Design and Development of Vehicle Detection and Payment System Using RFID Technology: A case of Addis Abeba to Adama Expressway

by

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A thesis submitted to the Department of Mechanical Systems and Vehicle Engineering

Office of Graduate Studies

Adama Science and Technology University

July 2019

Adama, Ethiopia

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July 2019

We the undersigned, members of the Board of Examiners of the final open defense by Mesay Dejene Altaye have read and evaluated his thesis entitled “Design and Development of Vehicle Detection and Payment System Using RFID Technology: A case of Addis Abeba to Adama Expressway” and examined the candidate. This is therefore to certify that the thesis has been accepted in partial fulfillment of the requirement of the degree of Master of Science in Automotive Engineering.

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Declaration

I hereby declare that the work which is being presented in this thesis entitled "**Design and development of automatic vehicle detection and payment system at Addis Abeba to Adama Expressway**" in partial fulfillment for the award of the degree of master of science in automotive engineering is an authentic record of my work carried out from February 2020 to July 2020 under the supervision of Dr. Ramesh Babu Nalamothu (Ph.D.).

The matter embodied in this thesis has not been submitted by others for the award of any other degree or diploma. All relevant resources of information used in this thesis have been acknowledged.

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This is certifying that the above declaration made by the candidate is correct to the best of my knowledge and belief. This thesis has been submitted for examination with my approval.

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DEDICATION

I dedicate this research to God Almighty my heavenly creator, my strong pillar, my source of inspiration, wisdom, knowledge, and understanding. He has been the source of my strength throughout this program and on His wings only have I soared.

I also dedicate this research to two beloved women who have meant and continue to mean so much to me. Although they are no longer of this world, their memories continue to regulate my life. First and foremost, to "Enat Asres Amare and Enat Tsion Girma" whose love for me knew no bounds and, who taught and show me the value of hard work. "እናቶቼ", I will never forget you. May you find peace and happiness in Paradise! Rest in peace!

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I want to remember the king of the past, one of the most famous and influential leaders among are, the lion king of Judah his majesty emperor Tewodros II (መይሳው ካሳ) Ethiopia, Emperor Menelik II (ዕምዬ ምኒልክ) Ethiopia, and History has never forgotten them our brave fathers and mothers who sacrificed their lives for the freedom of their country Ethiopia in the battle of Adwa. I will never forget their stories and their struggle, written in blood and gilded, will shine forever in my heart.

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Amen!!!

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NOMENCLATURE

AADT	Annual Average Daily Traffic
AAE	Addis Abeba to Adama Expressway
APNR	Automatic Plate Number Recognition
ARM	Advanced RISC Machine
AVI	Automated Vehicle Identification Technologies
AVIS	Automatic Vehicle Identification Managing System
BAP	Battery-Assisted Passive
CAEN	Costruzioni Apparecchiature Elettroniche Nucleari
CW	Continuous Wave
DCE	Data Circuit-terminating Equipment
DSRC	Dedicated Short Range Communication
DTA	Data Terminal Equipment
ELP	electronic license plate
ETB	Ethiopian Birr
ETC	Electronic Toll Collection
ETRE	Ethiopian Toll Roads Enterprise
GSM	Global System for Mobile
HIS	Hue-Intensity-Saturation
HOT	High Occupancy Tolling
HT	Hough Transform
ICSP	In-Circuit Serial Programming
IFF	Identification friend or Foe
IPS	Information Processing System
IR	Infrared Ray
ITS	Intelligent Transportation Systems
IVU	In-Vehicle Unit

LCD	Liquid Crystal Display
MAC	Media Access Control
MEMS	Micro-Electro-Mechanical Systems
MTC	Manual Toll Collection
OBU	Onboard Unit
OCR	Optical Character Recognition
OECD	Organization for Economic Cooperation and Development
RADAR	Radio Detection and Ranging
RFID	Radio Frequency Identification
RISC	Reduced Instruction Set Computer
RTA	Road Traffic Authority
RTI	Road Traffic Informatics
RUC	Road User Costs
SCW	Sliding Concentric Windows
SIM	Subscriber Identity Module
SMS	Short Message Service
USB	Universal Serial Bus
VES	Violation Enforcement System
VNR	Vehicle Number Recognition
VPS-T	Vehicle Positioning System technique
WLT	Wireless Location Technology
λ	Arrival level
μ	Service level

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ABSTRACT

Due to the manual working nowadays there is a large amount of rush at Tulu Dimtu Main Toll Plaza at Addis Abeba to Adama Expressway. Each vehicle on an average needs to stop at the toll booth for about 28 to 30 seconds to pay the toll. The average transaction time was an average of 29.8 seconds. This leads the vehicle to conjugate, and to waste fuel and time. Two approaches were subjected to analysis- the manual toll system and the designed automated toll systems. The quantitative approach was employed in the study: the service level, queue length, and performance capacity were calculated. The capacity of the existing system was 121 vehicles per hour and the average queue was 8.2 vehicles. Due to the delay time analysis of the wasted fuel at the toll plaza on average is about 5,067,886,300 ETB Birr per year was found. Based on a review of the literature on vehicle detection, this study explains more about the finding of the vehicle's unique identification number on the embedded tag with the help of a microcontroller. The system uses an RFID tag that is adhered to underneath the chassis of the vehicles, through which all the vehicle information and data are embedded that is read by the antenna deliberately placed on the asphalt near to the tollgate. Radiofrequency identification and detection is a technology that uses communication via electromagnetic waves to exchange data between antenna and tag attached to the vehicle. Each vehicle will be provided with an RFID tag that has stored the vehicle's unique Id and related information. The purpose of this thesis work is to improve the service level capacity of the existing system by designing an automatic vehicle detection system at a toll plaza using RFID with C programming software. To prepare the prototype microcontroller, the GSM module, passive RFID tag, and Servo SG-90 and to design an electrical circuit diagram Proteus Design Suite 8.10 demonstration software was carefully chosen. On these bases, it is recommended that applying the automated system as a key factor to increase the toll capacity. Further research is needed to identify other factors that could strengthen the effectiveness of ETC.

Keywords: *RFID, Electronic Toll Collection, toll plaza, microcontroller technology, vehicle identification, electromagnetic wave*

CHAPTER ONE

INTRODUCTION

1.1 Background

Now a day's traffic problem is very severe in Ethiopia. In Ethiopia, every day we have to face traffic jams for several hours which is very annoying similarly creating huge trouble in our daily life. Traffic jam mainly causes for reckless driving and also for the rash of the vehicles in the road. To reduce this crowded traffic problem, the Federal Government Road Authority constructed ring roads and expressways. Every driver has to pay toll (service tax) when he/she passes the toll plaza by any four-wheel vehicle at the expressway. Unfortunately, in our country, the toll system is manual which takes time to pass the vehicles and creating a traffic jam. The following Figure 1.1 shows the manual transaction system at the toll booth.

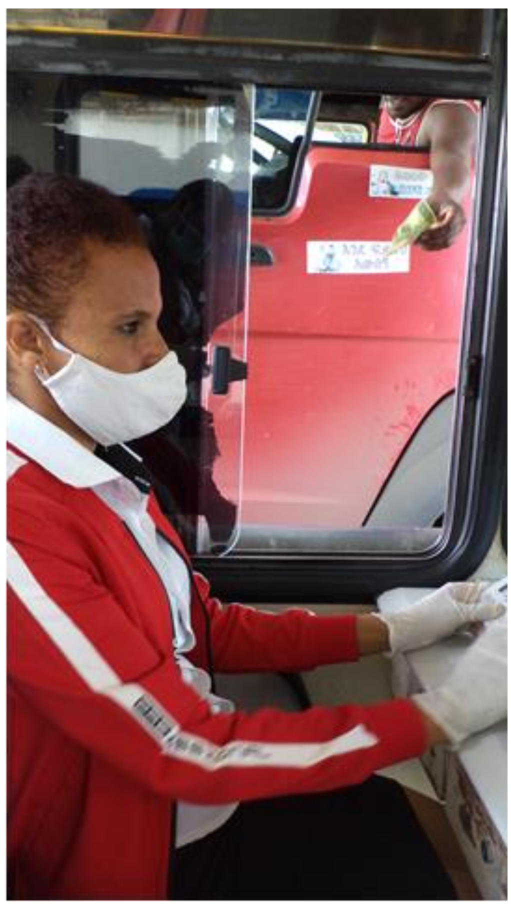

Figure 1.1. Manual transaction system at the toll plaza

In this thesis work, it is aimed to develop an electronic-based automatic toll collection system at toll plaza using RFID and microcontroller technology. With this system, there is no need for vehicles to stop at a toll plaza. The payment will be made online from the account of the vehicle owner and the conformation of the payments will be received.

The purpose is to provide time-saving, fuel preservation, and also provide a fast and safe situation for the toll system and controls the vehicle movement automatically at the expressway. To achieve the design and development of the automated system this thesis work is classified into three units. Such units are (Kanthi et al., 2014) as follows.

1. **Vehicle unit:** it consists of an RFID tag
2. **Toll plaza unit:** it consists of Microcontroller, GSM modem, and IR receiver
3. **Administration unite:** it consists of a GSM modem with a host Computer

As the following Figure 1.2 illustrated below that it shows how RFID tagged vehicle is identifies by an RFID reader and the vehicle data and information processing.

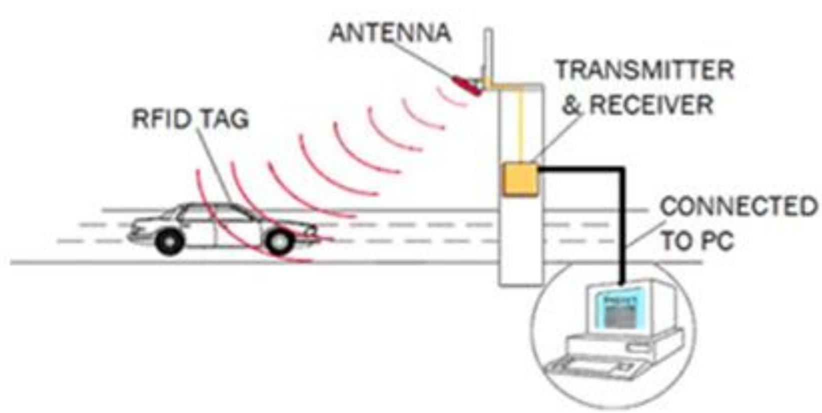

Figure 1.2. Working principle of an automatic toll collection system (source: google)

In the first unit, the IR antenna would send the radio wave to a near vehicle, the microcontroller checks whether the position of the IR receiver through the radio signal from the IR transmitter at the toll unit. Then finally, the microcontroller sends a short text message as per the vehicle ID to the administration unit. According to a short text message from the GSM modem, the administration unit processes it based on the data value and vehicle unique ID, then the predetermined amount will be deducted from the vehicle registered account. If the balance of a vehicle's owner accounts insufficient or not yet registered means the administration center will send a coded message towards the vehicle using GSM to halt the car immediately. Then the vehicle owner has to pay service charge without penalty at the toll unit manually. As long as the vehicle paid information is passed to the administration unit the system permits the tollgate to switch on. Besides, the vehicles get decelerated at speed breakers used in this system to read RFID tags which helps in the reduction of vehicle Overspeed driving.

1.2 Statement of the Problem

Currently, the vehicle identification system at each toll plaza in Ethiopia is entirely paper-based. Moreover, at the manual toll gate, every vehicle has to stop and wait for about 29.8 seconds per average to pay in cash and there should be one or two officers sit in the toll booth to collect the service charge and verify the memo (ticket) in the system manually from the database. Due to this reason;

- The existing system has a time-consuming
- Every vehicle has to stop to pay a toll this leads to possible road vehicle congestion

1.3 Objectives

1.3.1 General Objective

The general objective of this thesis work was to design and develop an electronic vehicle detection and the toll system to ease the toll system and reduce congestion and improve service capacity.

1.3.2 Specific Objectives

The Specific objectives of this thesis works are;

- To collect the details data about existing toll system
- To design and development of the control system
- To simulate the new system and analyze
- To prepare the prototype of the ETC system for demonstration

1.4 Significance of the Study

This study intended to contribute to the benefits of adopting technologies to the transport sector in Ethiopia, and the challenges of adopting thereof. The outcomes of the study will inspire more the toll road enterprise to be aware of the advantages of the tracking system and ultimately adopt the technology.

