and closing of overhead doors -Appropriate for extreme weather conditions -Easy to install	-Cannot detect a cars side by side. Cars have to be in a linear formation

**Table 2.3 Vehicle Detection Technologies<sup>5</sup>**

As seen from the table above, these sensors have their advantages and disadvantages. Choosing a specific sensor comes down to which one will best suit the terrain in which it will be deployed, how easy or cost-effective it is to install, and its application areas. For this thesis, the banner sensor would be appropriate because of its uses and the features it has. Drive-through systems use banner sensors to detect vehicles and alerts personnel that a vehicle has approached the kiosk. Loading docks and car wash facilities also use this technology for vehicle detection<sup>6</sup>.

NFC has gained a lot of popularity across various sectors of transport, telecommunication, banking, and many more. NFC is a form of wireless technology which enables devices to communicate with each other. These devices have short range radio waves that allow the exchange of data when they are brought together [12] or at least very close to each other. Embedding the NFC technology into mobile devices has made it possible for consumers to transfer money or data, to make payments, for smart advertising, and others [13].

It is now commonplace for businesses to employ the use of technology to help curb the problems of data privacy and security, whilst improving cost effectiveness. For a few years now, Japan and China have been using NFC as a way of effecting payments. Other parts of the world are now also adopting the NFC technology as a way of effecting paperless or contactless payments, in which a customer just touches his/her phone to a point-

<sup>5</sup> <https://vtechworks.lib.vt.edu/bitstream/handle/10919/37169/APPENDIX-B2.PDF?sequence=36>

<sup>6</sup> <http://www.clrwtr.com/PDF/Banner/Banner-M-GAGE-S18M-Vehicle-Detection-Sensors.pdf>

of-sale device <sup>7</sup>. In other words, NFC is now synonymous with contactless payments, which is an integral part of this thesis.

According to Mario Armstrong, a digital expert, technology behind mobile payments has changed immensely because more and more people now own smartphone devices. Mario Armstrong further added that about 150,000 merchants across the United States had NFC terminals, and that that number is only going to increase in the U.S., as well as globally<sup>1</sup>. Supporting the assertion made by Mario Armstrong is the growth of contactless payments made by Finnish residents. In 2015, contactless payments amounted to a tune of €230m, whereas in 2016, the amount rose to €1.36b [14].

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<sup>7</sup><https://pointofsale.com/20111012786/Mobile-POS-News/Pay-With-Your-Phone-MasterCard-PayPass-Google-Wallet-and-Mobile-Payments.html>

## 3. MOBILE PAYMENTS

The use of mobile devices has over the years increased exponentially. More and more people now own smartphones because of their functionalities. Billions of smartphones were procured by people during the year 2015, allowing various mobile network operators to accrue revenue of over \$3 trillion [15]. The advancement of mobile technology has made sure that using a mobile device is more than just to make and receive calls. Users of these mobile devices have the opportunity to surf the Internet on their devices for information, access their social media accounts, and many more. Another area which is fast gaining popularity is the use of mobile devices to make payments, generally referred to as mobile payments. Mobile payments are referred to as paying for goods and services with a mobile device.

Mobile payments have different adoption rate in different parts of the world. In general, European countries and the United States where the credit system is more mature and established have shown slow rates in adopting mobile payments [33].

A large population in Africa do not own bank accounts. Mobile payment solutions have become a substitute for those in the rural areas especially where visiting a bank is a major challenge. The introduction of mobile payments on the African continent has been successful so far, especially in Kenya where about 80% of the adult population is using it<sup>8</sup>.

### 3.1 Approaches to Mobile Payments

There are various ways mobile payments can be put into practice. Depending on the type of approach the user chooses, extra cost may be incurred, making some of the methods very popular than others. These are the common methods of implementing mobile payments [24].

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<sup>8</sup> <https://edition.cnn.com/2017/02/21/africa/mpesa-10th-anniversary/index.html>

### **3.1.1 Mobile Money Transfers**

The customer pays for the goods and services by transferring money from his or her mobile money account to the merchant's account. This method of mobile payment is the most widely used in Ghana because it does not require the sender or receiver to have a bank account. All this type of method requires is a registered number with the subscriber's network operator. Unlike some bank transfers, the receiver gets the money instantly, regardless of whether the sender and the receiver have different network operators. The main drawback is that the sender is surcharged if the receiver is on a different network operator.

### **3.1.2 SMS Charges**

This involves the customers sending a short code as a text message to the retailer. Each text message with that short code has a specific amount which is charged from the customers' prepaid account [25]. The amount is deducted from the air-time or calling credit, which the customer has. This type of mobile payment is very popular in Ghana when the subscriber needs to vote for his or her favourite contestant in a TV show for instance.

### **3.1.3 Digital Wallets**

A digital wallet enables a customer to make payments digitally through an electronic device. The digital wallet is linked to the customer's bank account and by so doing, payments can be made by providing the user details of the account online.

### **3.1.4 Contactless Payments**

With this method, the customer is required to make the payment by waving or tapping the reader with his or her phone. This method is made possible by the use of NFC's or RFIDs mentioned in chapter 2. Examples of such contactless payment services are Google Pay, Samsung Pay , and Apple Pay.

## **3.2 Factors Influencing the increase in Mobile Payments**

With the increase in the use of mobile devices all over the globe, consumers of goods and services are resorting to using mobile payments to transfer or receive funds. Although mobile payments are generally on the rise, some consumers are still skeptical about adopting this mobile technology.

Below are the factors that will hinder or promote the use of the various mobile payment solutions as discussed in [16].

### **3.2.1 Relative Advantage**

Taking into consideration the contexts in which mobile payments are utilized, research suggests that location and time are the key elements that positively impact the use of the mobile payment solutions [17][18]. Unlike the traditional way of making payments, mobile payments ensure that the consumer need not withdraw money from an ATM or the bank to pay for bus tickets or groceries for instance [19]. Interviewees from a survey conducted in [16] mentioned the possibility of avoiding long queues, and making payments ubiquitously were factors that led them to the use of mobile payment solutions. Additionally, the interviewees considered mobile payments convenient because they always have their phones with them and do not have to worry about paying for goods and services if they do not have cash readily available on them.

### **3.2.2 Compatibility**

The ability of the mobile payments to be easily integrated into the daily activities of the consumers is another determinant in the adoption of mobile payment solutions [20]. That is if the mobile payment being used will not interfere with the way they make payment, its adoption by consumers will be positively impacted. Compatibility in [16] was evaluated in regards to the different types of purchases involved in the mobile payments. Based

on the survey, four categories of when mobile payments were convenient to use were identified;

1. Paying for electronic tickets for transportation or cinemas
2. Payments for mobile contents like games, pictures and music
3. Small value payments in convenient shops or kiosks
4. Payments at various self-service machines

It is worth noting that most of the interviewees found it suitable to use mobile payments for small value payments, and were willing to pay bills worth up to 100 euros using mobile devices [16].

### **3.2.3 Complexity**

According to [21], complexity is the “degree to which an innovation is perceived as difficult to understand or use”. The low patronization of various payment services can be attributed to usability problems and the complex nature of the payment solution [16]. The easier and more convenient the mobile payment system is to use and understand, the more consumers would adopt to using it [22]. The interviewees in [16], mentioned that when it comes to paying for goods and services, using an SMS is complicated and slow to use due to the format in which the message should be in. They also criticized the complex nature of registration procedures involved in the mobile payments.

### **3.2.4 Costs**

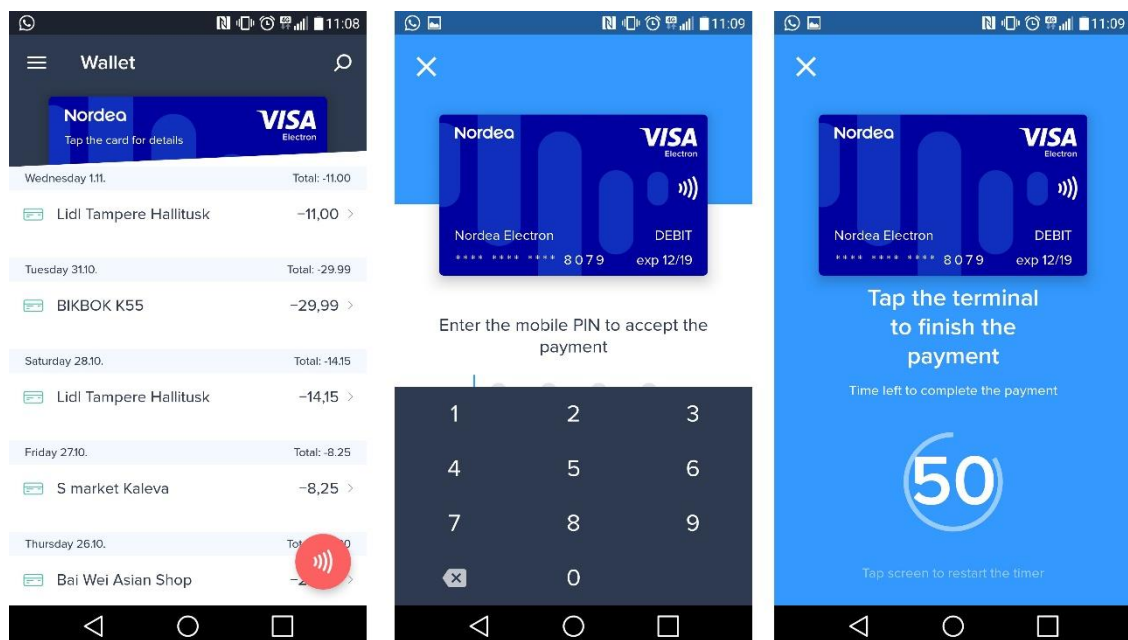
Additional costs which may be incurred when using a mobile payment service is another key determinant consumers look out for. In mobile payments, the transactional costs are usually added to the price of the item to be purchased. From the survey in [16], some interviewees pointed out that they stopped using mobile payments because of the additional costs they incurred. They also mentioned that they would rather use cash payments if mobile payments cost them extra for the same item.

