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DEVELOPING A DIGITAL TRANSPORT TICKETING SYSTEM IN LAGOS STATE

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THESIS
Abstract

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Abstract

The aim of this thesis was to highlight the inefficiency of the current paper ticketing system that is being used in the public transport system of Lagos state and how it can be modernized to make use of modern electronic fare collection systems and their benefits.

For a population of over 20 million and counting, which is about four times the population of Finland, it is quite strange that the state still uses a fare collection system that is inefficient, has huge fund leakages and it is not conducive for the citizens of the city. The paper ticketing system also contributes to environment pollution and degradation.

The thesis explores the technology behind Radio Frequency Identification, the different applications of the technology, the technology drawbacks, what to consider before implementing a RFID system, and how it can be adapted to public transportation and the benefits of the technology.

Lastly, the thesis highlights the critical infrastructures that is needs to be implemented before a successful Deployment of electronic fare collection system. It also discusses the need to implement security at the planning phase, the potential benefits for the passengers, drivers, stakeholder and the environment. Implementing this technology will further position the state as a technological city and thereby attracting more foreign investments.

Keywords
Radio frequency Identification, Electronic fare management system, Automated fare collection system

PREFACE

A journey of a thousand miles, they say, starts with a footstep. A journey that started in the autumn of 2015 is getting to an end. I am grateful that all the ups and downs of moving to a new country with a different culture and ways of doing things, I have not only survived, I have learned and thrive.

I want to say a big thank you to the Finnish government for giving this opportunity to be able to study in a world class university without paying a dime. I am especially grateful to the Savonia University of Applied Sciences administration for their support for the students, the excellent exchange programs, the modern and equipped laboratories, the libraries and even for the subsidized food. This might look normal for a native Finn but for people like me, it is a great privilege.

This thesis would not have been possible if not for the patience and understanding of my Supervisor, Mr Arto Toppinen. The words of encourangement from Ms Irene Hyrkstedt and Ms Tiina Salli and all my amazing teachers that spent their time and effort in making me useful for the society.

To my friend Nathaniel and his wife, you are no longer a friend but a family and thank you for all the time spent together. To all the wonderful people I met as a student in Savonia, I want to thank you all.

A special thank you to my family for being a strong pillar of support and to my wonderful fiancée, Precious, you brighten my day every day. This feat would not have been possible without you.

Lastly, to my creator, the maker of the Heavens and earth, thank you for the gift of life, breath and every wonder gifts you provide to make this earth a wonderful place to live.

Kuopio 02 May 2021
Victor Pelumi Awakan

CONTENTS

1 INTRODUCTION

This thesis topic arose from the need for an efficient and safe transport ticketing system for the most populous city in Nigeria, Lagos State.

Lagos State is located on the South-Western part of Nigeria and lies approximately on longitude 20 42'E and 32 2'E and between latitude 60 22'N and 60 2'N respectively. Due to the increasing population which is estimated to be around 15 Million in the year 2021, the need for a state-of-the-art ticketing system can not be overemphasied.

The current paper ticketing system used by the state is old and outdated. Apart from being old, it does not make the passenger trip enjoyable, since passengers must queue for a long time to purchase ticket and spend considerable time while showing the ticket to the drivers. The paper ticketing system can be easily forged and because a lot of money is involved in the system, this can lead to stealing which can result to a loss of revenue to the state government.

The system does not favour the drivers because they have to check if the ticket is valid before a passenger is allowed into the bus which takes considerable time and it is stressfull. After dealing with the passengers, drivers have to do their job of driving the buses to its destination.

For a state with this huge population to still be running a paper ticketing system is a big disservice to its citizens. As a former inhabitant of Lagos state who has experienced this inefficient system and the stress it brings, the writer believes that there is a need for improvement in the way the ticketing system is run. The desire to do something about the current situation of the Lagos state transportation ticketing system led to the writing of this thesis about a modern way of transport ticketing and how it would be of great benefit if it can be adopted by Lagos state.

After this introduction and its theoretical background, the thesis will explore the user requirement, Radio Frequency Identification theoretical background and how it will be applied to solve the user requirement need.