1.5 Delimitation (Scope)

This thesis work includes the survey of the existing toll collection system, designing an electronic-based toll system, simulation of the toll collection system using the software. Construction of prototype for demonstration of the functionality is also included in this work.

1.6 Beneficiaries

The Electronic Toll Collection system aimed at increasing the capacity of service level by reducing toll transaction delay time. This leads the beneficiary to the toll enterprise, all road users, and society.

1.7 Limitations

In this thesis work, the limitations are:

Due to the global pandemic disease COVID-19:

- The road transportation Adama to Addis Abeba had been stopped for several days
- Sudden inflation and too high increment cost of electronics devices, and some devices were not available in the market place.

1.8 Organization of the Thesis

This thesis work is organized with the following chapters.

Chapter One: Introduction, includes the basic concept and categories of vehicle detection, Statement of the problems, Objectives, Beneficiary, Significance of the study, Delimitations (scope), Limitations, and Organization of the thesis.

Chapter Two: Literature review, includes the introduction, RFID for electronic toll collection, Advantages of an ETC system, why RFID, and the research gap.

Chapter Three: Materials and methods, includes the introduction, Selected hardware materials, and the required software for the system, Methodology, Tests & results for system design modules.

Chapter Four: Results and discussion, includes an introduction to the design principles, The experiment site and data source, Results of the field study, Prototype of electronic vehicle detection, and the automated electrical circuits diagram of the system.

Chapter Five: Conclusions and recommendations, includes the summary of the thesis, Conclusion, Recommendations, and future work.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

To improve one country's economy transportation pays a great role as backbones. Advancement in transportation systems has created a lifestyle characterized by freedom of movement, trade-in factory-made properties and services, high service levels, and social mobility. The commercial prosperity of a country has been closely tied to competent means of transport. The rapid development of a particular country especially in providing good infrastructure facilities to the people has constantly become an important agenda to the government. Major factors of congestion, air pollution and many other relative problems become are increases due to the increasing number of vehicles on the road. Soon all commercial activists at some point practice different means of carriage to work. For this reason, resolve to enhance carriage have an instant influence on production and the economy.

The government of Ethiopia is undertaking vast and numerous developmental programs to become a leading toll road owner in Africa on highway security and provision excellence laid out for the all-inclusive revival of the country in 2020. Addis Abeba to Adama Expressway (AAE) is one of the construction mega-projects developed that covers 78Km is open for road traffic and managed through the Ethiopian Toll Roads Enterprise (ETRE, 2017).

2.2 A brief History of RFID

During the first century, Chinese were first used in magnetic fields. From the 1600s to the 1800s was increasing the base of scientifically associated thought for electrical energy, magnetism, and optics (Uddin et al., 2009). Charles Walton is known as the first patent holder for the RFID device and was awarded ten patents including "portable radio frequency emitting identifier" in 1983 and was the first acronym "RFID" (Aima, 2016). Radiofrequency identification (RFID) is rooted in discoveries made by Faraday during the mid-nineteenth century and discoveries made between 1900 and 1940 in radio and radar technologies. Faraday discovered the concept of mutual induction, which forms the basis for powering passive tags operating in the near field, formulation of electromagnetic waves by Scottish physicist James Clerk Maxwell and experimental setup by Heinrich Rudolf Hertz that was able to demonstrate the existence of electromagnetic waves can be mentioned as pieces of evidence. The collaborative effects of these discoveries have contributed a lot to the foundation of modern radio communications (Ilyas, 2008).

In 1896, Guglielmo Marconi invented the successful transmission of radiotelegraphy across the Atlantic, and it became very famous. In 1906, Ernst F. W. Alexanderson demonstrates the first continuous wave (CW) radio generation and transmission of radio signals. These signals are the beginning of modern radio communication where all aspects of radio waves can be controlled. In the early 20th century, approximately 1922, was considered the birth of radar. During the Second World War, The Germans, Japanese, Americans, and British were all using radar- which had been discovered by Scottish physicist Sir Robert Alexander Watson-Watt- to warn of approaching planes while they were still miles away; however, it was impossible to distinguish enemy planes from allied ones. The radar sends the radio waves; detecting and locating an object by the reflection of the radio waves. This reflection can determine the position and speed of an object. Some people think that in 1945 the Russian Government first use real RFID devices and it predates from that time. During the Second World War, the United Kingdom had used RFID and they distinguished their airplanes among the German airplanes (Landt, 2005).

Stockman (1948) stated that "considerable research and development work has to be done before the remaining basic problems in reflected-power communication are solved, and before the field of useful applications is explored". His vision flourished until other developments in the transistor, the integrated circuit, the microprocessor, and the communication networks took place. RFID had to wait for a while to be realized "Communication by means of reflected Power," where Stockman laid out the basic concepts about RFID. According to the 1930s and 1940s (Vernon, 1952), the expansion of radio and radar was an era of investigation for RFID techniques. In late 1960, Sensormatic and Checkpoint with several manufacturers such as KNOGO established Electronic Article Surveillance (EAS) equipment to counter theft. EAS is arguably the first and most widespread commercial use of RFID (Vernon, 1952). In 1977 one of the first RFID systems introduced to the market was launched by Los Alamos Scientific Laboratories in the form of an access control system. From 1963 to 1964, (Harrington, 1958) studied the electromagnetic theory and these techniques used to RFID and made two papers

"Field measurements using active scatterers" and "Theory of loaded scatterers". (Golio, 2001) In 1975, Radio Corporation of America (RCA) and Fairchild developed an electronic identification system. Moreover, in 1977, F. Sterzer of RCA also developed an electronic license plate for motor vehicles. Furthermore, (Meyers & Leigh, 1978) of Fairchild again developed a new component of RFID "Passive encoding microwave transponder".

In 1980, RFID reached into the new exploration world, that time gave more attention to enhancing tracking and access application in manufacturing and other environments. Hence, distinguished by the execution of an RFID system (Uddin et al., 2009). The 1990s was a significant decade for RFID innovation and it comes true application.

The RFID tag has two parts. The first is an integrated circuit for storing and processing a piece of the given information, modulating and demodulating an (IR) wave and can also be used for other specialized functions, and the second is an antenna for receiving and transmitting the wave. A recent technology called a chip (Kanthi et al., 2014). When the RFID tag passes through an electromagnetic zone it detects the reader's activation signal. Then the reader decodes the data encoded in the tag's integrated circuit (silicon chip) and the data is passed to the host computer. Figure 2.1 shows the three portions of automated toll systems including the RFID system, the balance deduction system in the host computer, and the toll gate control system (Attaran, 2007; Win & Myatnwe, 2014).

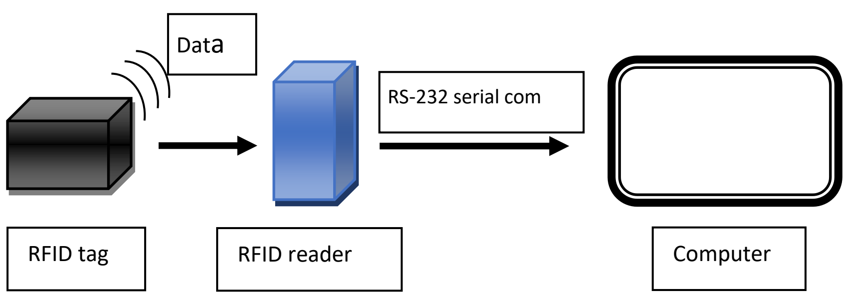

Figure 2.1. Complete RFID system

RS-232 is a standard for serial binary data interconnection between Data Terminal Equipment (DTE) and a Data Circuit-terminating Equipment (DCE) in telecommunications (Priyanka et al., 2015). A silicon chip and antenna and can be either active or passive, depending on whether they have a power source or not. Active tags have their energy supply like long-life batteries and are capable of initiating their communication with a reader. "Advanced active tags might even form ad hoc peer networks with each other" (Miles, 2008). Passive tags do not have their power source and consequently are not able to initiate communication with the reader. These kinds of tags obtain their energy source from a reader employing inductive coupling or capacitive coupling (Miles, 2008). Passive RFID applications that utilize low-frequency use inductive coupling while the higher ones use capacitive coupling. These types of tags have a short read range and are cheap to manufacture. Table 2.1 signifies the basic differences between active and passive tags considering metrics like power source, communication type, and the read range of the tags.

Table 2.1. Passive, semi-passive, and active tag comparison

Tag type	**Passive**	**Semi-Passive**	**Active**
Power source	RF energy	Battery	Battery
Communication	Response only	Response only	Response or initiative
Maximum read range	10M	> 100 M	>100M
Relative cost	Least expensive	More expensive	Most expensive
Typical applications	EPC proximity cards	Electronic tolls Pallet tracking	Large asset tracking

Operating frequency is also important in determining the physical dimensions of an RFID tag. Different shapes and sizes of the antenna will operate at different radio frequencies are available in the market with different frequency ranges. The frequency ranges typically express the RF ranges of the tags from low-frequency tag ranging from 30cm to 1m, mid-frequency ranging from 3m to 7m, and high frequency ranging from 1.6m to 27.5m. The functioning frequency similarly regulates how tags physically interact with each other. For instance, piling plane foil inset tags on top of each other may interfere or prevent tags from reading properly. The price of the radio frequency is depending on their frequency range (Ilyas, 2008). Table 2.2 lists standard frequencies and their respective passive read distances.

Table 2.2. Common RFID operating frequencies

Frequency Range	**Frequencies**	**Passive Read Distance**
Low Frequency (LF)	120 to 140 kHz	10 to 30 cm
High Frequency (HF)	13.56 MHz	10 to 60 cm
Ultra-High Frequency (UHF)	868 to 928 MHz	3 meters
Microwave	2.45 to 5.8 GHz	>3 meters
Ultra-Wide Band (UWB)	3.1 to 10.6 GHz	>10 meters

Based on their attachment with an identified object there are three different kinds of RFID tags i.e. attachable, implantable, insertion tag. Besides, Eastman Kodak Company has filed two patented applications for monitoring the ingestion of pathologically based on a digestible RFID tag (Tamura, 2008). Figure 2.2 illustrated the attachable type of passive RFID.

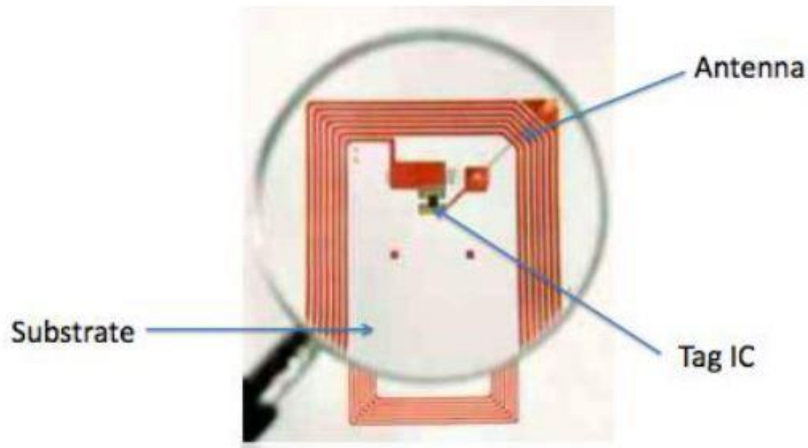

Figure 2.2. Passive RFID

2.3 Evolution of Toll Collection at Toll Plaza

The United States first deployed the electronic toll collection technology using RFID (Foote, 1981). Significant distributions contained within numerous inventions in automated tolling. In 1991, the world's first highway electronic tolling system was opened in Oklahoma, where the vehicles could pass at highway speed through the tolling point station. Harris County Toll Road Authority first installed both electronic toll and traffic management systems in 1992.