### 3.2.5 Security Issues

The adoption of mobile payments also largely depends on the security accompanying these mobile payments. Consumers are mostly concerned about their privacy and the security of their mobile devices. There are concerns about unauthorized accesses to their payments and other user data [23], if the device is hacked into or lost.

In view of this security problem, Nordea pay ensures that before the transaction can be completed with the app, it asks for the password to the app.

Figure 3.2.5 shows a few screenshots of the Nordea pay application which I used for paying a bill.



**Figure 3.2.5. Screenshots from the Nordea Pay app.**

The above images are from the Nordea Pay app. It shows how secure it is using NFC to effect payment. It requires the user to enter his/her pin before the payment side of the app can be accessed after which the user has less than a minute before the app automatically logs out.



### 3.3 Users Studies on Mobile Payment Solutions

User study is a research conducted on the users of a product or service to understand their needs, behaviours, and motivations through observations and other data collection techniques<sup>9</sup>.

There are a number of surveys which have been done on the customer satisfaction of using mobile payment solutions available on the market. This part covers user studies conducted in Italy and the United States of America.

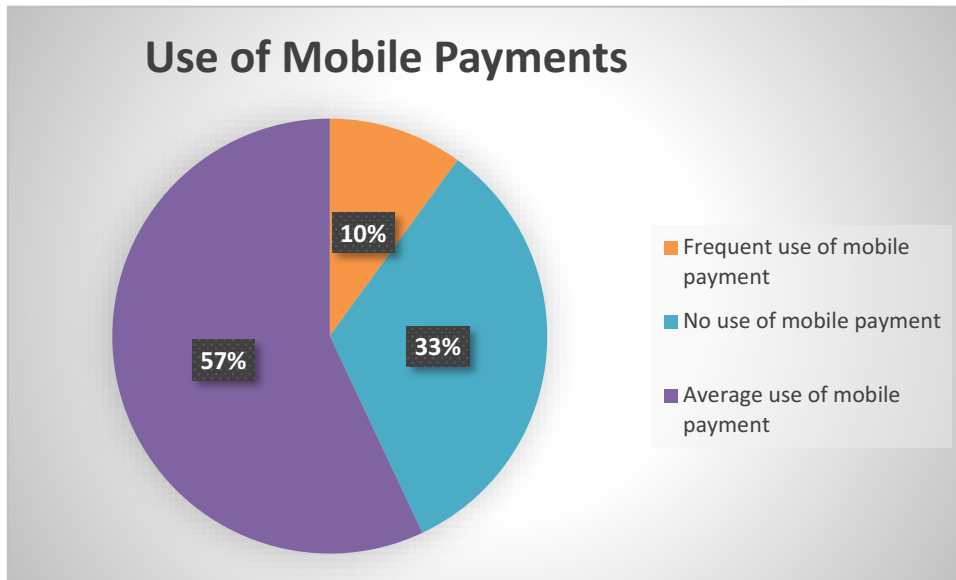
#### 3.3.1 User Studies in Italy

Even though the number of smartphone owners has increased significantly, research has shown that Italians generally still prefer to pay by cash [26]. The “Center of Expertise on Technological Innovation” in Italy conducted a survey through quantitative interviews of 1001 people, which was then followed by 2 focus groups with 13 participants ranging from the ages 35 to 54. These 13 participants were to own a mobile phone and should have used a mobile phone for at least 10 years. They were also to possess a degree (at least to a high school diploma), and to be gainfully employed. These requirements were specific to only the focus groups for qualitative analysis. The aim of the qualitative analysis was necessary because even though these people represented the biggest target group for mobile payment solutions because of the familiarity of the technology, they did not show any interest in using these solutions mentioned in (3.1) [26].

From the quantitative interviews, 10% of the respondents frequently used electronic payment systems and/or mobile devices for mobile payments or for mobile banking operations. 33% preferred to buy in the shops and also showed low interests in all types of electronic payments. Those who used an average of electronic media and have low use in mobile device for payments were in the majority representing 57% of the respondents [26]

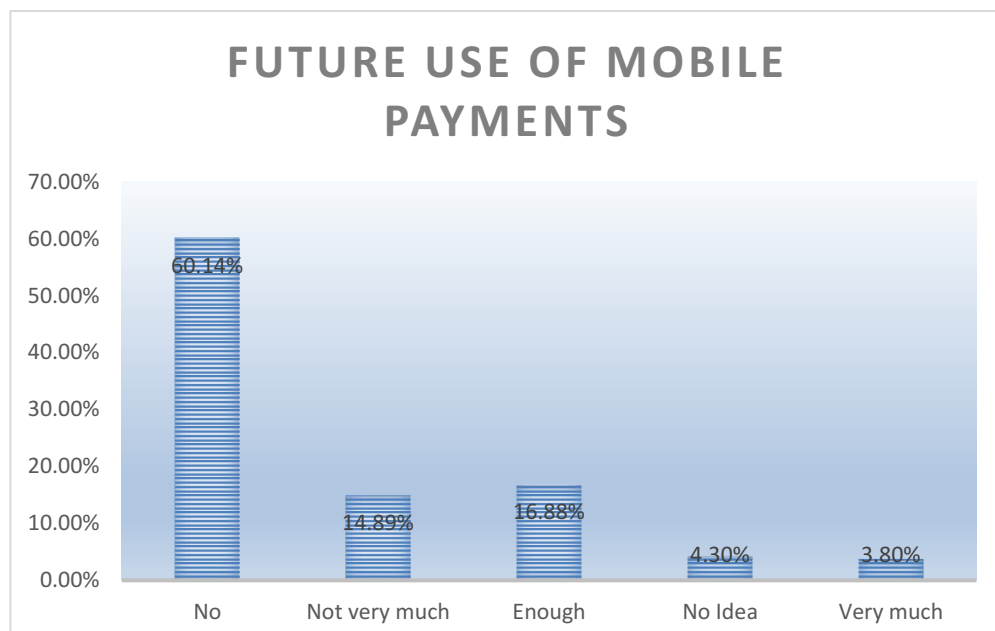
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<sup>9</sup> <https://www.usability.gov/what-and-why/user-research.html>



**Figure 3.3.1a. A chart of the use of mobile payments [26]**

Furthermore, when the respondents were asked about their familiarity to mobile payments, only 9.19% of them mentioned they were aware of the existence of such a technology. They were further asked if they would prefer to use their mobile phones to effect payments without the need of bringing out their wallets. 60.14 % of them said they will not use mobile payments, 14.89 said “not very much”, 16.88% said they will use it enough, whilst 3.8% said “they will use it”. 4.30% of them did not know if they would use it or not [26].



**Figure 3.3.1b. A chart on the future use of mobile payments [26]**

In reference to the future use of mobile payments, the respondents who were familiar with NFC technology (in chapter 2) and were interested in using mobile payments was 9.09 % which is a reduction from the previous 9.2% mentioned above because knowing about the existence of a technology does not necessarily mean it will be used. Those who were not aware of the NFC technology but were interested in using mobile payments were 16.98%, whilst those who were not familiar with NFC and were not interested in using mobile payments in the future were 73.93%.

Finally, the respondents were asked to give advantages and disadvantages of mobile payments from their perspective. In regards to the advantages, 33.77% said it did not present any advantages, 28.27% said it made payments faster, 18.28% were for the idea of not carrying cash around, and 16.68 said it was simple to use. Among the major disadvantages were lack of security (37.66%), preference for paying using cash (35.46%), lack of confidence in mobile payment solutions (14.29%) [26].

The focus groups confirmed the above results gathered from the quantitative interviews. The groups were shown how mobile payments worked through the use of NFC, and some videos showing the contexts in which mobile payments would be convenient. They were asked to give their general thoughts and feelings about the videos and the demos of the prototype. All of the 13 respondents were curious about this new payment technology and were willing to test it. But majority of them were of the view that mobile payment solutions were not revolutionary but just a different way to pay [26].

### **3.3.2 User Studies in US**

Between November 2012 and January 2013, PricewaterhouseCoopers (PWC) conducted a 2-phase survey to capture the user experiences of consumers who use mobile payment services. In the first phase, 1000 people were sampled between the ages of 18 to 74 across the United States, where as in the second phase, the survey was conducted with focus groups in Dallas, Texas [36].

With the issue of the awareness of the various mobile wallet applications available on the market like PayPal, Google Wallet, and Starbucks, all the respondents noted that they were aware of PayPal but only 83% of them actually use it. The focus groups mentioned that they were aware of PayPal because of its common usage especially

among the younger generation. Google wallet and Starbucks' application both had an awareness level of 59%. Only 15% use Starbucks which is higher than Google Wallet's 9%. The general consensus was that the consumers were happy with the performance of the digital wallets mentioned [36].