1.1 User Requirement

The user requirements to be fulfilled by this thesis are listed below:

i. Reducing waiting time at the bus stop
ii. Developing easier payment system for transport users
iii. Making payment convenient, safe and fast
iv. Eliminating theft and corruption
v. Eliminating the use of paper

2 RFID (RADIO FREQUENCY IDENTIFICATION THEORETICAL BACKGROUND)

Radio Frequency Identification is a broad term that refers to several information and communication technologies that share the capability to automatically identify objects, locations and individuals to computing systems without any need for manual intervention (George 2008). This communication is made possible due to wireless communication between the computing system and the item identified.

RFID makes it possible to identify specific items, objects or a location. These contain RFID tags that are marked with a unique identifier code that is embedded in the RFID tags. To locate the item or location, a RFID reader search for the tags, if the tags are within the vicinity of the card reader, it reads the code off of the tags and display the information on the tags or processes the data for other uses.
As there are different variations of RFID, the choice of RFID technology to use will depend on the application and the identifier code.

2.1 HOW RFID AUTOMATIC IDENTIFICATION WORKS

All RFID systems have two common features:

- The reader transmits the electricity needed by the tag wirelessly.
- Rather than generating its own signal, the tag relies on the reader's transmission to send out information.

The difference between other wireless communication and RFID is set by these two features discussed above. These features give RFID unique advantages and also its limitations.

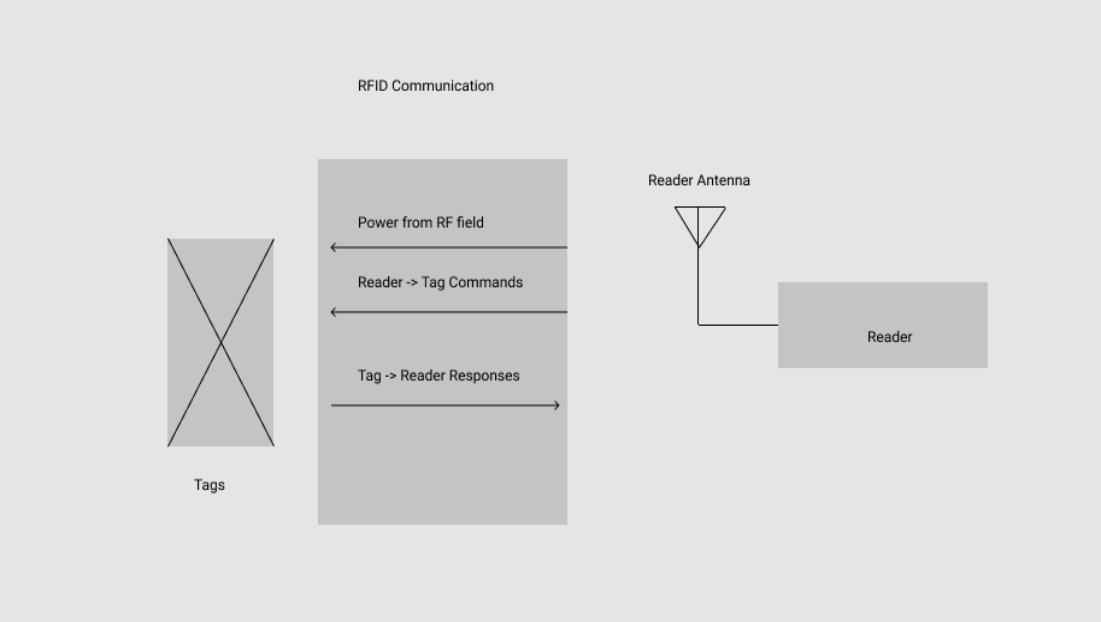

Figure 1. A pictorial representation of the interaction between a tag and a reader. (Awakan 2019-07-06)

The reader transmits enough power to the tag to power it and communicate with it. The tag in response sends the stored Information on the tag back to the reader.
The processes are discussed below.

2.2 Energy Transmission

To identify a tag, there has to be transfer of energy from the reader to the tag. These can be achieved in two ways:

- Capacitive Coupling or
- Inductive Coupling.