Karsaman et al. (2014) the two types of electronic toll systems are namely, automatic and electronic types. Several countries are using a semi-automatic (automatic type toll classified into semi-automatic and fully automatic) toll system in which each vehicle has to stop to scan the card and must wait until the gate opens. In other counties, the transaction is done whereby a fully automated system without the vehicle to stop at the gate. Using a fully automated system has several advantages, such as an increase in tollgate capacity, a decrease in congestion at the toll booth, saving of transaction time, reduction in emission, leads to fuel-saving, and simplify the toll operation.

2.4 RFID for Electronic Toll Process

Passive RFID tags utilize the induced antenna to induced ac voltage through the system that rectified to provide a voltage as a source for the device. As the dc voltage reaches a certain level, the device begins working. By providing an energizing RF signal, a reader can communicate with a remotely located device that has no external power source or battery. Since energizing and communication between the reader and tag is accomplished through antenna coils, the antenna becomes one of the most significant components of RFID systems. Antennas for RFID system usually are made of coils of magnetic wire. A current flowing into the coil radiates a near-field magnetic field that falls off with r^{-3} (r is the distance away from the antenna) (Jung & Lee, 2015). This type of antenna is called a magnetic dipole antenna.

Since around 1992, researches on an Electronic Toll Collection system using radio frequency identification and detection (RFID) has been introduced during RFID tags that began to be broadly used in vehicles to automate toll methods. The system uses an RFID tag that is mounted on the windshields of vehicles, through which data embedded on the tags are read by RFID readers; this automated system removes the needs of toll enterprises to manually perform ticket payments and manual toll collections (Kamarulazizi, 2010).

RFID technology-based presence supervision system the study has identified and explained the key benefits of RFID technology. RFID will open doors to a pool of applications from an excess of industries. Although the focal challenge to thwart the adoption is its investment cost, RFID technology provides an ocean of lucrative business opportunities that could convince several firms to adopt it (Gaikwad et al., 2017).

2.5 Concept and Categories of Vehicle Detection

This section introduces several kinds of traffic count and data collection tools that are in wide usage. With the development of technology, transportation engineers and researchers tend to make utilization of more developed technologies for vehicle identification, tracking, and data extracting. In the following section, the main characteristics and application of radio frequency identification and detection commonly used for vehicles detecting technologies are introduced.

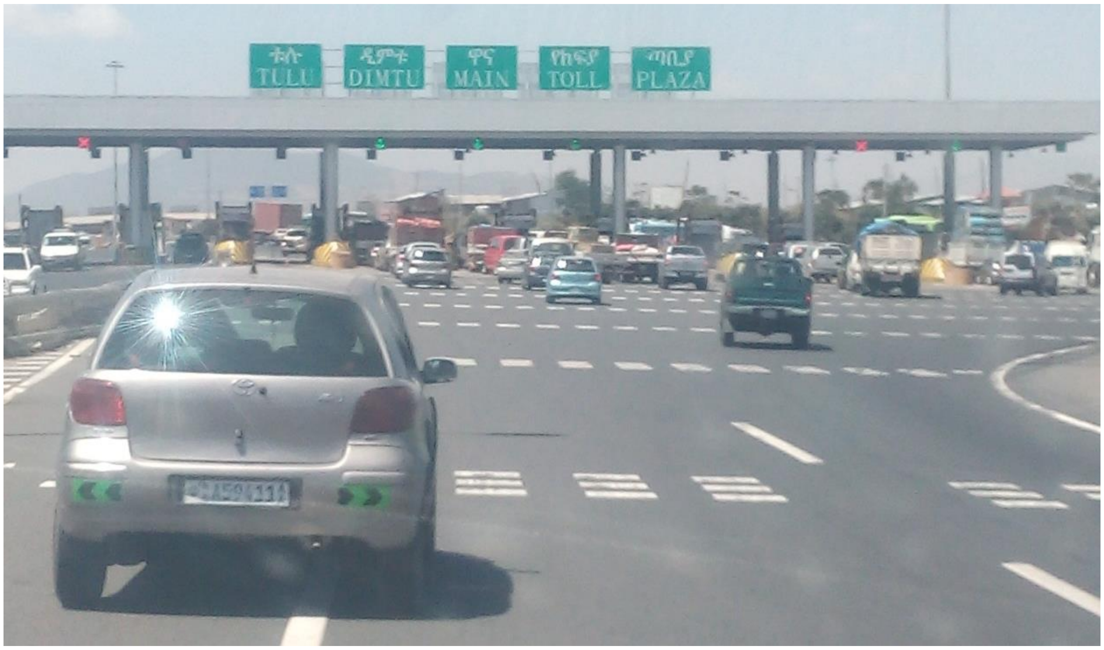

Figure 2.3. Tulu Dimtu main toll plaza

Figure 2.3 shows a toll booth in which the vehicle is required to stop before it can cross off and continue its journey. This toll system is a time-consuming and often possible cause for congestion on the road. The above-mentioned problems can be solved by implementing the proposed systems which read the RFID tag and send the data to the database to recognize the information either the information is correct or not.

RFID is programmed proof of identity technique. An excessive application of RFID technology permits loading and understanding the data deprived of requiring either communication or a line of sight between the tag and reader. RFID is a tracking technology used to detect and confirm tags that are applied to any product, person, or animal. RFID (Radiofrequency identification and detection) is a universal term used designed for detection technologies based on wireless communication making use of radio waves, which is a part of the electromagnetic spectrum (Boschma & Wenting, 2007). A basic arrangement contains three apparatuses.

a. Coil or an Antenna
b. A transceiver (with decoder)
c. Electronically programmed RF tag (transponder)

Homs et al. (2004) two-way radio transmitter-receiver the so-called Interrogators or Readers have to send a radio signal to the tag and simultaneously read what the tag responses. Gupta,

(2004) offered RFID data that combines with the existing applications for tracking and monitoring manufactured substances. With the help of RFID, can achieve those activities easily through configured data management system integrated with different applications into minimum integration cost. Nowadays, production methods are also improving, so the trustworthiness and the read range of the passive RFID system continues to improve the cost-effective way. The following Figure 2.4 shows the configuration of the RFID.

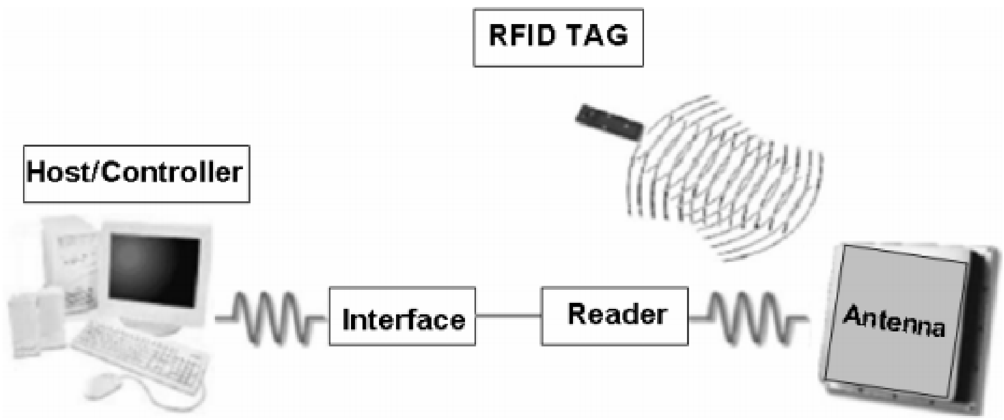

Figure 2.4. The basic configuration of the RFID system

2.5.1 Traditional Loop Detectors

Are fixed-location sensors, and other well-used technologies are generally in the mobile traffic sensor area. Generally speaking, mobile traffic sensors include any monitoring or data collection system with an appropriate device equipped with probe vehicles those equipped with Electronic Toll Collection (ETC) tags such as cellular phones, portable GPS devices (like GPS cellular phones), GPS navigation systems, Bluetooth Mac Address Matching, vehicles in Vehicle Infrastructure Integration, etc. (Xuegang (Jeff), 2010). These mobile traffic sensors are also known as probe vehicle technologies, which are typically Intelligent Transportation Systems (ITS) applications for real-time traffic monitoring.

2.5.2 Global Positioning System (GPS)

The Global Positioning System (GPS) is a space-based global navigation satellite system (GNSS) that sends reliable position and time data in all meteorological conditions and at all times and anywhere on or near the earth when and where there is a free line of sight of 24 satellites placed into orbit by the U.S. Department of Defense (Garmin Ltd, 1996). Since 1973 the development of GPS was started to overwhelmed the restrictions of earlier navigation systems, integrating ideas from quite a lot of precursors, together with numerous classified engineering design studies from the 1960s. However, in 1983 president Ronald Reagan decided to permit the system to identify a location on a map and to design identify the nearest for civilian use of GPS technology once it becomes operational.

GPS technology-based vehicle tracking system belongs to a category of traffic time measurement technologies called probe vehicle technologies. With an application of Global Positioning System (GPS) technology for a vehicle, detection is widely used. The first GPS pilot test was conducted by (Yim & Cayford, 2001) and also included the analysis of cellular phone tracking. This study successfully proves that GPS can be used for travel time calculation with a high frequency of reading. Besides, a GPS may be used as an emergency locator and security feature to track vehicle locations. GPS is one way in which satellites have become part of everyday life (Wright et al., 2013).

Cellular Probe Technology also belongs to the field probe vehicle technologies. Cellular technology began to receive attention from the transportation research field just quite a few years ago. It uses wireless communication signals to make vehicle identification and detection possible. When tracking the cellular phone signal in vehicles, the timestamp, location information of vehicles are caught. Since the detection of the phone signal in the vehicle never tells the type of vehicles, the detection study with a cellular probe is hard to do. However, by using Wireless Location Technology (WLT), which has been developed for mobile phone networks, cellular probe technology can be a potentially promising technology for obtaining vehicle travel information. There are plenty of studies on the estimation of travel time using a cellular phone-based system (Bar-Gera, 2007) and obtaining general traffic information (Cayford & Johnson, 2003; Fontaine & Smith, 2005) these studies receive robust results for traffic detection purpose.

The aim of designing an ETC system is to leaves the delay time on the expressway by automating the existing system. ETC controls whether the vehicle fleeting is registered in the database, red alert enforcers for those that are not, and deduct the predetermined charge from the account of registered vehicle owners without requiring them to stop.

2.5.3 Bluetooth Probe Technology

Bluetooth is a typical short-range wireless communication technology with its functionality embedded in various electronic wireless devices, such as cell phones, MP3 players, PDAs, laptops, GPS, car radios, and so on. Bluetooth-enabled devices can serve as "tags" for vehicle tracking by a unique identifier known as Media Access Control (MAC) address. Every Bluetooth device has a unique electronic address, used to identify it to other network devices (Bluetooth, 2008). The traffic monitoring effort also relies on the pairwise Bluetooth readers to take down the timestamps and location information of vehicles, the readers just get anonymous IDs for privacy protection. This might be an essential characteristic of a potential data source. The Bluetooth technology can be applied in freeway travel time arterial travel time and performance measures, traffic signal studies, pedestrian travel time, airport evacuation modeling, and transit travel time estimation. The exploration of this technology in traffic monitoring has been quite active recently both in the academic and industry field. A case study of estimating traveler's route choice and travel time using Bluetooth probe vehicles have been conducted at northwestern Indiana (Hainen et al., 2011). Some commercial companies have been manufacturing Bluetooth based vehicle detectors and systems. The study of travel time and speed measuring using Bluetooth carried out by Texas Transportation Institute in the Huston area is a notable study in the AVI detecting field (Puckett & Vickich, 2010). In the study, the Bluetooth detection system related concepts are given and shown in Figure 2.5 below.