In terms of transferring money using mobile wallets, most of the respondents were skeptical about its usage. Only 45% of them were comfortable with transferring money with the mobile wallets. Out of those comfortable with transferring money, 70% were comfortable transferring amounts between 100 to over 500 dollars.

In using their phones as an electronic debit/credit card, 43% said they were likely to pay for goods and services in a shop with their phones. However, they were not happy with the idea of using their phones to store their money. They were concerned about how to get their cash back if their mobile wallet is lost or stolen.

Although security is the main concern of the respondents, 78% of them thought that the incentives such as discounts and coupons encourage them to use mobile payment services. In addition, 57% thought another benefit of the digital wallets is that it is convenient to use and saves time [36].

## **4. RESEARCH PROCESS**

This chapter presents the objectives of the user study conducted, with its expectations. The recruitment process and the data collections methods are discussed.

The data collection was in two parts. In the first part, 10 drivers (main target group of the research) and 5 passengers were recruited. In the second part, a couple of government officials and toll booth attendants each were recruited. During the data collection, the proposed system was explained to the participants so that they had a general idea of the objectives of the prototype. Participants were asked to express how they felt about the proposed system and the prototype. Notes were taken of those who did not consent for their voices to be recorded. Audio recordings were made of the session of a few who gave their consent.

### **4.1 Study Objectives**

Mobile payments are important because it will be convenient for the motorists to use. They do not have to be carrying cash to the toll booths, and there would be no need for them to check whether the change they received from the tollbooth clerk is accurate or not.

The mobile payments will also help the state to monitor and collate all the tolls at the booths more accurately since all the payments would be stored on a designated server. In regards to the context of use, a few meters away from the tollbooth, the motorist opens the mobile payment app and touches his/her phone to the NFC terminal whilst in the vehicle.

The user study sessions were run with the aim of ascertaining the user-friendliness and the effectiveness of the prototype. For this aim to be realized, data was to be gathered first and foremost. This helps to know what the needs of the targeted group are. Feedback was the utmost output which were required from the target group.

## **4.2 Data Collection Methods**

When it comes to user requirements gathering, there are a number of ways in which data can be collected. These are the methods which were used in this thesis.

### **4.2.1 Interviews**

An interview is a meeting organized where a person asks questions (interviewer) whilst the other person provides the answers (interviewee). It is usually advantageous to run an interview in person so that the nonverbal cues would be seen especially the behaviour a participant exhibits when using a prototype during testing.

Interviews can basically be in 3 forms. They can be structured (where the interview follows a specific set of questions), semi-structured (where the interview follows a set of questions, with the possibility of adding new issues that come up) or unstructured (interview does not follow any specific pattern) [27].

Data was collected using both the structured and semi-structured interviews in this thesis.

### **4.2.2 Prototyping**

Prototyping is a way to gather user data with the main aim of getting feedback about a design, to enable changes or additions to the current design. Paper prototype was the first to be implemented. This was done because it was fast and easy to implement. Paper prototype helped to propagate the idea to the participants. After the use of the paper prototype, a high-fidelity prototype was designed using a computer to ensure that the design was working how it was supposed to work [28].

### **4.2.3 Observation**

This method involves the interviewer just observing the behaviour, mood, and other non-verbal cues the participants will portray during testing or when an activity is taking place. I used this method in two ways; the first was to observe the transaction between the drivers' and the toll booth attendants to see for myself what the transactions entail. And the second was when I observed how the participants were using the prototype.

### 4.3 Recruitment Procedure and Participants

The main target group of this system were motorists/drivers since they use the toll booths directly. Passengers are also a target group because they are also present during the transactions even though not directly involved. It was important to recruit some passengers because some of the passengers at some point also become drivers.

The most frequently used highway in Ghana is the Accra/Tema Motorway which has a number of booths across it. With this in mind, most of the interviews were done at the Accra Mall since many people go there for shopping and leisure. I met each driver at the parking lot and introduced the topic and myself.

The participants were given codes P1, P2, to PN, where PN is the last participant to be interviewed. Table 4.3a shows the demographics of the participants interviewed.

#### Part 1 of Interviews (Drivers)

Interviewees	Age	Gender	Occupation
P1	36	Male	Nurse
P2	32	Male	Bank Teller
P3	45	Male	Shop Attendant
P4	28	Female	Student
P5	62	Male	Taxi Driver
P6	47	Female	Entrepreneur
P7	36	Female	Unemployed
P8	30	Male	Delivery Man
P9	38	Male	Entrepreneur
P10	69	Male	Retired

**Table 4.3a. Background information on participants (Drivers)**

In recruiting the passengers I had to empathise with them. The idea was to interview them whilst they were in the actual context in which they would require the use of the proposed system. I boarded a commercial vehicle at the peak hours so that I could run the

interviews also as a passenger. Table 4.3b shows the breakdown of the passengers' demographics.

**Part 1 of Interviews (Passengers)**

<b>Interviewees</b>	<b>Age</b>	<b>Gender</b>	<b>Occupation</b>
P1	40	Female	Trader
P2	45	Male	Teacher
P3	17	Female	Student
P4	23	Male	Welder
P5	32	Female	Trader

**Table 4.3b. Background information on participants (Passengers)**

#### **4.4 Methods and Procedure**

Most of the interviews for the drivers were held in the shopping mall as mentioned in 4.3 above. Apart from a couple of participants I bought refreshments for, the others were good to go. The environment was spacious with enough room to ensure that other people did not eavesdrop on whatever we were discussing. The environment was comfortable enough for the interview to take place. The participants were assured that their responses will remain anonymous. Each interview lasted approximately 15 to 20 minutes, depending on how many questions were asked by the participant. The topic was introduced to them, after which they were encouraged that they were not under any sort of examination, and that I was just testing the design. They were urged to relax and speak of anything they were thinking of. Participants had the choice of quitting the interview process anytime they deemed fit if they were uncomfortable continuing with it.

As earlier stated in 4.3 above, I thought it wise to interview the passengers in that particular context. The interview atmosphere was not as comfortable as those that were run at the mall. We were in commercial buses with 3 or 4 people on a row. The interview was initiated as a form of conversation when we came across heavy traffic before the toll



booths. Since we were in a moving vehicle, notes were not taken neither were audio recordings. I only interviewed 1 passenger per trip so that I could remember his/her responses. In the middle of the conversation, I explained to them why I was asking those set of questions so that I could get their respective ages and subsequently their professions. The duration of the conversation differed from one passenger to the other. It depended on where the passenger was going to alight. On the average, all the interviews lasted at least 25 minutes.

Getting hold of a government official was a little frustrating because they are usually reluctant to answer any questions. They are very careful about the information they divulge to an interviewer. Some of the officials who promised to meet me never turned up, which is not at all surprising when it comes to the field of user study.

Through contacts from family and friends, I was able to get hold of a couple of officials who could not make it in person so the interviews were conducted on the telephone. The telephone interview was the best option since these officials were not going to test the prototypes. Knowing how feasible the proposed system was and the various payment methods to be used were the main focus of the interview in regards to the officials. They proposed that since there are a lot more privately owned vehicles in the country, the piloting should start from there. Appendix C shows the questions asked.

#### **4.4.1 Interview**

The respective interviews were conducted in a friendly environment, or at least where the participants felt comfortable enough to respond to the questions being asked. The approach was such that I started the interviews through a normal conversation (in the case of the passengers) without the would-be participant knowing my real motives. Later during the conversation, I had to make them aware of the situation because specific questions were being asked. Since we were in a public transport at the time, a few passengers were eavesdropping and asked some intelligent questions to which I gladly offered answers.

These are some of the comments made by participants on a few selected questions from the interview.

**1. Question: Can you describe the process when you get to the tollbooth?**

*P1: "When I get there, I give the money to the person in the booth and she gives me my change and also the receipt."*

*P2: "I choose the tollbooth with less cars and give the money to the attendant."*

*P3: "I stretch my hand to the teller and give it the money to him or her. She then gives me the receipt."*

**2. Do you know the fee before you give her the money?**

*P1: "Yes or I give a bigger amount if I am not sure."*

*P2: "Yes I know the amount but I think they charge different amount for different vehicles."*

*P3: "Yes I know the amount."*

**3. What do you think can be done about the traffic situation on motorway?**

*P1: "I have not thought of that because I don't use it during rush hours."*

*P2: "I think the payment could be made a little quicker if they could pay for example monthly and just swipe some kind of loaded card to reduce the delay. And also the no. of booth workers could be increased during early hours of the morning and rush hours in the evening."*

*P3: "In my opinion, I think that the tellers should increase their productivity when they are serving the cars. A better way will also to automate the whole process or expanding the motorway altogether but I do not think that will be happening since there is no land for the expansion."*

### **4.4.2 Observation**

Aside directly asking the participants various questions, I was also noticing how they behaved while using the prototype. In general, all the participants had pleasant feelings of using the prototype. Some were nodding whilst others smiled when everything went well. A few of them showed signs of frustration upon reaching the top-up page. Since the prototype was not linked to any database, they could not continue to top-up their accounts after they chose a bank from the dropdown menu.

After observing how the participants used the prototype, I observed for a few minutes how the process was like at the tollbooth. As a vehicle approached the tollbooth, the driver stopped and handed money to the clerk and a receipt was given in return. Some of the drivers did not have the money ready. They stopped first and started opening their wallets for cash or coins which caused delays.