In Inductive coupling," transfer of energy is through a shared magnetic field, and it is only the magnetic component of the electromagnetic wave transmitted by the reader that is involved" (George 2008) while capacitive coupling"uses only the electric component of the electromagnetic field generated by the reader antenna." (George 2008).

Either through capacitive or inductive coupling, the energy source is from the electromagnetic field created by the antenna of the reader when it transmits. When a tag is within the range of the field, electric current is generated on the tag via its antenna and can be used to power the chip in the tag. To avoid fluctuations in the electromagnetic field created by the antenna, a capacitor is used in the tags to "regulate the flow of current and provide a relatively uniform and usable supply to the chip." (George 2008).

2.2.1 RFID inductive coupling

RFID inductive coupling is usually used for closed or "what are termed vicinity coupled cards". (George 2008) It is the transfer of energy from one circuit to another through the mutual inductance between the two circuits. For RFID inductive coupling to work, the reader and the tag must have an induction coils. When the tag is moved closed to the reader, the field generated from the reader coil will couple to the coil from the tag. It will result to a voltage been induced in the tag that will be used to power up the tag circuit.

Due to the short range of the electromagnetic field generated by an inductive coupling the systems that used them do not require an operating range of more than one meter.

Figure 2. RFID Inductive coupling tag (Awakan 2019-07-06)

2.2.2 RFID capacitive coupling

RFID capacitive coupling is usually used for short ranges where close proximity is needed. Unlike the inductive coupling, a capacitive coupling uses electric currents instead of magnetic field in order to couple. It uses the plates of the capacitor to provide the required coupling.

The capacitance between the reader and the tag provide a capacitor through which a signal can be transmitted. The RFID tag picks up the signal generated from the reader which is used to power the devices inside the tag. The data from the tag is returned to the RFID reader by modulating the load.

2.2.3 Difference between passive and active tags

A Passive tag is an RFID tag that does not contain a battery. The power is supplied by the reader. The radio waves from the readers make the antenna coil inside the tag form a magnetic field which energizes the circuits and the tag in return sends the information encoded in the tag's memory to the reader.

Advantages of Passive Tags

- Smaller in size
- Less expensive
- Last longer

Disadvantages of Passive Tags

- Can only be used for short distance communications
- Data in passive tags can not be updated

An Active tag has a battery which can be used as a complete or partial source of power for the tag's antenna and circuits. Some tags can have a replaceable battery or sealed units.

Advantages of Active RFID Tags

- They can provide a long communication range
- They have highest data bandwidth

Disavantages of Active RFID Tags

- They can't work without batteries
- They are expensive
- They are large in size and not suitable for all kinds of application

2.3 Communication between tag and reader

Communication between the tag and the reader has to occur before the information stored in the tag can be read and displayed to the screen.
This communication can either be inductive or capacitive coupling. The reader sends a signal to the tag, processes the obtained data and forwards it to the RFID middleware.
A RFID Reader consists of:

i. Antenna Subsystem
ii. Controller
iii. Network Interface

i. Antenna Subsystem: The antenna sub-system is used to handle all communication with the communicating RFID tags and communication with the RFID middleware. The antenna ranges from duplex antennas to a transmitter of receiver antanna.

ii. Controller: The job of the controller is to determine when information read from a tag amounts to an event to be sent to the network. The reader controller is also in charge of managing the reader's end of the reader protocol.

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iii. Network Interface: The readers use different means to communicate with the network and other devices. After a tag is read and an event is recognized, the network interface is used to transmit the data to a RFID middleware.
A few examples of the network interface used are: RS 232, RS 422, Ethernet or Bluetooth.

3 SELECTION CRITERIA FOR RFID SYSTEMS

The usage of RFID systems has surged these past years. This is due to the widespread use of contactless smart cards used in payment and transportation. The different use cases for RFID means-that it is important to be mindful of the criteria to be used for particular RFID systems.

Makers of RFID systems have to make sure that during development the different technical parameters of RFID systems are taken into account and are optimized for various fields of application. For example, in product identification, ticketing or access control.

As there are no specific binding standards for RFID sytems yet, it may be quite challenging to select the most suitable systems for one use case. A few criteria to be taken into account are outlined below.