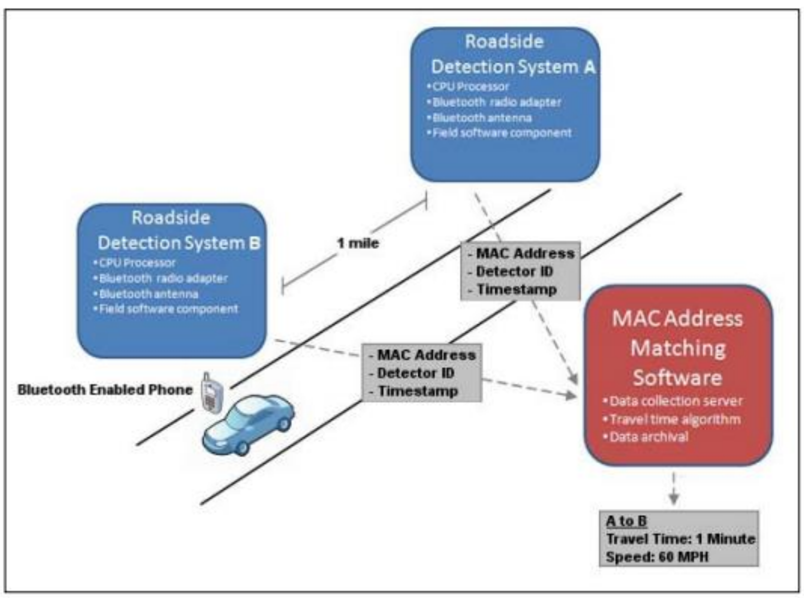

Figure 2.5. Concept of Bluetooth detection system

2.5.4 Radio Frequency Identification and Detection Technology

Radio-frequency identification (RFID) is a technology that uses communication via electromagnetic waves to interchange information between a terminal and an electronic tag attached to an object, for identification and tracking (Kaur et al., 2011).

However, before anything like radio frequency identification began, the pioneering systems were automatic object detection systems. One of such findings and patents was a radio transmitter for object detection systems designed by John Loggie Baird in 1926 (Baird, 1928). Nine years later, Robert Watson Watt was credited with a patent for his “Radio Detection and Ranging” system or the RADAR. Henry Stockman in his seminar entitled “Communication through Reflected Power” in 1948 had already presented the communication technology that is used in the current RFID system (Stockman, 1948).

There are two acquisition methods, which define the method used to read tags in the field. One is a global scroll, the primitive command method. During the operation of acquisition, the readers just send the command to the air and every tag in the receiving area can get the request and immediately send back its ID to the reader. Another method is called inventory. This single high-level command transforms itself into a complex series of reader-tag interrogations that eventually resolve themselves into a single list of tag IDs seen by the RFID Reader. Passive RFID is now commonly used in various fields, such as warehouse management, medical, animal identification, usages at toll stations, and parking lots that have been applied in various countries.

Later, applications based on radio frequency began to emerge. The first official application using radio frequency identification was during World War II when the British Royal Air Force used radio frequency to identify friendly aircraft from an adversary one in a special “Identification friend or Foe” (IFF) called application. IFF helped radar operators and pilots to distinguish friendly aircraft from enemies using RF signals. IFF system has also helped in preventing “friendly fire” incidents (Miles, 2008).

However, for objects with high-speed motion, active tags should be attached to ensure the detecting range and tracking accuracy. Some major organizations such as Loggers use RFID technology to track its fleet, the 915 MHz active tags are used (Swedberg, 2005). Those tags are UHF tags so that the detection range can be up to 300ft (about 100m) (Kaur et al., 2011). Although active tags needs attached power source and thus are higher in installing budget, they are truly necessary for traffic monitoring. As the implements of RFID on freight vehicles become more and more popular, a good vehicle identification and monitoring method becomes realistic.

2.5.5 Vehicle License Plate Recognition Technology

In 1976, the first automated license plate detection and recognition technology were invented by the Police Scientific Development Branch (PSDB) at the home office in the United Kingdom (Lakshmi et al., 2011).

Bai & Zhou, (2006) identified that the Automatic Vehicle Identification Managing System (AVIS) which has RFID technology, managing technology with electronic license plate (ELP) communication technology acquires more scrutiny in the society. The scheme detects every single registered vehicle and gathers the vehicle information continuously by RFID technology.

Shevale, (2014) describes the smart vehicle license plate screening system and recognition at a toll plaza using a special-purpose surveillance camera. License plate recognition can be used in many applications such as parking control, entrance admission, speed control, road traffic control, and so on. To identify the vehicle by using license plate recognition the required algorithm sequence start captures the vehicle image then makes clear the blurred image, extracts the image of a license plate, and recognizes the vehicle from the database. Some counties like Australia and Korea uses standard feature license plate such as the dimension of the plate, the license plate border, and font character.

Masurekar, (2016) designed an automatic vehicle number recognition capture the vehicle image with the help of a web camera. The system is an image processing technology that uses an efficient algorithm to detect the vehicle captured real plate and the templet matching technique is used for character recognition from the database. During fleet all the data information such as passing time, date, and toll amount stored through the database to maintain the record. The system requires four modules: i.e. image acquisition, license plate extraction, character segmentation, and character recognition. Searching algorithm relay on the color algorithm.

Using number plate image communication, the technology of automated toll system for vehicle information and the payment is done only make using number plate image via SMART CARD. NPR (Number Plate Recognition) using photo masterminding structure orchestrated with a completely objective of the security structure. The number plate is labeled in the database with the client's close to home data, ledger, and vehicle subtle elements (Prathiba et al, 2017).

Detection of a vehicle through the application of VLPDR (Vehicle License Plate Detection and Recognition) has become a serious initiative and an advanced area of research. Hence primarily, the system works by capturing the vehicle image and thus, interprets the license plate's registration number automatically. The AVDR (Automatic Vehicle Detection and Recognition) system proves to be an operative instrument which supports to systematize the activity, too long and the physical technique of the employees which they encounter and deal with in their regular daily life, and aids to deliver efficiency in the identification of the vehicles from hundreds and thousands of vehicles observed in the regular patrolling task. AVDR combines license plate detection with vehicle shape detection to make a system more secure rather than disposed to false intrusions.

The need for the successful implementation of the License Plate Detection and Recognition (LPDR) system has evolved over many years and hence, many research algorithms, protocols, and schemes have been proposed on the topic. Therefore, ALPDR (Automatic License Plate Detection and Recognition) System can be described under two main divisions (Goswami & Gaur, 2014).

1. Online or Active ALPDR System
2. Offline or Passive ALPDR System

2.5.5.1 Online or active ALPDR System

In an Active ALPDR System, technologies like LASER, RADAR, surveillance cameras, and radiofrequency are implemented to carry out a successful identification of the vehicle. In the LASER System, a barcode is positioned on the car whereas, in the case of radiofrequency systems, a tag is installed in the vehicle. This tag includes information on the license plate along with the other necessary information. Surveillance Cameras keep a proper track of the positioning of the vehicles by interpreting the localized License place in an image from the arriving video frames. An RFID reader is installed in a location for the identification of the vehicle and it has the potential to interpret the information mentioned on the tag from a specific distance. The Radiofrequency system does not require the image of the vehicle to recognize the vehicle's identifications, which eliminates any false recognitions (Yan et al., 2001).

2.5.5.2 Offline or Passive ALPDR System

In a Passive ALPDR System, the interpretation of the vehicle license plate takes place by capturing the images of the vehicles and then maintaining a database of these images in a centralized information server. Here, the recognition of the vehicle takes place by processing the image of the vehicle license plate. This process to a great extent depends upon the quality of the image captured. Complications may arise due to noises in the image of the license plate and hence, this may lead to generating erroneous and inaccurate results.

2.5.5.3 License Plate Recognition Based on Color

A vehicle number plate can be detected based on plate color, edge, and other features. After applying intensity variance and edge density method license plate detection performed. An edge-based color aided plate number detection method discussed in (Abolghasemi & Ahmadyfard, 2009). Contain vertical edge density estimation and the Gaussian mixture is used to emphasize the constancy of intensity value at a surrounding region along the horizontal direction. Finally, the processing of color and structure analysis of the plate are used to the segment license plate.

APDR systems comprise different components. The key module of this system is to recognize the text in an image. This image contains the license plate of the vehicle which is then analyzed to get the plate information. Each character of the license plate is recognized by this system by comparing it with the stored templates (Zheng et al. 2008).

Yao & Yi, (2014) proposed a system of new license plate detection techniques using Adaboost detector on many stages of data combination. This planned multiple-stage data combination system consists of an advanced Adaboost sensor with a color sensing module and with a Support Vector Machine (SVM) detector. These two stages also check whether the image that is detected by the Adaboost sensor is a license plate.

2.5.5.4 License Plate Recognition Through Video

In Patel et al. (2013) the study considered image size from the different approaches under camera surveillance, and the Sliding Concentric Windows (SCW) technique for faster detection of a region of interest is developed. The analysis of the study's overall success rate is 96%. To extract the image by using relevant features like shape, texture, and color. To detect vertical and horizontal line from rectangular vehicle number plate used Hough Transform (HT) and then processed it by converting Red, Green, Blue (RGB) to Hue-Intensity-Saturation (HIS).

In Cui & Huang, (1998) license plate character extraction from a video is discussed. As per the author localization of license plate means finding a text in the image. The license plate background with light color and the character with a dark background. To do localization, spatial variance method is used for finding a text region and none text region as high variance means of text region and non-low variance means non-text region.

Karande et al. (2016) the scientific research introduced detecting vehicle license plate numbers using Optical Character Recognition (OCR) and by digital camera. Using processed data for further processes like segmentation, image binarization, number plate extraction, and storing of image.

2.6 RFID for Electronic Toll Collection

In 1959, the first electronic toll system for the Washington Metropolitan area was proposed by Nobel Economics Prize-winner William Vickrey. Through the proposed system each vehicle would be integrated with a transponder. “the transponder’s radio signal which tagged on the vehicle would be read when the vehicle closed to the gate and at host computer would calculate the charge at the management unit according to the time of day and add it to the vehicle’s bill”. In the 1960s and the 1970s, the free flow toll system was tested with a fixed transponder at the basements of the vehicle and readers, which were placed underneath the surface of the roadway (Andurkar & Ramteke, 2015).

Norway has been the world's pioneer in the widespread implementation of this technology in Bergen to introducing composed with a manual system in 1986. Later, Trondheim introduced the world's leading use of fully unassisted full-speed automated tolling in 1991. Nowadays Norway has 25 toll highways respectively working with entirely electronic fee collection, as the Norwegian technology is entitled. In 1995, Portugal became the first state to implement a single, worldwide scheme to complete fees in the country, the Via Verde, which can similarly use in car parks lots and gas stations too. At the western, the United States of America is another country use the widespread automated system in several states, rather than manual system toll roads.

In the scientific research of Amol & Nawgaje, (2015) the traditional manual toll collection is not efficient over highway transport in the modern way network thus collecting the toll and traffic management to introduce a new system with advanced technology is electronic toll collection. The proposed system uses radio frequency identification technology, GSM, and computer host. The RFID is used to access the vehicle's data and information, RFID tag with an exclusive Id is programmed mounted on each vehicle, programmed data hold on the tag is read by nearly RFID reader placed at toll gateway. If the vehicle belongs to the registered person, a programmed expanse is automatically deducted from his/her account, a short text message will send to registered cell phone number and the toll gate opens.

Automated toll collection targets to remove the delay on toll highways employing collecting tolls electronically. The programmed structure controls the cars passing plaza which are recorded in the database and electronically debits from the accounts of registered car owners without requiring the vehicle to stop. In existing systems, faces numerous problems such as there is no allowable speed limit near to the tollgate, wastage of fuel, and the time of customers, difficult to control a crowd, and optimize the queue length of vehicles. The time delay caused by passing through toll stations includes slowing down, accelerating waiting, and service time. The existing system allowed all the payment types like prepaid, postpaid, and cash (Yu et al., 2011).

Ethiopian Toll Roads Enterprise (ETRE) established under Regulation no 301/2014 issued by the Council of Ministers in July 2014 as public enterprise according to the Public Enterprise Proclamation No. 25/1992. All the road toll collection systems are commonly used in Ethiopia is a manual transaction. Particularly, Addis Abeba to Adama Expressway (AAE) has 19 entries and 29 exits. Nowadays, over 14,000 vehicles for 7 days and 24 hours are streams of traffic flow are increased and toll gate on highways are congested (ETRE, 2017). This will cause a traffic jam and a waste of time. The objective of this thesis is to transform the existing manual system to computerized toll system with the help of RFID and microcontroller technology. The accomplishment of the first-year strategic plan (2015/16G.C) was evidenced by servicing a traffic flow of 5,043,463 (five million forty-three thousand four hundred sixty-three) vehicles surpassing the estimated plan of 4,714,286 (four million seven hundred fourteen thousand two hundred eighty-six) vehicles with (107%) success rate and the 24/7 traffic flow was nonstop managed without any major interruption and inconvenience for the customers. Besides, the various customer handling departments were able to deliver their services with customer satisfaction orientation.