During the interview of the passengers (part 1 of the interview in section 4.3), I observed the transaction between the driver and the tollbooth clerk up-close. The transaction went on smoothly but I realized that a receipt was not issued to the driver. The driver realized it some meters away from the tollbooth when he asked the bus conductor to check the change he received from the tollbooth clerk.

### **4.4.3 Background Questionnaire**

In the case of the drivers, questionnaires were handed to all of them to capture their demographics; age, occupation, technological background, just to mention a few.

Table 4.4.3 shows some of the overall responses collated from the background questionnaire

<b>Question</b>	<b>Once a week</b>	<b>Some-times</b>	<b>Fre- quently</b>	<b>Never</b>	
How often do you use the Internet?	1	4	5	-	
Do you use a smartphone often?	-	2	7	1	
How often do you use a computer?	2	3	4	1	
Do you come across tollbooths?	2	2	6	-	
	<b>6am to 7am</b>	<b>7am to 8am</b>	<b>8am to 12pm</b>	<b>12pm to 5pm</b>	<b>5pm to 10pm</b>
I use the tollbooths at (an individual was allowed multiple answers)	7	2	1	3	8
	<b>1 (very bad)</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5 (very good)</b>
How good are you in using apps on your phone?	2	2	1	2	3

Table 4.4.3. Responses from background questionnaires

## 4.5 Summary

In order to ascertain the feasibility of the proposed ETC, a total of 19 people with diverse backgrounds, across different age groups were interviewed.

The interviews were in two parts. The first part being the interviews involving the drivers and the passengers, and the second part being the ones with the officials and the booth attendants. With the exception of the passengers interviewed, which usually lasted until the passenger was getting off, the average time used for the other interviews was between 15 to 20 minutes.

The officials provided good insight on the problem which the ETC is supposed to help solve and also ideas to help in the implementation.

A few of the interviews were a little emotional because the successful implementation of this proposed ETC will mean a few more people will be unemployed since the manpower would be cut down by a greater percentage.

There will however be some job opportunities in the IT sector in terms of running the systems and maintenance.

## 5. DESIGN AND IMPLEMENTATION

In this chapter, the description of the proposed system's design and implementation phase, which begins with the conception and development of the idea is given. A more detailed description of the system's application and subsequently its features is also given, including the objectives of the system.

Designing of the proposed system was done iteratively, which was completed in a couple of months. This phase consisted of two parts.

The first part being the ideation, where the ideas behind the using of proximity sensors in automating toll booths are developed and communicated.

Implementation, which is the second part, involves the various technologies that would be used to help with the implementation of the ETC system. Iterations in testing were employed to enable changes in the prototype as against the feedbacks received from the various testing processes, to further improve the quality and the functionality of the user interface.

### 5.1 Forming of the Proximity Sensor Concept

In fully grasping the idea of using proximity sensors in toll booths systems, brainstorming was done on regular basis. The primary objective of this project was to compare other In fully grasping the idea of using proximity sensors in toll booths systems, brainstorming was done on regular basis. The primary objective of this project was to compare other technologies to illustrate why the use of proximity sensors is appropriate to the terrain of Ghana as opposed to the others, that will also be in line with research goals. The underlying goal was to design a system which is user-friendly so that people who are not technologically savvy can still use it.

During the ideation phase, a few meetings were held with my supervisor. My supervisor brought up the idea of illustrating the current toll booth system in Ghana in the form of a diagram. The ideas were drawn on a white board, but I was advised to illustrate them by way of storyboarding.

A storyboard is an illustration of drawings or sketches to help people to visually relate to how a person is interacting with a product or service, in the form of a story.

From Bill Buxton's book [31], storyboards are used to show the flow of a story to help the stakeholders understand the problem and propose new ideas to them, whilst reducing the costly elements of the design. All these phases and processes predominantly use the methodology of UCD.

User Experience (UX) is the thoughts, feelings and perception a user has as a result of interacting with a product or service [30]

In UX, UCD methodology is a list of processes or phases that a product goes through from the beginning of the design to its implementation or deployment, whilst also considering the actual users of the product. This means that the users of the product are involved in each of the phases. The UCD process is basically made up of 4 iterative process [32];

- The context of use : - which is the situation in which the product would be used
- Requirements : - the tasks or goals the users are expecting the product to achieve
- Design Solutions : - the stage where the proposed design solutions of the product are made.
- Design Evaluation : - the stage whereby the design solutions are tested to check its usability through user testing

As mentioned, these phases are all iterative which means that after the evaluation phase, if the product is not satisfying enough to the users, then the whole process is repeated until a preferable outcome is achieved.

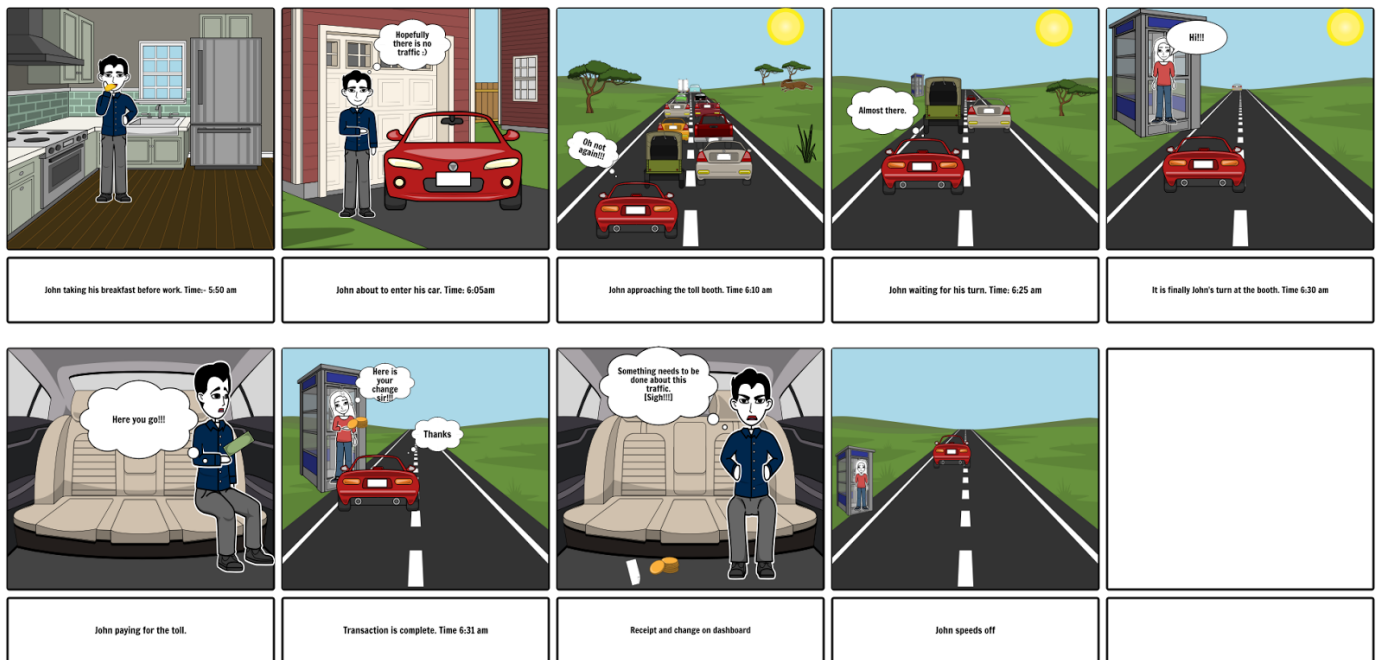
Before the aforementioned phases can really begin, a preliminary stage is first undergone, that is to identify the need for the product, which has been well documented in Chapter 1. The context of use in this case would be in a vehicle whilst at the toll booth. The basic requirement of the product is to let the user be able to pay his/her toll, and also to top-up his/her account. The design solutions for the product has been given in 5.4.1 below, whilst the evaluation is in Chapter 6.

It is worth noting that the most important aspect of the proposed system is the payment. Again, suggestions were made by my supervisor that the use of NFC devices can be integrated with the proximity sensors. If motorists are to always pay cash at the booths, the

primary reason for proposing this system would not have been achieved. There would still be long queues of cars awaiting their turn.

## 5.2 Description of Current System

Currently in Ghana, vehicles have to wait for some time in queues at the tollbooths just to pay and continue their journey. Depending on the time of day, the waiting time may not be less than half an hour. This is because the tollbooths are usually overwhelmed by the number of cars waiting to be served. Figure 5.2. is a diagram showing the current situation.



Create your own at Storyboard That

**Figure 5.2.** A storyboard depicting the current tollbooth system



### 5.3 Proposed System

The idea of this system is to reduce the average waiting time of cars per toll booth. This can be done by incorporating efficient ways of paying for the tolls so that the human element is eliminated. Tollbooth clerks tend to get exhausted doing the same thing over and over again, which makes them less productive whilst hours go by.