3.1.1 Operating Frequency

For RFID systems that operate between the frequencies between 100 kHz and 30 MHz use Inductive coupling while microwave systems in the frequency of 2.45 – 5.8GHz are coupled using electromagnetic fields.

Compared to inductive systems, the microwave systems have significantly higher range, which are usually between 2 – 15 m. The downside of inductive systems is that they require external backup battery.

3.1.2 Range

To determine the range of an application, the three factors listed below have to be put into consideration:

- The positional accuracy of the transponder;
- The minimum distance between several transponders in practical operation;
- The speed of the transponder in the interrogation zone of the reader.

In the case of contactless payment for example, the positional speed is very low, since the hand is used to place the transponder in the reader. To avoid the problem due to several transponders sending data to the reader which might be difficult to identify which one belongs to the passenger, the optimal range of the system is from 5 – 10 cm.

3.1.3 Security Requirement

The implementation of security in the planning phase can't be overemphasized because of the rise of hackers and state actors.
Security measures like encryption and authentication should be implementated in a precise manner to avoid unexpected surprises in the implementation phase.

The security of ticketing systems for use in public transport is one of the areas where the implementation should be of high importance because data in the contactless smart cards could be accessible to anyone. A potential attack on the ticketing system could damage the public company in charge of the system both in reputation and in huge financial losses. For applications like this, a high-end transponder with encryption and authentication should be a must.

3.1.4 Memory Capacity

Two factors determine the memory capacity of a RFID system; the price and the chip size. For cheaper applications that require low stored information, permanently encoded read-only data carriers are use. The other data are stored in the central database of the controlling computer.

EEPROM memories are primarily used in inductive coupled systems while SRAM memory devices with a battery backup are mostly used in microwave systems. The memory capacities of EEPROM are between 16 bytes to 8 Kbytes while SRAM offers between 256 bytes to 64 Kbytes.

4 APPLICATION OF RFID IN PUBLIC TRANSPORT

RFID is used in different areas of life like the identification of animals, contactless payment system, in the identification of items and in anti-theft systems. In this thesis, the focus is on the usage of RFID in public transport.

The public transport is one area where RFID system pontential will show the most benefit in its usage. In Lagos, it is almost impossible to place a figure on how much is been generated from the use of paper ticketing system because the system to keep track on how much ticket is sold by the dealers or drivers is not very efficient. For the transport companies to be competitive and minimise losses from unaccountable sold tickets, a long-term solution must be found that will cut these losses by reducing costs and increasing profits. The use of RFID contactless smart card as travel pass could help significantly.

4.1 Challenges of Paper Ticketing System

There are many challenges that come from using a paper ticketing system that RFID will try to solve. Listed below are a few of the problems encountered by the use of paper ticketing:

- Paper tickets is prone to fraud which is hard to detect.
- Selling tickets by the drivers causes a long queue and wastes passengers' time.
- Paper tickets litter the environment and the source of paper is one contributing factor to global warming.
- It becomes hard to stop fare-dodgers.

4.2 Requirements of RFID Electronic Fare Management System

Unlike the paper ticketing system, electronics fare management system must meet high expectations and requirements. It is very important that the material used in the systems are resistance to degradation, wear and tear, writing and reading speed and should be easy to use. These high expectaiopns can be met easily with RFID systems.

4.2.1 Resistance to wear and tear

Contactless smart cards are usually designed to last for a decade. They are very good in resisting the effects of dust, rain and dirt both for the reader and smart cards. They are also easy to handle as they can be kept in a purse, wallet or handbag. They are very light and easy to handle and use.

Figure 3. A contactless smart card for buses that is used in Kuopio. (Awakan, 04-05-2021)

4.2.2 Transaction Time

Time is of essence in business and that is true in transportation business as well. The time taken to buy a ticket or verify a ticket pass is very critical in transport systems. With RFID Systems the time taken to buy and verify is within a few seconds.