To implement an RFID based toll system, RFID tagged vehicle, RFID scanner equipped toll plaza, centralized database, and laser transponders are components mainly required. Hence, the system is categorized into four major mechanisms (Kalantri et al., 2014):

a) Automated Vehicle Identification,
b) Automated Vehicle Classification,
c) Transaction Processing, and
d) Violation Enforcement

2.6.1 Automated Vehicle Identification Technologies

Automatic vehicle identification (AVI) has recently emerged technology in numerous road traffic administration and toll collection applications. The system made up of an in-vehicle transponder (tag), a roadside reading unit, and a central computer system (Boyce et al., 1991). When a vehicle having a radio frequency tag crosses a pavement antenna, the existing data on the tag is moved to the antenna (reader unit). The appropriate data may in the range from a simple vehicle identification number to toll account balances or the vehicle’s journey data. For computing travel times, the central computer monitors several consecutive reader units and matches them to the transponder identification numbers created in the central computer system.

AVI is a general traffic surveillance tool derived from auto-identification Harrison et al. (2006) which serves institutes who want to identify items, capture information about them, and somehow get the data into a computer automatically. AVI has been widely used in monitoring the performance of Electronic Toll Collection (ETC) and High Occupancy Tolling (HOT) systems (Lu et al., 2007).

Texas Huston was the first city in the United States of America to apply AVI technology for monitoring traffic conditions (Puckett & Vickich, 2010). Because of the excellent performance of AVI application in toll station monitoring, Huston's AVI monitoring system deploys the "EZ-Tag" Embedded in the vehicles, which are used in the automatic toll collection system, to be the transponder tags. AVI devices include tags placed in vehicles, and tag readers set along the roadside. By recording the timestamp of a vehicle passing the two readers, the travel time between readers can then be generated. AVI technologies have not been used widely for traffic monitoring. The potential advantage of AVI technology over fixed-location detectors resides in its ability to collect point data as well as point-to-point data, which are expected to provide a better description of certain aspects of traffic conditions. Considering its higher efficiency and accuracy and lower cost compared to a traditional plate-matching method, it is expected to fill in the gap for traffic tracking purposes, especially in merchandise performance monitoring. Bluetooth and Radio Frequency Identification (RFID) technologies belong to the category of AVI technologies.

The AVI system is used to determine the identity of the vehicle which is passing through ETC tollbooth for charging the toll to the corresponding customer. While passing through the toll lane, a receiver communicates with the tag installed on the rear windshield of the vehicle and reads the vehicle information (Masurekar, 2016).

Companies like SUPER RFID has developed an RFID based system for identifying a vehicle and help control traffic management. This system includes functions like vehicle registration, annual check, traffic statics (counting car numbers and measuring speeds), anti-theft, police supervision, over-speed check, traffic light violation control, and so on (Mattern, 2014). To achieve its goal, the company has used Automatic Vehicle Identification done by providing each vehicle with a unique ID tag and traffic management approaches. The later uses a wireless vehicle detector applied to check speed, count car numbers and work in conjunction with a camera monitoring system to realize required functions. An automatic vehicle identification using RFID, a firsthand experience, describe the performance of different RFID systems purchased from CAEN (Italy) and Alien Technologies, after applying them to a rail system in India. They located the tag either on the side or attached it to the undercarriage of a train. Trials with CEAN systems work on ISO-18000-6b protocol. The tag they used can store 2k bits of data (256 Bytes) (Butani et al., 2013).

An RFID Tag is made up of a coupling element and a chip; each tag has a unique electronic code, attached to the object used to identify the target. The RFID reader is an electronic device that is used to respond and write the data on RFID tags electronically. There are two types of readers handheld readers and fixed readers. Handheld readers are designed that perform like handheld barcode scanners and fixed readers are mounted above the object to read tags automatically as an object close to the reader. The antenna produces wireless waves to trigger the tag and to read and write data to it (Kamran et al., 2010). Here below the following Figure 2.6 shows the major components of RFID and the way how to detect an object by using RFID.

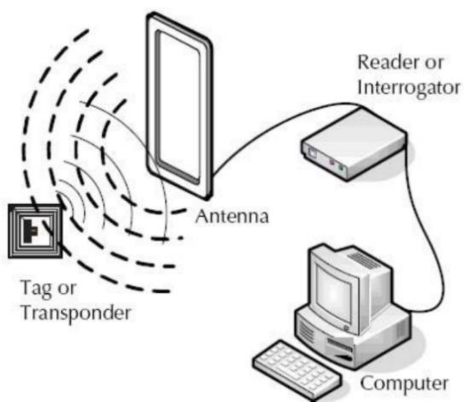

Figure 2.6. The Working of RFID

2.6.2 Automated Vehicle Classification

AVC system contains sensors installed at the toll lanes which are used to identify the type and class of vehicles for charging a proper toll. The charge depends upon vehicles' weight and size. The vehicle type may include light vehicles or heavy vehicles. A vehicle class can be determined by the physical attributes of the vehicle, number of occupants in the vehicle, number of axles in the vehicle (Masurekar, 2016). Vehicle Classification is needed, as toll charges levied on a vehicle depend not only on the toll route being used but on the class of the vehicle such as Saloon, Van, Truck, Bus, Multi Axle Vehicles, etc.

Following scientific journal Faria & Devkatte, (2017) introduced toll gate automation designed to record the details like owner's name, registration date, vehicle model, etc. this system is useful for tracking vehicles automatically, time management, and also for tollgate automation. The scientific research describes the application of toll gate automation which is a step on the way to improving the tracking & monitoring of vehicles, traveling in predetermined routes. The system automatically detects vehicles and records the vehicle code number & time.

In the research paper of Manikandan et al. (2018) examined the RFID based toll deduction system and how to make well-organized and perfect. The vehicle will be prepared with a radio frequency (RF) tag which will detect RF reader located in on toll plaza. Then the particular amount will deduct from the user’s account. This study can be a well-thought-out mountable device in motor vehicles used today.

In the scientific paper of Blythe, (1989) offered recent experiments in Hong Kong on road-use pricing, and Berlin and London on route-guidance, it is clear the high-tech development in the fields of data-communications and Road Traffic Informatics (RTI) will renew the old debate as to how the use of road system should be charged for. In particular, if vehicles can be charged for road-use electronically, without stopping them to do so, then the government strategy towards road-use pricing could be significantly changed, even though the solid communal and political oppositions might continue to be overcome (Kelly, 2006). The paper is not just centered on the technical issues posed by automatic toll collection but set within the social/political context surrounding any widespread implementation of such a policy.

According to Ethiopian Toll Road Enterprise, at Addis Abeba to Adama Expressway user vehicles are classified into 7 broad classes based on the number of axles, the vehicle weight, total weight, and the number of tiers.

Suppose, if the vehicle passes the toll plaza having 4 number of tires with 2 axles, to justify the vehicle character description and to show the result on the display unit, now the vehicle total height and axle distance from one to the other is required as a parameter. If the vehicle height less than 1.3 m the description will be small automobiles (class 1) or if the height becomes ≥1.3 m the description will be minibus (class 2). Table 2.3 shows the classification parameters declared by Ethiopian Toll Road Enterprise.

Table 2.3. Vehicle classification for toll

Vehicles		Classification Parameters				
Class	I-Axle number	II-Tire number	III-Height of vehicles head(m)	IV-Axle distance (m)	Character description of vehicles	Remarks
1	2	4	<1.3	<2.4	Small Automobiles SUV	At the same time to satisfy the parameters I, II, and III or IV in any conditions
2	2	4	≥1.3	≥2.4	Minibus	At the same time to satisfy the parameters I, II, III and IV conditions
3	2	6	–	–	Medium Bus, ISUZU	
4	3	–	–	–	Big size Bus Dump Trucks	
5	4	–	–	–	Heavy Trucks Trailers	
6	5	–	–	–	Heavy Truck Trailers	
7	≥6	–	–	–	Trailers Heavy Truck	

Currently, the price of Tulu Dimtu toll plaza at Addis Abeba to Adama Expressway is tabulated in Table 2.4.

Table 2.4. Addis Abeba to Adama Toll Road Tariff

Addis Adama Toll Road Tariff		
Toll Category	Vehicle Class	Toll tariff per KM (ETB)
1	V1-V2	0.76
2	V3	0.82
3	V4	0.97
4	V5-V7	1.05

In this thesis work the following vehicles are exempted from tolls: from an emergency section Fire Brigades/Fighting and Medical Service/Ambulance, from the military section such as National Defense Army, Regional Special Force, Traffic Police & Police Army, and the official section such as high legislative official rank vehicles including Ministers and Diplomatic vehicles.

2.6.3 Transaction Processing

Once the vehicle identified, the toll charges need to be billed to the road user and the toll collected passed to the toll concessionaire. The ETC organization has to keep this monetary operation reliably and safely. The customer account can be post-paid (more usual), where the client reserves a balance in his/her account which is then deducted during road service, and the service charge bill will send to the client at the end of each month via email or cellphone (Ananthamoorthy, 2017).

Congestion can happen at tollgate due to the manual ticket payment and transaction system. This problem can be resolved by the implementation of an automated toll system. The country's toll enterprise advises that the queuing at the tollgates when exhibited traced air pollution. The average money transaction period on the existing system was taken approximately 29.8 seconds. The study demonstrates that the automated toll system is more effective than the manual toll system in terms of reducing the number of queuing vehicles (Karsaman et al., 2014).

2.6.4 Violation Enforcement System

VES captures images of the license plates of vehicles that pass through an ETC tollbooth without a valid RFID tag or insufficient balance in its account. To identify violated vehicles the system is well equipped under camera surveillance to take a picture violating vehicle license plate. Violators are identified immediately, as the barrier will not permit the violator to proceed. However, the tollgate barriers also might approve clients which are the huge widely held of a vehicle passing through, to slow a near stop at the toll gate, negating much of the speed and capacity benefits of electronic tolling. Vehicle Enforcement System (VES) helps in tracking theft vehicles. Violator recognition and management system are important for the achievement of an ETC without policies and systems in place for this, an ETC system will simply not work.

Larionov et al. (2017) have examined a system where Automatic vehicle identification is widely used in traffic rules enforcement systems. Speed cameras as a crucial part of most identification systems have high cost and rely on clear optical conditions to enable the license plate reading. Radio identification equipment has essentially lower cost and is more reliable in terms of weather conditions.

Figure 2.7 shows that the violated vehicle license plate number was posted on each toll booth's window in front of the operator to ferret out the guilty.