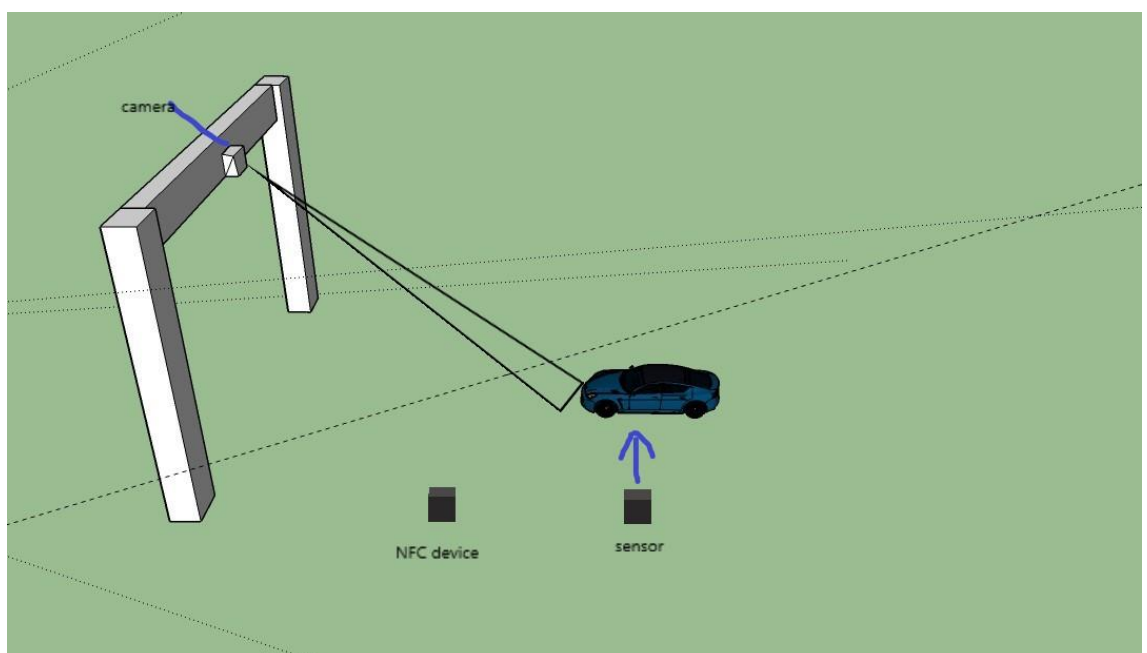
It is also unhealthy working in that environment because of the exhaust fumes.

Using NFC devices, coupled with proximity sensors will prove a long way to lessen the waiting times and a more healthy atmosphere around the booths.

#### 5.3.1 Charging System

Ordinarily, every car is supposed to have a registered number plate. That would have been the easiest way of knowing the amount each car will have to pay in tolls. It would be easier because each car is registered at the DVLA. The type of vehicle would just have to be stated when registering the car.

The idea is that, a few meters away from the tollbooth, an overhead camera captures the characters through a character recognition software from the plate (as mentioned in chapter 2.2). The combined characters are then run through the DVLA database (figure 5.3.1b) to retrieve the vehicle type and allocates the fee for the toll accordingly.



*Figure 5.3.1a. A picture depicting how the proposed system will work.*

**DATABASE**

No.:	NAME OF OWNER	DOB	SEX	LICENSE TYPE	CAR TYPE	NUMBER PLATE
1	Sam George	16/8/1986	M	A	Truck	GT-1000-15
2	Jane Doe	20/2/1990	F	B	Sedan	GT-2221-17
3	Vicky Vick	10/7/1979	F	B	Sedan	ER-5121-16
.	.	.	.	.	.	.
.	.	.	.	.	.	.
.	.	.	.	.	.	.
.	.	.	.	.	.	.
<b>15874</b>	<b>John Doe</b>	<b>12/5/1974</b>	<b>M</b>	<b>B</b>	<b>Sedan</b>	<b>GT-1234-15</b>
15875	Happy Hope	1/6/1985	M	A	Van	GW-8700-13

*Figure 5.3.1b. The proposed database of which would be linked to the ETC*

From figure 5.3.1a above, even though the most important fields are the car type and the number plate, it is essential to have the other fields for proper records keeping that is why the name of the car owner and other fields are included.

When the license plate of the approaching vehicle is captured and the individual characters are retrieved, the combined characters are run through a database as shown in figure 5.3.1b. The aim of this is to retrieve the type of car belonging to that particular license plate. Different type of vehicles have different toll fees. Trucks have higher tolls compared to sedan. So if the approaching vehicle is a sedan, the appropriate fee appears on the NFC terminal. The amount will then be charged from the user's account when he/she touches the NFC terminal with the phone.

### **5.3.2 Payment Methods**

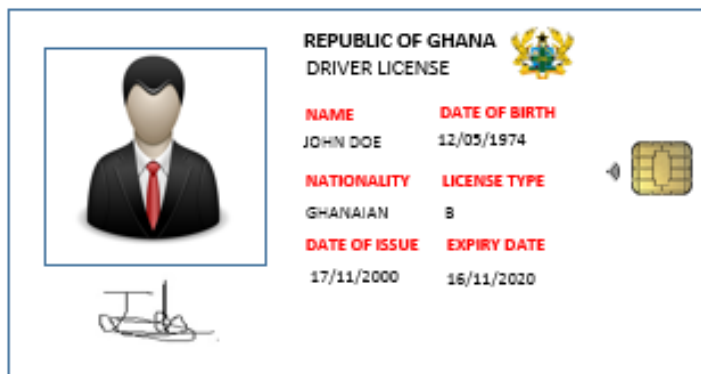
As mentioned, the main course of delays at the booths involves the exchange of money between the motorists and the tollbooth workers. The motorists give the money to the clerk after which the clerk looks for change where need be. Most of the time, the transaction requires change which drags the process a bit further. This section underlines the possible ways in which the paying of the toll would be much efficient. The payment methods are listed below.

### 5.3.2.1 Mobile Payments

This involves the use of mobile phones primarily to effect payments. The “cash” will be electronically stored on the device. Upon reaching the booth, the motorist touches the NFC device with his/her NFC-enabled phone to effect payment. That person’s account is then debited accordingly.

### 5.3.2.2 License

Since every driver is supposed to have a license, it would be easier to have the licenses embedded with chips to look like that of ATM cards. The motorists swipe the card at the toll booth at the NFC device. The amount is then charged from their ETC accounts. Figure 5.3.2.2 shows how an NFC enabled license would look like.



*Figure 5.3.2.2. Design of a license with NFC compatibility*

### **5.3.3 Topping-Up**

The automated system requires that the user is able to top-up his/her account if and when the account is running low on electronic cash. The ETC app on the user's phone will have the functionality of allowing the user to top up anywhere and at anytime, provided that person has a bank account that allows him/her to perform online transactions. In the case whereby the user does not have a bank account, or the account is not linked to online banking services, there will be service points at various fuel stations and offices where utility bills are paid, to make it easy for users to access the service. Many banks are now offering online banking services, and also have their respective bank apps. Fidelity mobile banking, Barclays mobile banking are examples of apps that the users can download and link to their ETC mobile app.

## **5.4 Implementation**

To effectively implement the ETC, some equipment need to be provided at the booths. A camera for the Automatic License Plate Recognition camera, connected to a Character Recognition software on a server is needed. The servers will in turn be connected to the DVLA database to help retrieve the necessary data for the transactions.

An NFC device or terminal is also needed to enable the motorists effect payments. The terminal will be mounted at the side of the road, in a well secured box or structure, to safeguard it from bad weather conditions.

A vehicle detection sensor will also be mounted at the side of the road to help detect vehicles that are approaching the booth. This sensor will be the banner technology as discussed in chapter 2. Figure 5.3.1a depicts how the implementation will look like.

Finally, a mobile payment app installed on the user's phone to enable him/her interact with the ETC system will also be needed.

## 6. RESULTS

In this chapter, results from the various interview sessions from the different iterative processes are documented. Feedback from the respective user studies were used to make changes to the proposed system where need be. After changes were made to a specific design, it was subsequently tested with potential users of the system.

### 6.1 Mobile Payment App Design

To enable the motorists use the ETC system, they need to have a mobile payment app installed on their mobile phones to enable them make contactless payments at the booths, check their account balance, top-up their accounts, and check the history of the tollbooths visited.

The prototype was designed with one key thing in mind – simplicity. A book by Steve Krug, “Don’t Make Me Think”, advocates that the product should be self-explanatory. The book further states that if something looks like it will require a great amount of time, it is less likely to be used [29].

As mentioned, the prototype was designed to be simple and easy to use whilst also keeping it consistent in how it looks.

It begins with the user creating an account using the registration page. After the successful creation of the account, the user is taken to a page with 3 tabs; the accounts, tollbooth, and history pages. The user can check his/her account balance or top-up using the accounts page. The user opens the tollbooth page a few meters from the tollbooth to make the payment at the NFC terminal. The transaction can only be completed if the correct pin to the app is provided in the tollbooth page. The history page shows all the tollbooths the user have visited previously. Finally, the top-up screen allows the user to top-up his/her account or another person’s account.

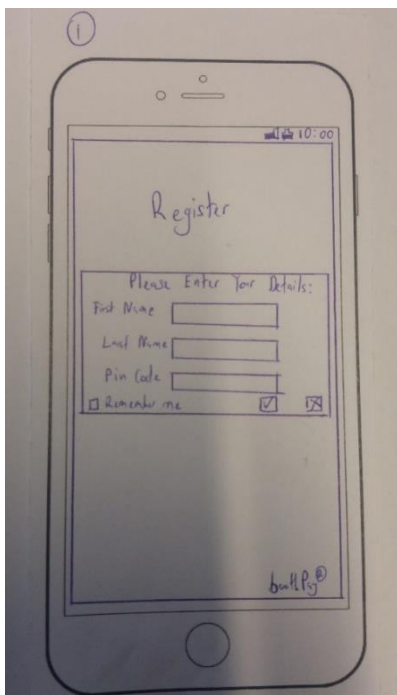
The buttons are in 2 colours; green and blue. From the designs, the blue buttons are used to cancel an operation or to close a page, whereas the greens buttons completes an operation. Refer to screen 1 to screen 6 in section 6.2.2 for the final app design.