4.3 Benefits of RFID Systems

The benefits of RFID can be sub-divided into three categories as listed below:

- Benefits for passengers.
- Benefits for drivers.
- Benefits for transport company

1. Benefits for passengers

- The goal of the cashless policy can be achieved easily with the use of contactless smart cards. With this, there is no need for cash but rather the cards can be topped with a specific amount which will be deducted when they board a train, tram or bus. This will also limit the need for the driver or passengers to carry change.
- The need to argue with the driver about the amount of the fare will be eliminated as the fare will be deducted automatically from the contactless smart cards.
- The smart cards are valid even if the card is empty or there are changes in the fare.

Figure 4. An electronic ticketing machine in Leppaväärä, Espoo. It provides easy and convenient way of buying tickets for all journeys. (Awakan, 04-05-2021)

2. Benefits for the driver
    - Drivers can focus on their job as they don't have to sell tickets anymore.
    - Drivers are less susceptible to theft as there is no money in the bus.

3. Benefits for transport company
    - Reduced maintenance and operating costs of sales dispensers.
    - Secured system from vandalism
    - Fare changes are easy and no need for new printing of tickets.
    - It reduces fare-dodgers.

4.4 Fare Calculation

Calculating the fare for conventional payment systems can be complicated and not straight-forward compared to electronic fare management systems. Using electronic fare management systems brings a new way of calculating fares. There are four basics models used for electronic fare calculation, as shown in Table 4.1.

Fare system 1	A fixed amount is deducted at the beginning of the journey regardless of the distance travelled.
Fare system 2	The beginning of the journey is recorded on the card and upon alighting at the final station, the fare for the whole trip is automatically calculated and deducted from the card.
Fare system 3	This fare system is best used for interlinked networks, in which the route can be travelled using different means of transportation at different fares. A predetermined fare is deducted from the card every time the passenger changes vehicles.
Best price calculation	All journeys made in a month are automatically recorded on the contactless smart card. Any journey exceeded in a day or month are automatically converted into a cheaper 24-hour or monthly card.

Figure 4. Different fare systems for payment with contactless smart card. (RFID HANDBOOK, 2008)

Figure 5. An electronic ticket validator displaying different zones in Urheilupusito, Espoo. It charges according to the passenger's travelling zone. (Awakan, 04-05-2021)

5 LESSONS FOR LAGOS STATE

For Lagos to take the role of a mega-city it is aspiring to be, the Lagos state government has to step-up the infrastructure of the city especially the public transport. One way of doing this is to adopt the use of the electronic fare management system in the city's public transport.

For the electronic fare management system to function and benefit the citizens, there are a few key areas of infrastructure that the city has to make more efficient.

5.1 INFRASTRUCTURES

For the fare management systems to be efficient and beneficial to the populace of Lagos, some key infrastructure needs to be put in place.

5.1.1 Good Roads

Good roads serve many purporses. Having good roads facilitates the movement of goods and services from point A to B. At present, Lagos state is still experiencing terrible traffic congestions. This is often caused by bad roads or the closure of some roads due to repair. The enourmous hours spend due to traffic congestion can run into millions of naira in losses to the government.

To make the benefit of electronic fare system worthwhile, the state road network needs to be functional and in good condition.

5.1.2 Electricity

Electricity is another important area of infrastructure that needs to be improved on. Although with modern technology, it is possible to use solar charged systems or generators. These energy sources can not be relied on at times especially on cloudy or raining days.

The bus terminal displays, automatic ticket vending machines, the issuing centers, inspector terminal and data management centers all require constant and reliable electricity to work. Hence, this infrascructure is a critical part of modern automated fare collection system.

5.1.3 Fast Internet

At the moment, the internet speed of Nigeria is around 3.9Mbps which when compared to some African countries like Kenya – 12.2Mbps – shows how slow the internet is. To add to the problem is the unstable nature of the connection from all the local internet providers.

A slow internet will be a huge problem for an automated fare system, it will make buying a ticket from the automated ticketing machine slow, authenticating passengers in the bus will be a sluggish and displaying route on the display board will not be in real time.

To avoid issues like this, the state must ensure that the internet infrastructure is upgraded to latest technology for example 5G network.