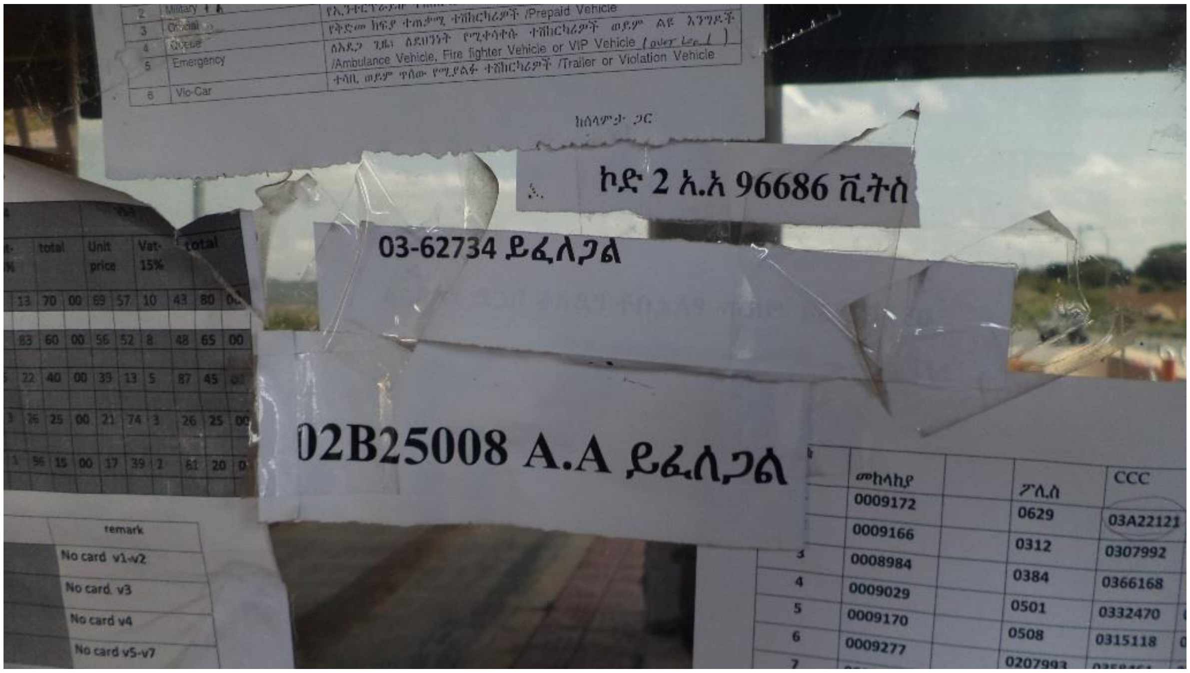

Figure 2.7. Violated vehicle license plate number at the toll booth

2.7 Advantages of an Electronic Toll Collection System

The electronic toll collection system is a digital system of collection toll from vehicles without stopping them. By providing several lanes on the highway it improves the speed of the vehicle, the competency of road traffic management, and can save drivers' time. An ETC system is capable of automatically charging a toll to programmed client account. The system controls whether a fleeting car is registered, automatically charging those vehicles, or the system is about the vehicles that are not registered as well.

2.7.1 Increased Capacity

The electronic toll collection system will increase the capacity of transportation when passing the toll plaza as we will divide the road by four lanes. Therefore, the proposed system resolves an exited problem such as manual cash handling, increases efficient toll collection by reducing traffic congestion at a toll plaza, and helps in lower fuel consumption (Chapate & Nawgaje, 2015).

2.7.2 Fuel-Saving

The deceleration, acceleration, and idling are completely disregarded. This results in fuel saving for the clients using the electronic toll collection system. The waive of acceleration and deceleration consequences in a reduction in the operating cost of the vehicles.

2.7.3 Time-Saving and Tracking Objects

Radiofrequency identification (RFID) is the advanced technology with wireless use to transfer data, to automatically identify and track tags that are attached to vehicles (Sangole et al., 2015). ETC users do not expect to stop for paying toll, thus there is a considerable saving in the travel time. Beside this reliability is increased as the travel time can be estimated fairly exactly. The toll collection charge is decreased over some time. There is an absentee in the man-hour required as the system does not involve any human interaction for the toll operation. Time saving ETC users do not stop for paying toll, thus there is a significant time saving during pass across. Besides the travel time, trustworthiness is improved as the travel period can be appraised honestly precisely.

Manufacturing uses RFID for numerous applications such as access control of person or vehicle, warehouse stock safekeeping, luggage, fast food establishments, logistics service, departmental access control in large buildings, and automatic toll system (Ahsan, 2011).

Since RFID technology has been made with much excitement for the past few years. The major motives for this development it had tagging with a single chip on physical objects such as places, people or animals, and any things under the control of a computer. RFID technology is together welcomed as the sign to the Internets of Things, and strong disapproval as hostile observation technology, and in more thrilling, it is being scared represent as a mark of the Beast (666) mentioned specifically in the *Book of Revelation* ("Book of Revelation 13:16," 1962). An RFID structure categorized into two infrastructures, the technical infrastructure contains the real data capture technology embrace of tags, reader and the transmission medium or the logical infrastructure denotes the overall identification (ID) arrangement instead of things (Fine et al., 2006).

RFID increases two mains confidential concerns for users secret tracking and inventorying. The tag responds to the reader's request without notifying their holders or carriers. Thus, where read rang permits, secret scanning of tags is posing a threat to believable. Utmost RFID tags produce unique identifiers, even tags that keep data with cryptographic algorisms. In consequence, an individual implanting an RFID tag successfully begins transmission through radio wave with a personal unique ID to close readers, as long as involving the tagged vehicle for secret tracking. Such tracking is possible likely even if a fixed tag serial number is casual and holds no inherent data. The thrill of privacy raises when a tag serial number is combined with personal information (Juels, 2005).

2.7.4 Vehicle Theft Detection

Today's biggest problem which is not solved by any system that is the stolen vehicle problem for that case the stolen or the theft vehicle is the biggest issue. In Ethiopia, the stolen vehicle rate is increasing day by day and police crime investigation division doesn't find the stolen vehicle easily hence more time taken to find the stolen vehicle and robber. (Bhore & Agre, 2017) presented the automated system avoids vehicles stolen and indicates where the location providing security as anyone can utilize RFID. For security purposes also RFID can be used.

Kodavati et al. (2011), in his scientific research, he concluded by saying that vehicle tracking system is necessary to prevent any vehicle theft and also allows to remotely control a vehicle only by a text message. All vehicle information that passing the toll booth is stored in a database for future reference. It also consists of stolen vehicle directory if that matches the incoming vehicle then and the message will send to a registered police station (Amol & Nawgaje, 2015).

2.7.5 Tracking Over Speeding

In the developed countries road facilities are a major concern. Current studies show that one-third of the amount of deadly or serious accidents are associated with over speeding, as well as changes in the roadway (like the presence of roadwork or unexpected obstacles). A decrease in the number of accidents and extenuation of their significances is a great concern for road traffic authorities, automotive manufacturing, and transportation investigation clusters (Amol & Nawgaje, 2015).

Radio Frequency Identification (RFID) tags are small transponders that reply to interrogations from an antenna by wirelessly communicating a serial number or similar identifiers. They are seriously used to trail items in manufacturing surroundings and to tag things in supermarkets.

They are typically assumed as an advanced barcode. However, their possible area of use is much larger (Gurjot et al., 2012).

Singh & Teja (2013) introduced a vehicle alerting speed limit and crash detection system. The study presents a system that uses Micro-Electro-Mechanical Systems (MEMS), Radio Frequency (RF), GSM, and GPS technology. The main objective of the study was to introduce the design of a smart display controller that is designed in a way to suit the car's dashboard and present with the alarms of approaching crash and speed limit.

Al-shabibi (2019) introduced an automobile speed violation detection system using radiofrequency and GSM technologies. The system built with two radio frequency readers along with a passive radio frequency tag that is attached to the vehicle via PIC 18f45k22 and the GSM module is used to inform the current vehicle condition to the vehicle's owner and police station through Short Message Service (SMS). Furthermore, a picture of a vehicle is taken via the camera and a fine is charged when the speed limit is exceeded.

Thomas et al. (2014) proposed an automatic speed control of vehicles using radiofrequency. In this research, the speed of vehicles can be controlled within a certain limit in restricted zones without interruption of the drivers. The RFID tags are posted at the regions and the antenna is attached to the vehicle. The coded signal has sent from the tag when the antenna closes to the surrounding. Whenever the vehicles arrive into these regions their receivers will receive this code and the speed of the vehicles is controlled automatically with the help of the microcontroller unit present inside the vehicle. The tags are placed at the beginning and the end of the regions for which the speed should be reduced.

Hafeez et al. (2015) designed and implemented a smart vehicle speed monitoring system-using radio frequency where the monitoring system stations are placed on different locations. Each car has its RFID tag and each station through RFID and cameras system is saving the information of vehicles like vehicle identity, a time when it is crossing, speed, pictures, etc. The RFID reader will save information for all these vehicles, which are passing through this RFID reader. Every station is connected to the main database station, which is collecting data from all these stations.

Car over speed checking system using RFID module including reader and tag is another type of application that is utilized on vehicles (Ilyas, 2008). This is achieved with the help of two readers positioned at a distance. Each car has its RFID tag, the monitoring system stations are placed at different locations. The RFID reader saves the information of the car such as the time it is crossing, speed and displays the information on the LCD. The minimum time it will take the car to pass the two readers, have already been calculated with the help of the specified speed and the distance. Using the Arduino Uno (Monk, 2013), if it takes any car lesser time to pass the specified time, it indicates over speeding.

If the vehicle travels above the prearranged speed limit the new system will track with 100 % accuracy. In the research paper of (Hafeez et al., 2015) it is suggested that RFID can be used other purposes like managing database of vehicles speed, locations, car identity, etc. the main objective of this RFID is particularly using in access control, a navigation system, human identification, managing database, and lot more areas. The authors have discussed one of the possible ways of RFID based system which can manage database and generate traffic fine for the vehicles violating speed limits all plazas are expected to equipped with an RFID reader, speed checking camera, and snap camera. The monitoring system stations are placed on exit and entry points respectively. In each station through RFID reader and cameras system is saving the information of particular vehicle identity, time of vehicle crossing, speed rang, picture of the vehicle color effectively. This intelligent system can be implemented especially for speed monitoring of vehicles, also to identify the last location of vehicle and status of vehicle how to monitor the speed of vehicles using RFIDs and how to take necessary action like fining based on over speeding and violation of road sign rules.

2.7.6 Pollution in an Environment

On the manual toll booths, the vehicles are getting congested into multiple queues and the driver of the vehicle will not turn off the engine and the carbon-di-oxide will get outside into the environment for a long time at one place that increases county's air pollution (Kieu et al., 2015). With the number of vehicles increasing every year, the time and fuel wasted on waiting at the toll plaza is ever increasing. An automated toll system used for toll collection without making traffic congestion and waiting in a long queue with the help of RFID techniques (Bhisikar et al., 2017). Due to the long queue and congestion results in toxic gas coming out from the exhaust pipe as shown in Figure 2.8.

Figure 2.8. Toxic gas coming out from vehicles

The main atmospheric contaminants are particulate matter, carbon monoxide, Sulphur dioxide, nitrogenous oxide, and volatile organic compounds. Also, many heavy metals are existing in particulate matter in the air. The particulate matter in the air is a compound mixture of organic and inorganic elements ranging from sea salt and soil atoms to dust particles produced by burning fossil fuel. Particulate matter from the combustion can be emitted directly in the form of elemental and organic carbon, or it can form in the atmosphere form other contaminants.

Carbon monoxide (CO) is an odorless, colorless gas that comes about because of incomplete combustion. Sulfur dioxide (SO_2) is a colorless gas that occurs because of the presence of Sulphur in the fuel (diesel). The most important nitrogenous oxides are nitric oxide (NO) and nitrogen dioxide (NO_2). NO_2 absorbs light in the visible range which lessens visibility.

2.7.7 Wastage of the Paper

The existing system is the manual system, in that the payment of the toll tax is by hand and after the payment, the toll admin gives one paper receipts to the driver by this the paper wastage get an increase (Priya, 2017).

2.8 Why RFID

Passive RFID, besides satisfying the functional requirements for transmit greater amounts of data at much faster rates than the loop system, and is the cheapest solution available in the local market. It is also a reliable, tested solution, despite being a relatively new technology. It is extremely simple to use and administer, requiring no actions on the part of the user (the sticker itself can be stuck on the vehicle by the auto vendor or maybe the manufacturer). It should be emphasized that the most persuasive reason in favor of passive tags is the cost and low maintenance, and requires no battery replacement or any other action on part of the user.

Summary of literature review: based on a **s**ubsequent deep study on the related scientific analysis of the researches mainly focused on the detection, the classification, and the technique of controlling things using RFID and microcontroller is reviewed. Besides this to bring a fast and safe transportation system in the country, the way of increasing service capacity, efficiency, and trustworthiness, and fuel consumption for measured results of queue length both on the ETC system and the manual system are carefully considered into account.

Research gap: in fact, applying an RFID to automate the toll system was a recent technology around Europe and the USA. To detect a particular vehicle the antenna was set above on transom or it might be posted on the roadside (pavement). And the RFID tag has adhere to the windshield at the onboard unit (OBU). Hence, the system required an active radio frequency rather than passive radio frequency to detect vehicles from a far distance.