## 6.2 Iterations

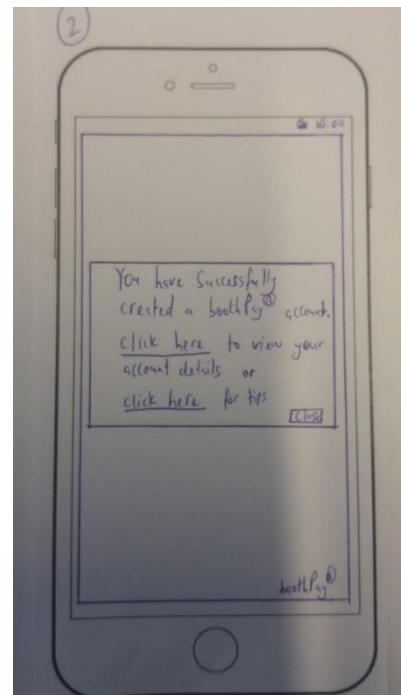
The evaluation was done based on the performance of each participant, which was done through observing them. Performance in this regard is the maximum time the user is to use to complete the tasks as against the actual time the user used to complete the task. All the participants interviewed (Chapter 4), especially the drivers, were spread across the 2 iterations explained into detail in the paragraphs that follow. As part of the qualitative analysis, Standard Deviation was used to analyse the data in 6.2.1 and 6.2.2.

### 6.2.1 First Iteration

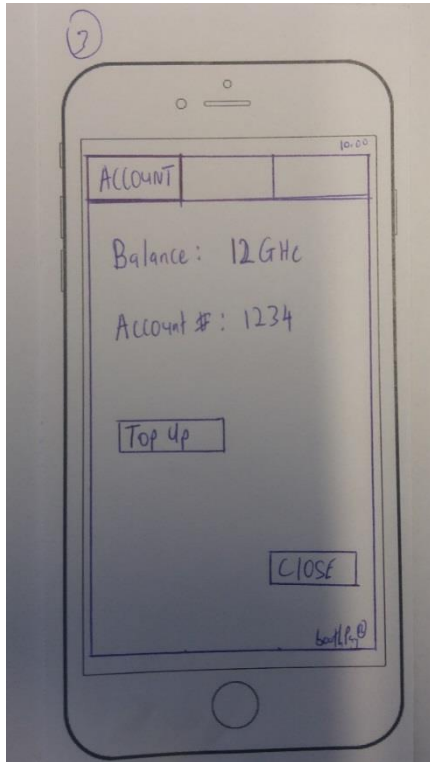
As mentioned, the initial design was implemented on paper. It was made as a paper prototype just to convey the system's idea to its potential users. Quick feedback was needed since there are almost, always changes made to the first designs made. These are screens 1 to 6 from the paper prototype below, which were later used to design the screens in section 6.2.2.



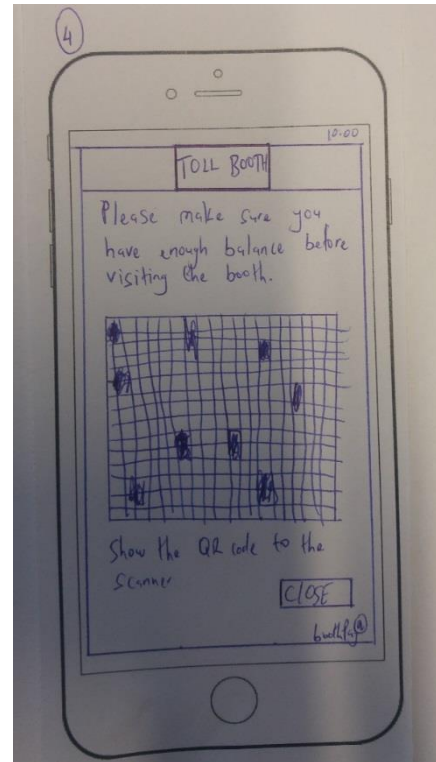
**Screen 1. Registration page**



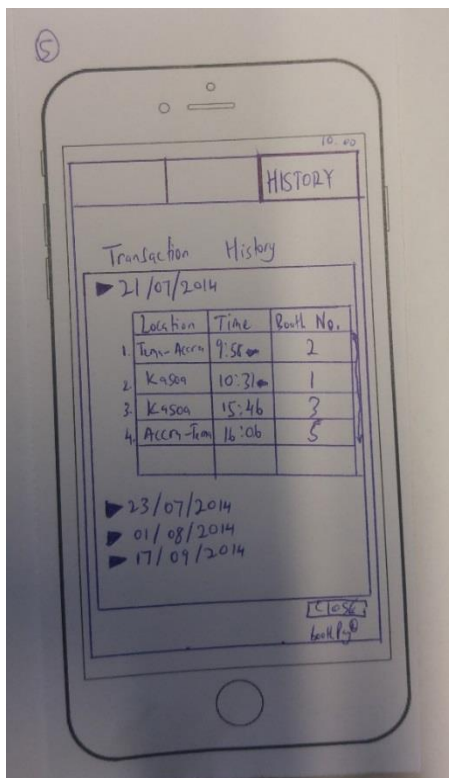
**Screen 2. Confirmation page**



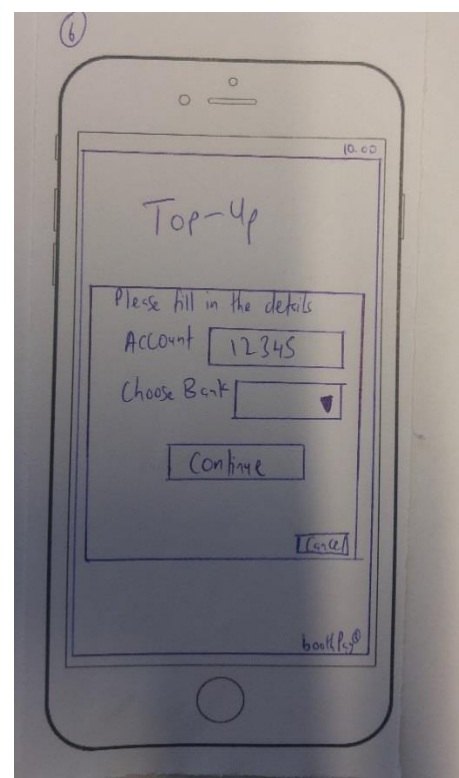
**Screen 3. Accounts Page**



**Screen 4. Toll Booth Page**



**Screen 5. Transaction history page**



**Screen 6. Top Up page**

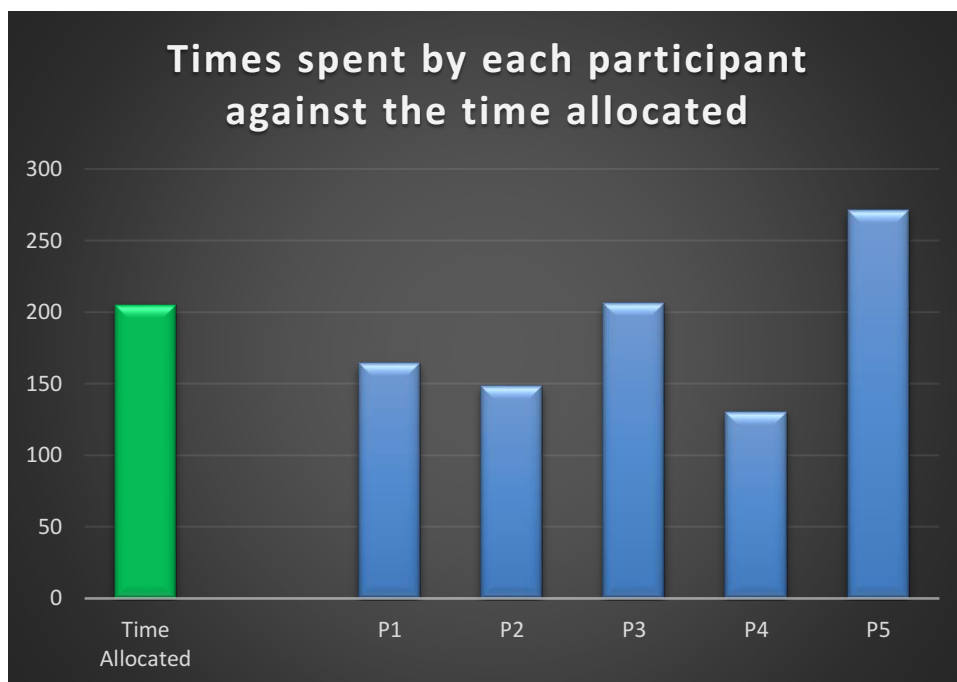
From the above images, the user is supposed to register, and get access to his/her account. Since the paper prototype is not interactive, they were asked to explain or to tell what a specific screen does or what they think that screen is supposed to do.