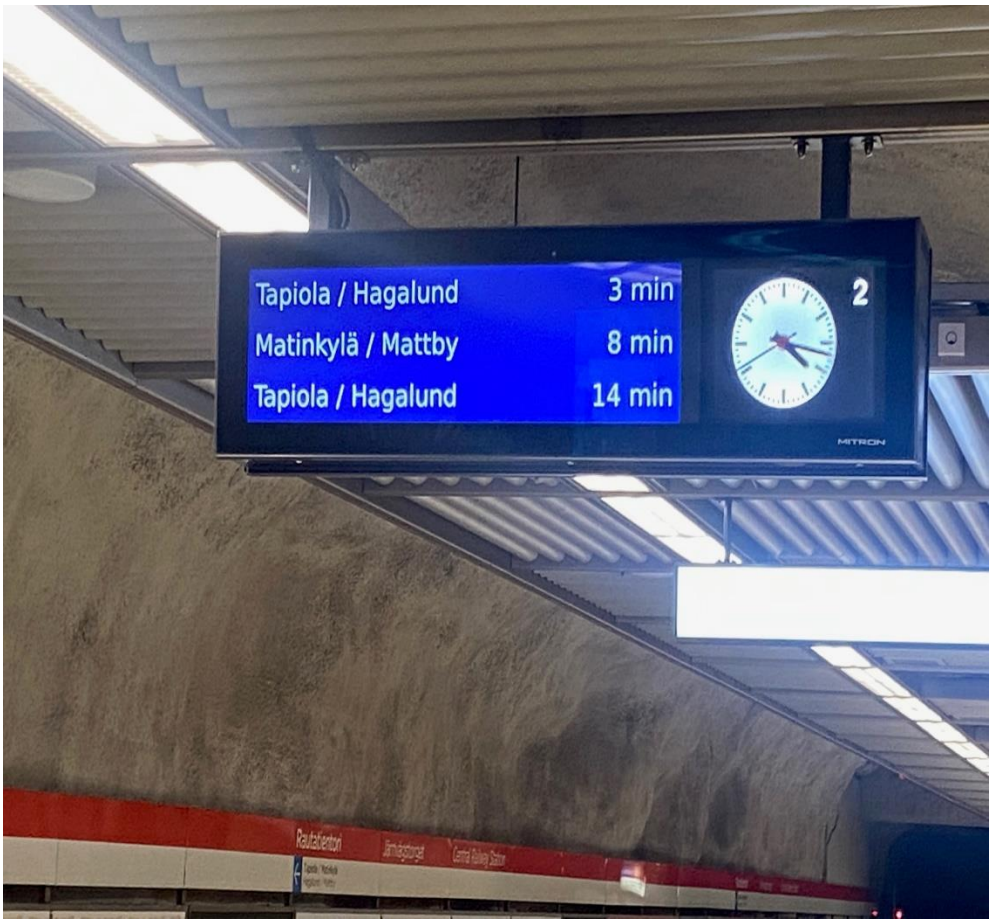

Figure 6. A display board showing the arrival of the metro in real-time. (Awakan, 04-05-2021)