On both the manual and automated toll road, the minimum speed limit near a toll plaza was not stated and the required international roadside traffic signs are ignored.

The automated system requires sufficient balance in his/her account. But the most common widely used around Europe and the United States of America is a Postpaid system. Then the client will receive the total service issued charge bill at the end of each month through cellphone or email from the ETC.

From this thesis work, the outcome enables to deliver instant and efficient expressway transaction could take place within a few seconds (not more than 6 seconds) and the system is not yet implemented in Ethiopia as well as in Eastern Africa.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Introduction

To have a complete structure a system 13.56 MHz passive RFID antenna and pairs of RFID tag, microcontroller, GSM module, LCD, SG-90, DPDT Relay, Buzzer, and suitable software were used and explained in detail.

3.2 Materials

To design and develop the proposed automated system the required materials and equipment both hardware and utilized software for this thesis work are briefly explained. Table 3.1 shows the required materials with their specification.

Table 3.1. Materials and specification

No	Item	Unit	specification	Quantity
1	Microcontroller	Pcs	AT Mega 2560	1
2	RFID and Reader Module	Pcs	RC-522 13.56 MHz	1
3	Servo SG-90	Pcs	23×12.2×29mm,1.8kg/cm (4.8V)	1
4	LCD Display	Pcs	16×4	1
5	SIM900A kit	Pcs	version 3.6, 3.3V to 5V	1
6	Buzzer	Pcs	5V	1
7	DPDT Relay Circuit	Pcs	12V	2

3.2.1 Passive RFID

Tags are attached to the vehicle to be identified. The system requires nearly range support of an RFID reader and the tag itself. Some types of tags can be read from quite a few meters from away and beyond the line of sight of the reader. Most passive tags signal by backscattering (deflection of radiation) the transporter wave from the antenna. This means the antenna has to be intended both to accumulate power from the received wave and also convey the outbound backscatter signal. The reply of the passive RFID is not essentially just an ID no; the tag memory chip holds nonvolatile data, possibly writable for storing data. The selected passive RFID tags do not have any power source and hence they have an indistinct operational life span. The power required for working is taken from the antenna when the tag comes in the area of the reader or antenna. Tags are available in a variety of sizes ranging from sizes that can fit into an adhesive label. The passive RFID is made up of three parts: Antenna which is in charge of taking the energy and transferring the tag ID, Semiconductor chip attached to the antenna, and encapsulation which keeps the tag integrity. The encapsulation keeps the antenna and chip from severe weather conditions. These encapsulations can be made up of small glass vial or from a laminar plastic substrate with adhesive on one side so that it can be easily attached to the goods. Tags either may be read-only, having a factory-assigned unique serial number that is used as a crucial into a database or maybe read/write where the object precise data can be written into the tag by the system user. Figure 3.1 Passive RFID module and tags are shown below.

Figure 3.1. Passive RFID antenna and tags

3.2.2 Transponder (Antenna)

A transponder is generally known as RFID tags stores the data according to the application and are available in a variety of shapes and sizes according to the application. Often, the system consists of a slight RF transmitter and receiver. The reader transmits a programmed wireless signal to interrogate the tag. The tag receives the inquiry and then responds with its unique identification information. This may be unique tag encryption or maybe vehicle Id no, license plate number, owner’s information, or other detailed data.

The antenna communicates with a tag by sending an encoded radio signal to interrogate the tag. The tag receives a given wave then responds to the embedded message with its identification information. The transponder can detect many different RFID tags at the same time as long as the tags are inside the read range of the antenna. The antenna acts as the sensor as well as the interface between RFID transponders and Information Processing System (IPS).

The three types of antenna/transponders are categorized as follows: Type I is (ready only) which means all the data are read from the tag status (lost, valid, etc.), Type II is (both read/write) means allows the information to be retrieved from or written onto the tag, Type III (both read/write with an interface to display device or an onboard computer, also called a smart transponder) are capable of two-way communication between the onboard unit (OBU) and the roadside antenna. The onboard unit consists of a smart card, smart card reader, and transponder. The smart card which has a microprocessor chip embedded in the wafer-thin plastic varies in memory size and computing power. All smart cards can process data and store the required information. In this thesis work read/write type II antenna has been selected.

3.2.3 LCD

It is called (Liquid Crystal Display). The 16×4 (A 16×4 LCD means it can display 16 characters per line and there are 4 such lines with 5×8-pixel matrix characters) LCD used to display the present information of all in the system generated data which is coming from the controller unit. LCD provides an interactive user interface and the unit requires +5V DC to operate properly. The power condition is characteristically in the order of microwatts for the LCD because it is a low power device. However, it might an external or internal light source. It is limited to a temperature range of about 0 to 60^0 C and the response time in the range of 100 to 300ms. The lifetime is steadily increasing beyond 10000+hours limited and the color generated by the LCD is dependent on the source illumination. The following Figure 3.2 and Figure 3.3 LCD Screen and Pin diagram of LCD are shown below.

Figure 3.2. LCD Screen

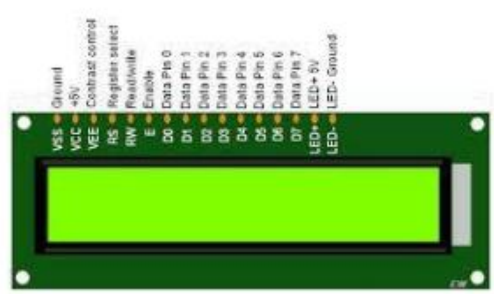

Figure 3.3. Pin diagram of LCD

3.2.4 ATMEGA 2560 Microcontroller

The major heart of the system is a microcontroller. ATmega is a microcontroller board based and an open-source programmable circuit board that can be integrated into both simple and complex. Entirely it has 54 digital input/output pins including 14 pins used as PWM outputs, 16 analog inputs, 4 hardware serial ports, 16-MHz crystal oscillators, a USB connection, a power jack, an In-Circuit Serial Programming (ICSP) header, and a reset button. By receiving input from various sensors and can interact with a large collection of outputs such as LEDs, motors, and displays. Because of having 256 KB of flash memory for storing code, flexibility, and low cost, the device has become a very popular choice looking to create interactive hardware developments. The programing of an ATmega 2560 can be done with the help of the Integrated Development Environment (IDE) and supports C-programming language. Figure 3.4 shows an ART Microcontroller below.

The board can work properly plugged in with a recommended range of 7 to 12 volts. The power pins are as follows:

> **VIN**= the input voltage to the ATmega board when it's using an external power source.
>
> **5V**= the regulated power supply used to power the microcontroller and other components on the board.
>
> **3.3V**= a 3.3-volt (50mA current) supply generated by the on-board regulator.
>
> **GND**= ground pins.

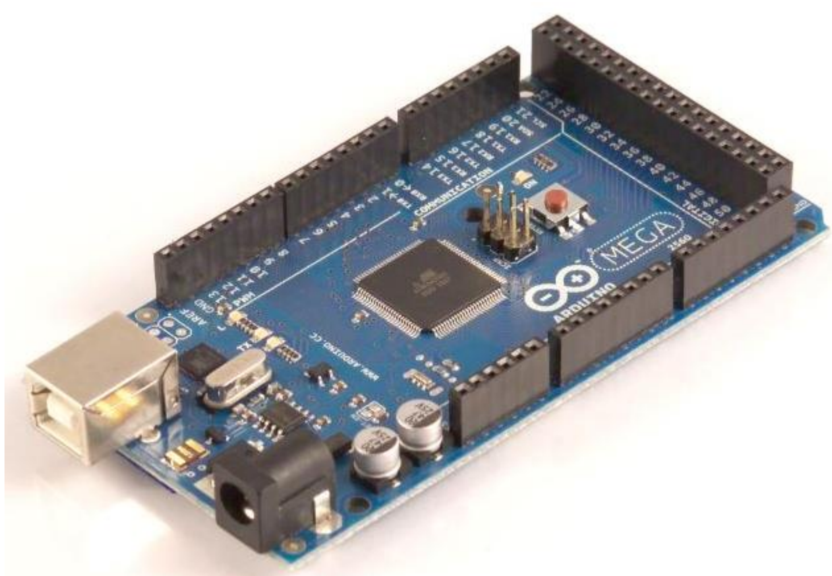

Figure 3.4. ART Microcontroller

3.2.5 Servo SG-90

The name used servo the motor rotates through a fixed angle step in response to each input current pulse received by its controller. Servo motors have an angle range of 0° to 180° and controlled through a computer, microprocessor, and programmable controllers by sending a pulse of variable width. The parameters for this pulse are that it has a minimum pulse, a maximum pulse, and a repetition rate. To control the speed of the servo, the switches are open and close at different rates to apply average voltages across the motor. The angle is determined by the duration of a pulse that is applied to the control wire. This is called pulse width modulation. The servo expects to see a pulse every 20ms. The length of the pulse will determine how far the motor turns. Given the rotation constraints of the servo, neutral is defined to be the position where the servo has the same amount of potential rotation in the clockwise direction as it does in the counter-clockwise direction.

It is important to note that different servos will have different constraints on their rotation but they all have a neutral position, and that position is always around 1.5 milliseconds (ms) pulse will make the motor turn to the 90-degree position (neutral position). When a command pulse received each time the output shaft rotates in a series of discrete angular intervals. When the number of pulses supplied is definite then the shaft of the servo motor turns through a definite known angle. Due to this the servo motor is suitable for open-loop position control because no feedback needs to be taken from the shaft. The only moving part through a servo motor is a rotor, which is brushless and has no commutator, and windings. This feature makes it quit, strong and consistent. A servo motor is a motor that forms part of a servomechanism which converts electrical energy into mechanical energy. It is possible to achieve very low-speed synchronous rotation with a load that is directly coupled to the shaft. Figure 3.5 SG 90 Servo is shown below.

Figure 3.5. SG 90 Servo

3.2.6 GSM

GSM stands for Global System for Mobile communication (GSM) originally from Groupe Special Mobile the most popular standard for mobile phones in the world. It is also pioneered to a low-cost alternative to short text messages which is now supported on all mobile standards and it supports voice call and data transfer speeds of up to 9.6 kbps together. The idea of GSM was developed at Bell Laboratories in 1970. It is a widely used mobile communication system in the world. GSM is an open and digital cellular technology used for transmitting mobile voice and data services operate either 900 MHz or 1800 MHz frequency bands. GSM system was developed as a digital system using Time Division Multiple Access (TDMA) technique for communication purposes.

A GSM digitizes and reduces the data, then sends it down through a channel with two different streams of client data, each in its particular time slot. The digital system can carry 64 kbps to 120 Mbps of data rates. There are various cell sizes in a GSM system such as macro, micro, Pico, and umbrella cells. Each cell varies as per the implementation domain. There are five different cell sizes in a GSM network macro, micro, Pico, and umbrella cells. The coverage area of each cell varies according to the implementation environment. Figure 3.6 GSM module with antenna is shown below.

Figure 3.6. GSM module

3.2.7 DPDT Relay Circuit

DPDT stands for the double-pole double-throw relay which is an electromagnetic device used to separate two circuits electrically and connect them magnetically. They are often used to interface an electronic circuit, which works at a low voltage to an electrical circuit that works at a high voltage. Figure 3.7 DPDT Relay is shown below.

Figure 3.7. DPDT Relay

3.2.8 Buzzer

A buzzer is an integrated structure of electronic messages ringers, DC voltage power supply, bare widely used in computers, printers, copiers, alarm, electronic toys, automobile electronic equipment, telephones, timers, and other electronic products for hair sound device. Figure 3.8 Buzzer is shown below.

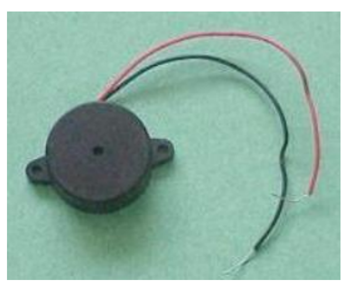

Figure 3.8. Buzzer

3.2.9 LED

LED is the acronym for “Light Emitting Diode”. LEDs are semiconductor devices that produce light. These were initially used as indicator lights but are now used extensively for indoor and outdoor lighting. In the simplest terms, a light-emitting diode (LED) is a semiconductor device that emits light when an electric current is passed through it. Light is produced when the particles that carry the current (known as electrons and holes) combine within the semiconductor material. Figure 3.9 LED lamp is shown.