Table 6.2.1 shows the report of the first iteration of 5 drivers interviewed;

	P1	P2	P3	P4	P5
<b>Screens (all times in seconds)</b>					
1.Registration. Time Allocated (30 secs)	40	28	33	15	55
2.Confirmation. Time Allocated (10 secs)	10	8	12	7	15
3.Account. Time Allocated (60 secs)	35	45	55	22	65
4.Toll Booth. Time Allocated (45 secs)	15	17	30	20	40
5.History. Time Allocated (30 secs)	29	30	36	40	45
6. Top Up. Time Allocated (30 secs)	35	20	40	26	51
<b>TOTAL TIME SPENT</b>	<b>164</b>	<b>148</b>	<b>206</b>	<b>130</b>	<b>271</b>

**Table 6.2.1. Times spent by each participant on the various screens**

Figure 6.2.1 shows the data in table 6.2.1 below.



**Figure 6.2.1. A bar graph representing the total time used by each participant compared to the allocated time for iteration 1**



The total allocated time to complete the usage of the prototype in iteration 1 was 205 seconds. From figure 6.2.1., P1, P2 and P4 were able to finish the testing before the 205 seconds mark. P5 used over 60 seconds more than the allocated time, whereas P3 was just over the mark by a second.

From table 6.2.1, since the drivers had different technological backgrounds, their timings were different. Those who rarely used smartphones or the Internet in general struggled with the prototype. In addition, some of the times were way more than the actual times allocated because some further explanations were required which also took up a few more seconds.

From Table 6.2.1,  $\bar{x} = 183,8$  seconds, which translates to approximately 3 minutes. The standard deviation,  $S_x = 50,33$  seconds.

## 6.2.2 Second Iteration

Changes were made with the feedback collated from the various participants from the first iteration. This second iteration was an interactive one where the participants used the prototype on a smartphone provided. The interactive prototype was made with an online-based software called proto.io. It is used to create fully-interactive prototypes which would mimic an actual app on a smartphone or a computer<sup>11</sup>. Below are screens 1 to screen 6 of the interactive prototype.

The only change to the screens from 6.2.1 was made on the tollbooth screen. In the paper prototype, there is a QR code present. During the testing, participants did not understand the purpose of the QR code. It was seen to be redundant since the mobile phone was going to be used to touch the NFC terminal so there would be no need for a QR code to be scanned.

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<sup>11</sup> <https://proto.io/>



**Register**

Please enter your details:

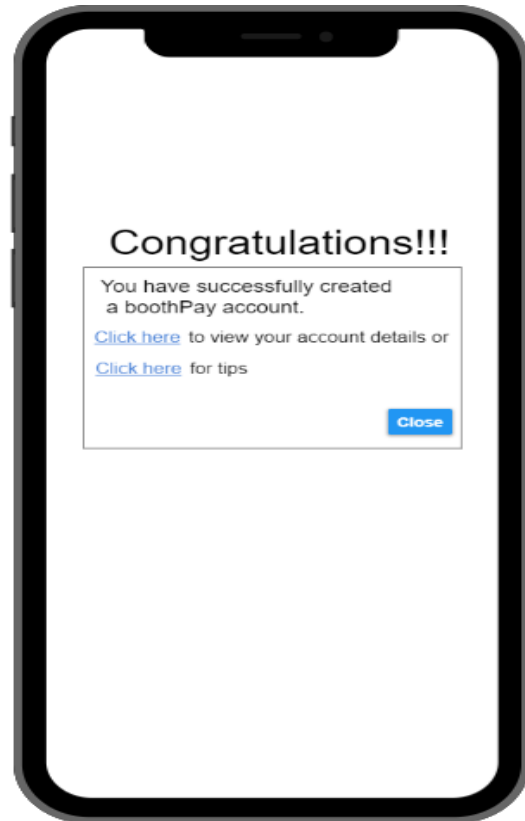
First Name:

Last Name:

Pin Code:

Remember me

*Screen 1. Registration page*



**Congratulations!!!**

You have successfully created a boothPay account.

[Click here](#) to view your account details or [Click here](#) for tips

*Screen 2. Confirmation page*



**ACCOUNT TOLLBOOTH HISTORY**

Balance:

Account #:

*Screen 3. Account page*



**ACCOUNT TOLLBOOTH HISTORY**

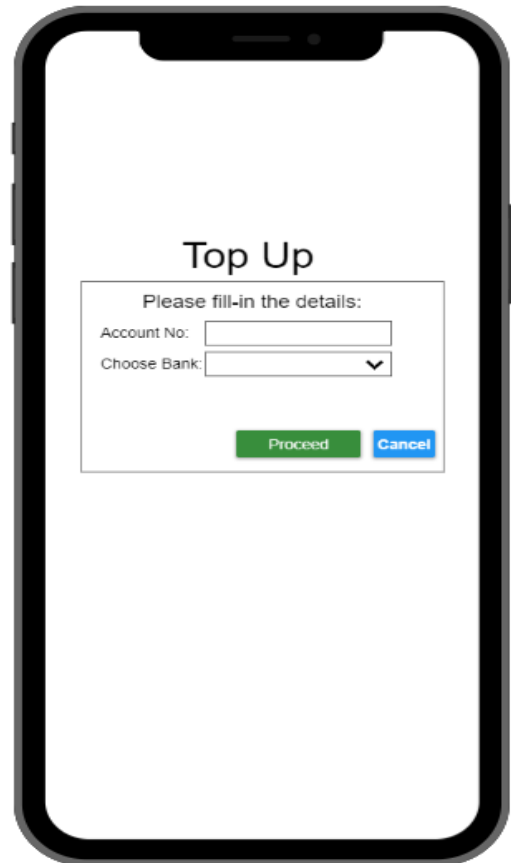
Please make sure you have enough balance before visiting the toll booth

Enter Pin

*Screen 4. Tollbooth page*



*Screen 5. History page*



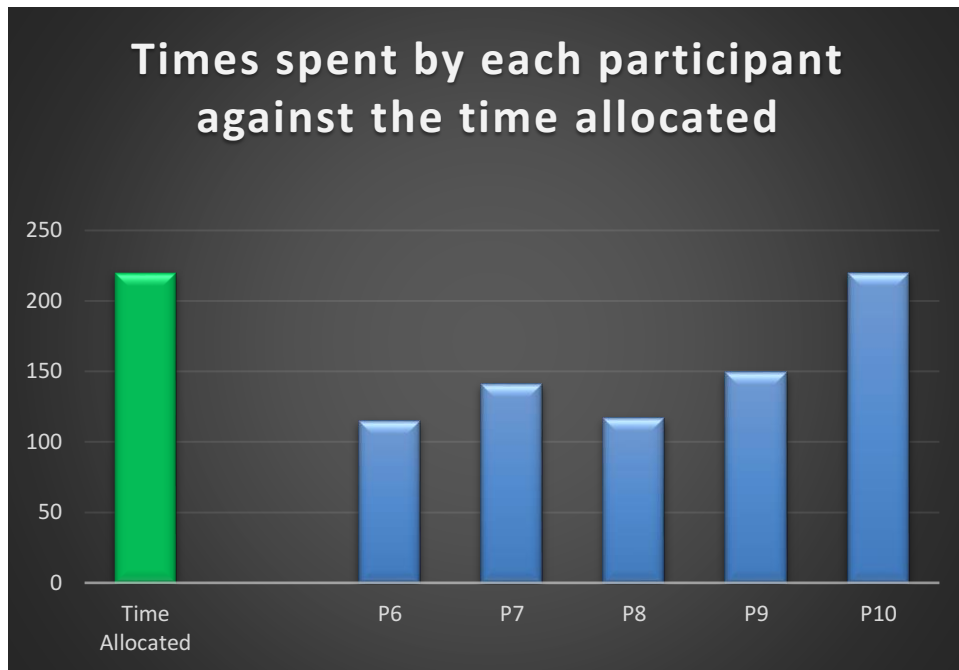
*Screen 6. Top-up page*

After the changes were made using the software, it was again tested with 5 drivers. Table 6.2.2 is the report for the second iteration.

	P6	P7	P8	P9	P 10
<b>Screens (all times in seconds)</b>					
1.Registration. Time Allocated (40 secs)	30	37	26	28	51
2.Confirmation. Time Allocated (15 secs)	12	10	15	13	50
3.Account. Time Allocated (60 secs)	20	26	15	41	34
4.Toll Booth. Time Allocated (45 secs)	17	20	17	23	25
5.History. Time Allocated (30 secs)	23	25	26	24	33
6. Top Up. Time Allocated (30 secs)	13	23	18	20	27
<b>TOTAL TIME SPENT</b>	<b>115</b>	<b>141</b>	<b>117</b>	<b>149</b>	<b>220</b>

**Table 6.2.2 Times spent by each participant on the various screens**

Figure 6.2.2 shows the data in table 6.2.2 below.



*Figure 6.2.2 A bar graph representing the total time used by each participant compared to the allocated time for iteration 2*

The allocated time in this iteration was 220 seconds. Participants P6 through to P9 were able to finish the testing before the allocated time, whereas participant P10 finished right on time.

From table 6.2.2, the allocated times of some of the screens were adjusted because those they required the user to actually type in some input where needed.

Like in the first iteration, questions were asked when the users were using the prototype. Since these screens were interactive, some of the users were just browsing through the screen which took some extra seconds more. Otherwise, as per my observations, majority of them finished in the time allocated.