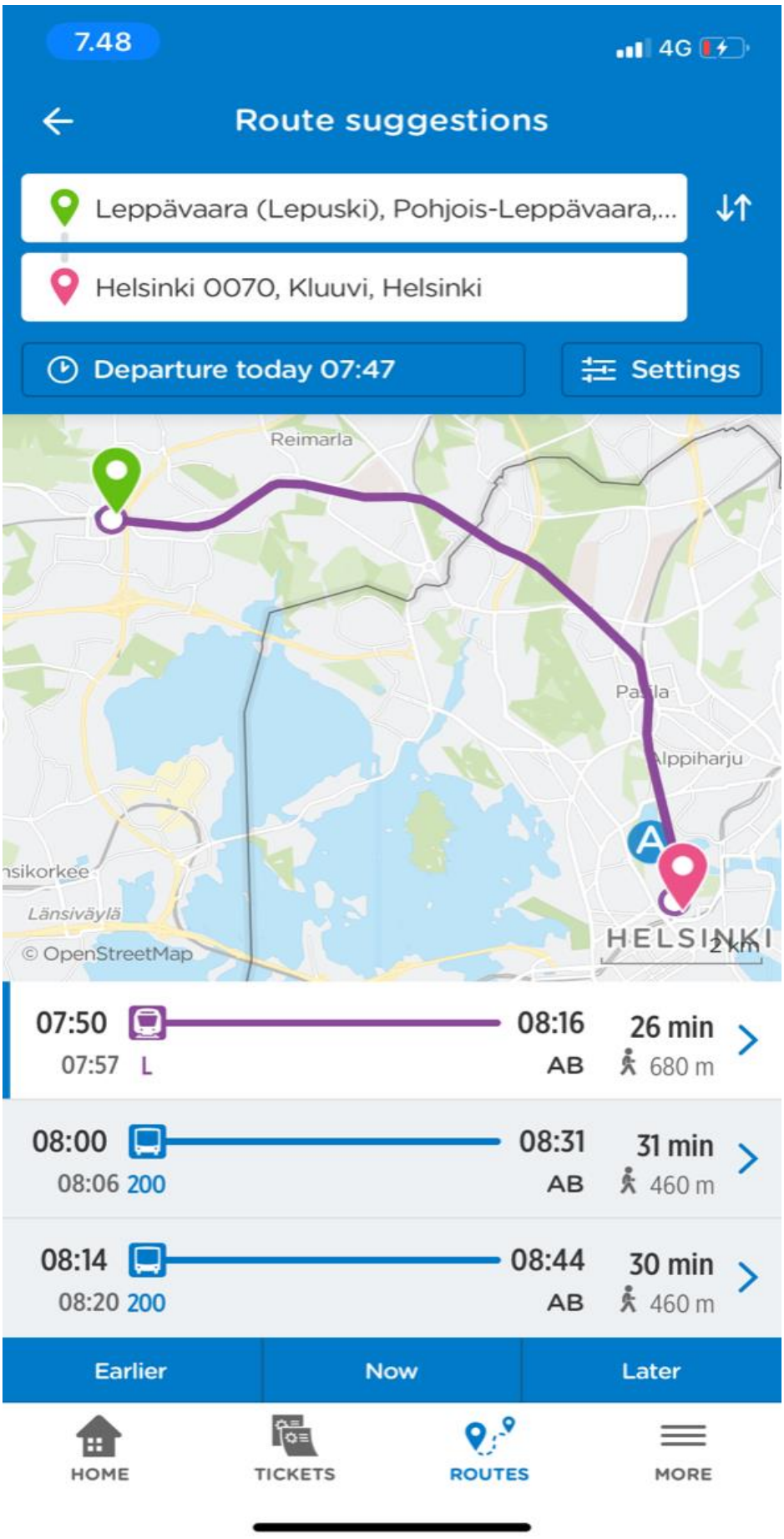

Figure 7. A mobile application journey planner from the HSL app used in Helsinki. (Awakan, 04-05-2021)

5.1.4 Security

The security of a modern automated fare system consist of two parts. As mentioned in chapter 3.1.3, the security of the whole system should be well thought out. Encryption and authentication should be baked into the system from the planning phase to prevent bad actors from getting into the system.

The second aspect of security is to prevent vandalism of the infrastructure and barriers to prevent fee-dodgers. These measures will prevent loss of revenues.