From Table 6.2.2,  $\bar{x} = 148.4$  seconds, which translates to approximately 3 minutes. The standard deviation,  $S_x = 38.17$  seconds.

### 6.3 User Satisfaction

After the test with a participant was completed, he/she was given a user satisfaction form to fill. This form was used to gather their opinions, and whether or not the proposed system matched their desired expectations. A sample of the user satisfaction form used is provided in Appendix B.

Table 6.3 is a report on the user satisfaction survey run after the various interviews were completed. The results have been grouped based on the responses of the participants.

	Strongly Agree	Agree	I don't know	Disagree	Strongly Disagree
The system is important	6	3	1	-	-
The concept was difficult to understand	2	5	-	3	
Registration was easy	1	9	-	-	-
The system gave tips on how to use it	-	4	1	-	5
Main page was easy to understand	4	6	-	-	-
Easy to check balance	4	5	1	-	-
Easy to top up	1	4	2	2	1
Transaction history is important	2	7	-	-	1
Appearance of the system was good	2	8	-	-	-
I would use the system in future	2	5	3	-	-

**Table 6.3. User satisfaction report**

From the table above, it can be seen that most participant were of the view that the system would be important to implement. Even though at first, the concept was a little confusing for some of them to understand, they expressed good perceptions and feelings towards the concept and the prototype.

## 7. DISCUSSION

In this Chapter, various challenges to the design and implementation of this proposed ETC are discussed. In addition, how the proposed system can be improved in the near future is also discussed.

Finally, concluded remarks about the entire thesis are made.

### 7.1 Challenges to the Design and Implementation

Like many technologies, the proposed system has its own drawbacks and challenges. These challenges can be problems that will or can arise when the system is implemented. Weather conditions can render the overhead camera inoperable or may cause images captured to be blurry, and the camera which is using the ALPR software captures a few plates at a time which means that cars need to be in a linear formation. That is where competing technologies like the RFIDs are most convenient to use. RFIDs have the added functionality of reading multiple tags at a time irrespective of the speed at which the vehicles may be going.

Also, there are lack of standards that regulate the uniformity of the license plates which means that there will be inconsistencies in the plate characters, the use of special logos, and the sizes of the plates. Different vehicle designs have different license plate positions so the camera may not be able to read the characters since the plate will be at a different position [34]. Adding to this is that some newly imported cars in Ghana may not have their number plates installed. The lack of the number plate will hinder the operation of the ALPR if and when that car uses the toll booth.

The technology requires the use of constant electricity to function. Ghana has been going through a lot of energy problems in recent years. Communities spend hours or sometimes days without electricity. If the ETCs are located where the communities experience frequent power outages, it is going to hinder the operations at the toll booths. To curb this problem, generator sets need to be supplied at all the various ETCs at extra costs.

Solar panels can be installed because Ghana has sunshine throughout the year.

The payment methods as discussed in Chapter 5 require the use of apps on smartphones or the driver's license. In a situation where the smartphone is misplaced or the battery runs down, the motorist would not be able to pay the toll. Also, drivers using their licenses as a payment method even though laudable but also has its own challenges. In Ghana, drivers are not obliged to always have their licenses with them when they are driving. If using the license for payment is the only payment method the driver uses, then it will be problematic if he/she does not have it readily available at the time of using the booth.

Trying to reduce the impact of the motorists losing their licenses or phones or otherwise, the idea to integrate a QR code scanner with the NFC device came up as shown in the images from the paper prototype (the "tollbooth" screen). This would have meant that the motorists would be advised to have a copy of their QR code printed out and placed in their glove compartments of their cars. Upon reaching the booth, if the license is not readily available or the phone is dead, the person would just show the printed version of the QR code to the scanner.

How to actually implement it was one of the challenges taking the scope of the thesis into consideration.

In addition, NFC devices are also susceptible to attacks. Because the NFC technology works wirelessly, the communication between devices can be intercepted by an attacker, which is known as eavesdropping. The attacker usually has a powerful antenna compared to that of the mobile devices, which allows him/her to easily intercept communication over a long distance [35]. Also, the data which is being sent can be corrupted by the attacker using a malicious software running in the background of the sender's/receiver's phone. Aside the data being prone to being corrupted, the attacker can modify it. The attacker manipulates data by attacking it during its transmission [35].

Furthermore, the setting of the research made it a lot more difficult to gather additional data. Since Ghana was used as the case study, user studies were done only during my short visit to Ghana.

## 7.2 Future Works

As mentioned above in 7.1, using proximity sensors, and the cameras have their own flaws. Using these technologies means that the vehicles upon reaching the toll booths need to stop for a few seconds. Inasmuch as the proposed ETC is still convenient and effective as compared to the manual way of collecting tolls, a lot can be done or implemented to make it much more convenient and effective. Using RFIDs will be the next technology of choice.

Like the “Salik” mentioned in Chapter 2, it would be better if motorists had no interactions at the toll booth at all to make traffic free flowing. The only time the users would have to interact with the system is if and when they want to top up their accounts or to check their account details. Websites and apps would have to be designed to help topping up and other functionalities easier.

## 7.3 Conclusion

The thesis was put together with the view of coming up with ways in which the traffic situations on toll roads can be managed in Ghana.

Reminding ourselves about the problem statements mentioned in Chapter 1, the use of the NFC technology will help the state to effectively collect the toll fees at the various booths. This technology will ensure that the monies collected do not remain on-site since the electronic cash will be stored away safely on dedicated servers of the companies tasked with the collection of the fees. This also ensures that the place is secured from thieves because there would be no physical cash to steal. The technologies mentioned will also curb the problem of traffic jams on the toll roads since using an NFC device to effect payment is a lot faster than using actual cash because of the matter of giving out change to the motorists and other factors.

Some of the motorists were asked whether or not expanding the roads would not solve the traffic situation on the roads. They agreed that it is true that expanding those roads and providing more toll attendants would ease the pressure on the current booths available



but that alternative will take time to implement. And also that the toll booths will still be susceptible to attacks, not to mention that the siphoning of funds will still be an issue which will need to be resolved.

With the influx of smartphones and smart devices in Ghana, and people generally using the Internet and various mobile phone apps, the idea this thesis set out to convey, together with its objectives, seem to be the most feasible and viable.

Due to the time and scope of this research, not many would-be users or motorists were interviewed during the user study, but it is with great belief that if this idea becomes a reality, with proper education of the product, using proximity sensors to automate the toll booths in Ghana will be a successful one.

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## APPENDIX A: CONSENT FORM

Consent form for a Master's Degree Thesis

Institution: Tampere University of Technology

Department: Information Technology

Major: User Experience

Topic: **USING PROXIMITY SENSORS TO AUTOMATE THE TOLL BOOTHS IN GHANA**

Thank you for agreeing to participate in this user study I am running. A copy of this form would be given to you for future reference.

I, ..... voluntarily agree to participate in this research.

I understand that the topic relates to the solving of vehicular traffic which is caused on highways and other roads with toll booths, and to effectively collate the revenue being taken in these toll booths.

I understand that I can decide to stop the interview if I am uncomfortable without any consequence.

The purpose and nature of the research has been properly explained to me verbally and that I have had the opportunity to ask questions regarding the subject matter.

I agree to my interview being audio-recorded.

I understand that all the information I provide, personal or otherwise, will be treated confidentially.

Interviewee signature: .....

Date:

.....

Interviewer name and signature

.....

## APPENDIX B: USER SATISFACTION FORM

Please evaluate the system based on these statements by ticking the appropriate box

	Strongly Agree	Agree	I don't know	Disagree	Strongly Disagree
The system is important					
The concept was difficult to understand					
Registration was easy					
The system gave tips on how to use it					
Main page was easy to understand					
Easy to check balance					
Easy to top up					
Transaction history is important					
Appearance of the system was good					
I would use the system in future					

Which feature or features were you most impressed with?

- 1.
- 2.
- 3.

Which features were you not satisfied with?

- 1.
- 2.
- 3.

Overall rating of the system (scale of 1 to 5) .....

## **APPENDIX C: BACKGROUND QUESTIONNAIRE AND INTERVIEW QUESTIONS**

### **Participant Profile**

- Name: -
- Gender:-
- Age:
- Occupation:-

### **Interview Questions on Toll Booth**

- Where do you live?
- Do you come across toll booths when you are driving?
- How often do you use the Accra/Tema motorway?
- At what times do you usually use it?
- Can you describe the process when you get to the toll booth?
- Do you know the fee before you give out the money?
- How is the traffic situation like when you use the motorway?
- What do you think can be done about the traffic situation on the motorway?

### **Interview Questions on Technology**

- Do you use the Internet?
- On which devices do you use it?
- How often do you use the Internet, and for what purpose?
- Do you have a phone/smartphone?
- What kind of apps do you have?
- How comfortable are you in using the apps on your phone?

---

### **Questions for Officials**

- How often do you come across toll booths?
- Is there traffic jam leading to the toll booths?
- What do you think causes or may cause traffic delays at the toll booths?
- What is your opinion on automating the toll collection system?
- Is there any challenges you can think of in regards to the proposed payment systems?
- How do you think the idea of automating the process can be successfully piloted?

### **Questions for Toll Booth Attendants**

- Can you please tell me how the toll booths works?
- Does the process cause traffic jams and why?
- What do you think can be done to improve the current system?
- How many cars do you serve on the average?
- Do you have breaks and at what time?