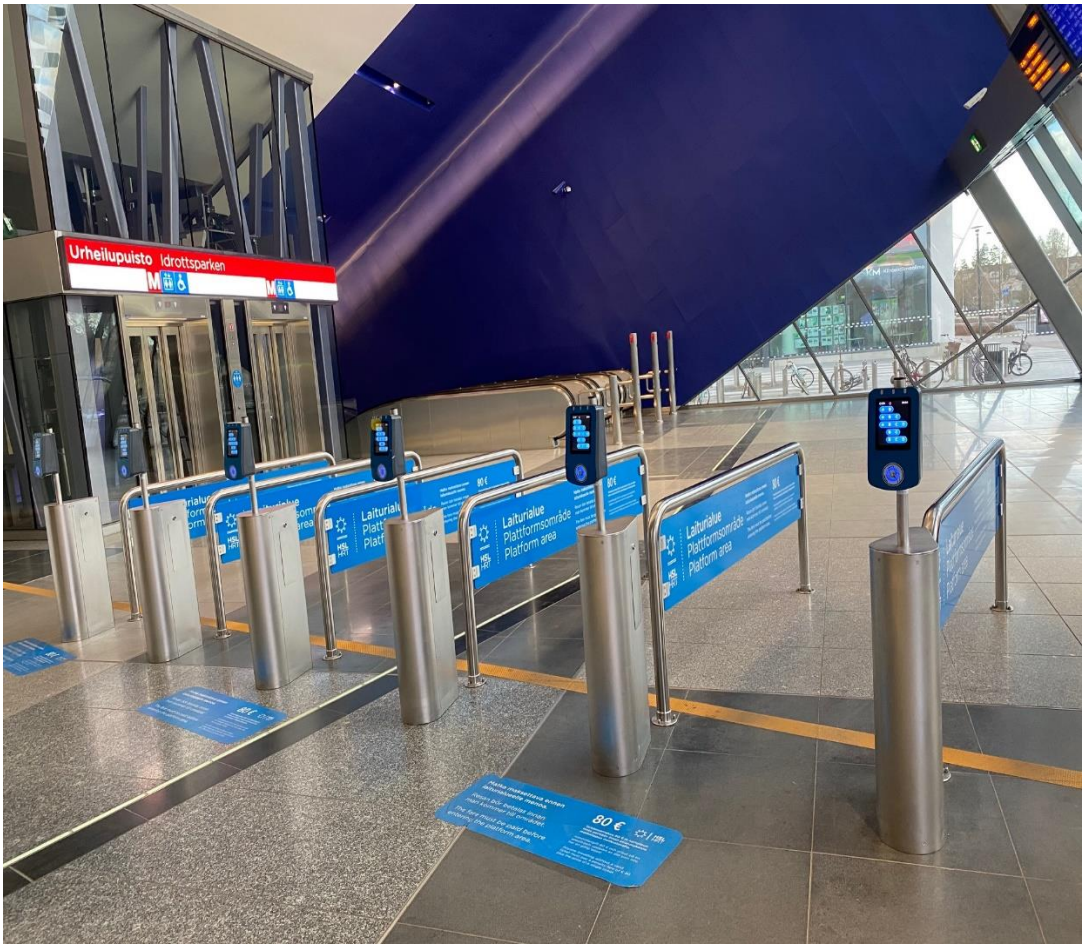

Figure 6. A barrier to prevent fare-dodgers in Urheilupusito, Espoo. (Awakan, 08-05-2021)

6 CONCLUSION

This thesis was started by considering the challenges facing Lagos state as it tries to live up to its name as a modern metropolitan city. One of the challenges discovered was in the city transport system that is based on the old system of paper ticketing. The thesis mentioned some of the disadvantages of paper ticket like loss of revenues, slow processes, inadequate customer satisfaction, etc. The benefit of a modern contactless fare system was explored and its benefits to the paper ticketing system were compared.

The electronic fare management system is based on the Radio Frequency Indentification technology. In the thesis, the theorical background of the technology, how it works, the different ways of energy transmission and how the reader and tags operate are discussed.

The thesis further discusses the selection criteria for choosing the right RFID solutions depending on the usage. Four criteria that are essential to the success of a RFID system were discussed. They are: operating frequency, range, security and memory capacity. These four key criteria have to be considered carefully when planning out RFID systems and their trade-offs must be considered as well.

The most important part of theorical knowledge is applying it to solve a real problem. The application possibilities of RFID technology are numerous, from animal identification, contactless payment, anti-theft to items identification. In this thesis, the RFID technology is applied to electronic fare management system for the public transport system. The benefits to the passengers, drivers and other stakeholders were mentioned and how the fare can be calculated based on the four basic models.

Lastly, this thesis discusses how Lagos state can make use of the RFID technology in its public transport network and the challenges it faces at the moment due to inadequate infrastructure. The thesis also highlighted the most important areas of infrastructure that are critical to a successful deployment of electronic fare management systems and its overall benefits for the populace and the government.

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