Figure 3.9. LED lamps

3.2.10 Jumper Wires

Jumper wires are simply a wire that has connector pins at each end, allowing them to be used to connect two points without soldering. Jumper wires are typically used with breadboards and other prototyping tools to make it easy to change a circuit as needed. Figure 3.10 Jumper wires are shown.

Figure 3.10. Jumper wires

3.3 Software

The microcontroller was programmed using the C programing language. The software used to design and develop the automated vehicle detection and toll system using RFID is described below.

3.3.1 Arduino IDE

The Arduino Integrated Development Environment (IDE) is a cross-platform application for the various operating system that is written in functions from C language. The software allows programmers to combine the different features of writing a computer program and used to write and upload programs to Arduino compatible boards. The Arduino IDE supports the languages

C and C++ using special rules of code structuring. The Arduino IDE supplies a software library from the wiring project, which provides many common input and output procedures. An IDE allows developers to start programming new applications quickly because multiple utilities don’t need to be manually configured and integrated as part of the setup process. The features such as to save time, to organize the workflow, and solve problems.

The Arduino IDE employs the program avrdude to convert the executable code into a text file in a hexadecimal encoding that is loaded into the Arduino board by a loader program in the board's firmware. By default, avrdude is used as the uploading tool to flash the user code onto official Arduino boards. Arduino IDE is a coding software that makes the programming world more accessible to beginners with its simple interface and community-driven system. However, Arduino IDE makes coding so much simpler for beginners. It is, in essence, a text processor with programming-specific functions.

3.3.2 Embedded C Program

C is a general-purpose, procedural computer programming language supporting structured programming, lexical variable scope, and recursion, while a static type system prevents unintended operations. By design, C provides constructs that map efficiently to typical machine instructions and has found lasting use in applications previously coded in assembly language. Such applications include operating systems and various application software for computers, from supercomputers to embedded systems.

C language was designed to be compiled using a relatively straightforward compiler to provide low-level access to memory and language constructs that map efficiently to machine instructions, all with minimal runtime support. Even with its low-level proficiencies, the communication was intended to inspire cross-platform program design. The ideals yielding C program written with portability in mind can be organized for a wide diversity of computer platforms and working principle with few changes to its basic code.

The language is existing in numerous types of stages, from embedded microcontrollers to supercomputers.

3.4 Method

3.4.1 Tollgate Location

This study was carried out at Addis Abeba to Adama Expressway which the country's first high way is situated in North West Shewa, Oromia, Ethiopia, its geographical coordinates are 9° 41' 0" North, 38° 40' 0" East near to Addis Abeba, Ethiopia. Figure 3.11 shows the satellite location of Addis to Adama Expressway.

Figure 3.11. The satellite location of the expressway from Tulu Dimtu to Adama

3.4.2 Research Approach

This study assumed both qualitative and quantitative approaches. The qualitative research method is valued to study as interviews with tollgate officers, system administrators, and authorized personnel at Ethiopian Toll Road Enterprise about the existing system in words and analyzed through interpretations and categorization.

The quantitative method is a process of collecting and analyzing numerical data. It can be used to find patterns and averages, make to organize results of the number of vehicles that pass through the toll plaza (per hour, per a day, per month), the time delay during a transaction and to calculate the toll capacity and queue length of the vehicles per lane in numbers and graphs, and analyzed through statistical methods of the populations.

3.4.3 Preparation and Data Collection

Data collection is a systematic process of gathering relevant observations and measurements. The quantitative data collection consisted both of primary and secondary survey data. The primary data namely the number of vehicles pass the gate per year, toll information, and usage (surveyed both telephones based and internet-based) obtained from the main office system administration officer at Ethiopian Toll Road Enterprise, Tulu Dimtu. Whereas the secondary data were obtained from direct field observation measurements. The importance of the research design stems from its role as a critical link between the theory and argument that inform the research and the empirical data collected (Seem et al., 1988).

3.4.4 Sampling Technique

To draw a valid conclusion from the result, the type of sample technique used in this thesis work is a probability sampling method of simple random sampling. The technique which involves the random selection of all kind vehicles has an equal chance to make a statically inferences about the whole field survey.

Simple Random Sampling- in this type every member of the population has an equal chance of being selected including the whole population means (all types of vehicles are considered equally).

3.4.5 Sample Size

600 various types of vehicles together with from small automobiles to heavy-duty vehicles at both gasoline and diesel vehicles are observed and measured their transaction delay time at each tollgate. All these samples are collected on daytime at several hours a day (3:00 to 10:00) Monday to Friday.

3.4.6 Methods of Data Analysis

The best technique recommended for an overview interpretation of the data is descriptive techniques. Because it aims to accurately and systematically describe a population situation or phenomena.

3.4.6.1 Vehicle Arrival Times

Observation of arrival times was performed by counting the number of vehicles that enters to the tollgate at a certain time point. All the existing tollgates are selected for each of the field surveys operated by a different operator at different times. The first step was to determine the point of the longest tollgate having nine-lane boundaries, where the speed of the vehicles was still constant when they entered to the tollgate. The next step was to count the number of vehicles every 5 minutes.

3.4.6.2 Average Transaction Time Delay

The transaction time of each vehicle incoming the booth was recorded using a stopwatch. A total number of 600 vehicles at all tollgates were surveyed in this study, mainly at Tulu Dimtu Main Toll Plaza. The transaction time started from the time of the driver provided the toll payment, followed by the time the toll operator received the money and ended at the time the driver got out to receive the change and/or receipt. The average transaction time at the toll plaza was 29.8 seconds. The following Table 3.2 illustrated the total time transaction and delay time at the main toll plaza.

Table 3.2. The average transaction delay time (second)

Tulu Dimtu Main Toll Plaza Total Average Transaction							
Tollgates	**Toll gate 1**	**Toll gate 2**	**Toll gate 3**	**Toll gate 4**	**Toll gate 5**	**Toll gate 6**	**Average transaction**
Average Trans	29.478	30.2004	30.5251	30.3252	28.3546	29.4269	29.8
No of vehicles	100	100	100	100	100	100	

3.4.6.3 Collected Data Adequacy

The required number of vehicles was calculated based on the degree of accuracy and the level of confidence. For each six tollgate's 100 vehicles were surveyed respectively. The test was performed using the following formula (Rouphail et al., 2001).

$$N' = \left[\frac{40\sqrt{N\Sigma \times j^2 - [\Sigma xj]^2}}{\Sigma xj}\right]^2 \quad (1)$$

Where:

N'= Number of measurements required

N = Number of observations

X_j= Simulation variables

The sample test calculation at Tulu Dimtu Main Plaza on five tollgates as follows;

$$N' = \left[\frac{40\sqrt{600(29.478^2 + \cdots + 29.4269^2) - (29.478 + \cdots + 29.4269)^2}}{(29.478 + 30.2004 + \cdots + 29.4269)}\right]2$$

$$N' = 398.19$$

$$N' = \frac{398.19}{600} \times 100 = 66.4\ \%$$

$\therefore$ the collected data are sufficient

However, if the sample size is too small, one may not be able to detect a significant present consequence, whereas samples that are too large may waste time, resources, and money. Hence, it is necessary to optimize the sample size. Moreover, calculating the sample size in the design phase of the study is gradually becoming a prerequisite when looking for ethical board approval for a research project (Noordzij et al., 2010).

3.4.6.4 Data Analysis

The descriptive technique is a better technique for this thesis for an overview interpretation of the data. Descriptive technique statistically is the mode. Then, the model refers to the most frequently occurring value in the data set to provide a general overview of the variables being studied (Oates, 2006). The obtained data were analyzed to determine the length of the queue and the capacity of the gate based on a fixed arrival level (λ) at various service times (μ) for the payment systems at the existing (manual) system. The work program and the analysis diagram are shown in Figure 3.11 given below.

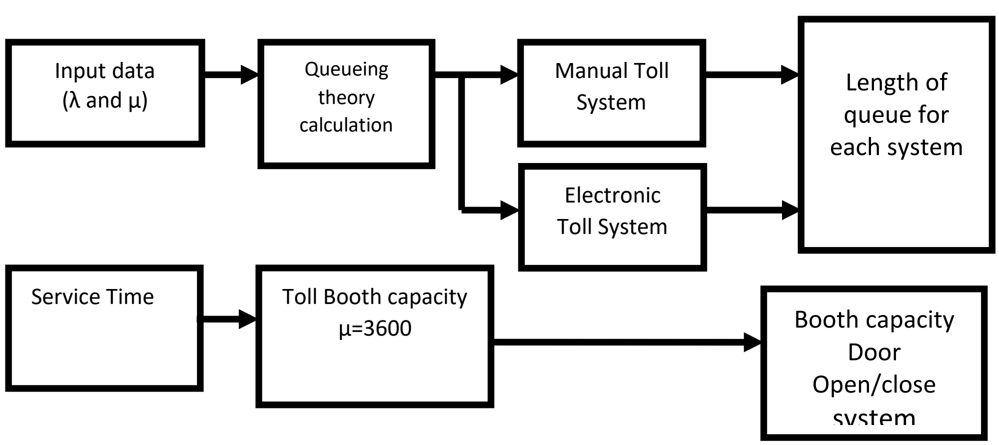

Figure 3.12. Work and analysis diagram

Based on the field surveyed analyzed data obey the Poisson distribution model. To obtain the average transaction time and the service level capacity can be shown in the following formula (Xing et al., 2016):

$$p_r(k) = \frac{(qrt)^k e^{-qrt}}{k!} \tag{2}$$

Where:

$p_r(k)$= the probability of k car arrives within the time interval t;

q_r= the arrival rate of vehicles

t= interval time

The arrival vehicles analyses obtained by the following distribution:

$$p_s(k) = \frac{(a\lambda)^k}{k!} e^{-a\lambda(T-\Delta t)} \qquad k = 0,1,2,3,\ldots \tag{3}$$

3.5 Design Aspects

To design the new system many factors should be considered includes Security, Communication, reliability, and safety issue.

3.5.1 Security

Once the RFID tag delivered to the client, the enterprise has a mislaid regulator over the component and the device must be designed to prevent cause damage. The toll plaza and the external equipment are all subjected to theft and destroy deliberately by oneself. Security at this unit is necessary. One way to increase security is requiring that all the enterprise employee has to use an identification badge.

3.5.2 Communication

Communication between the vehicle tag and the antenna is one of the key system elements. The three-communication links: between toll lane and tollbooth, between tollbooths, and between tollbooths and the host computer. The link needs to utilize easy-to-install equipment that operates through all vehicles and under all weather conditions. The communication link must be secure and dependable. The vehicle code is transmitted through RFID communication between the vehicle and the toll plaza. An RFID module, in combination with a modem, is used to transmit and receives electromagnetic signals (Sharma et al., 2016).

3.5.3 Safety

Safety is a very important issue. Retrofitting existing system, where automated and the manual toll is to be placed contagiously, is usually more difficult, safety-wise than building a new infrastructure that separates the two different payment methods.

3.5.4 General Observation

The working condition plays a very vital role while designing and realizing the RFID applications. Metal substances (metal-foil wrappers) and wide-range electrical noise in the area of tags, extreme working temperatures, the existence of fluids, and physical obstacles can extremely disturb the performance of the system. To have a better and reliable system the surrounding area must be a "clear zone" rather than obstructed.

3.6 Tests and Results for System Design Modules

1. Automatic Vehicle Identification and Classification System
2. Violation Enforcement System and Theft Identification

3.6.1 Automated Vehicle Identification and Classification System

In this section, to identify and classify the arrival vehicle authenticated by a microcontroller. In the detection process, the detectable connection is the basic speed measurement unit. The length of the detectable link is determined by the detection range.

Whenever any person buys a vehicle, the first thing to be done is to get his or her vehicle registered at the Road Traffic Authority (RTA) office. RTA officials will not only dispense a number plate to it but also will give an RFID enabled tag. This card will have a unique ID feasible to use with that vehicle only. The vehicle owners can also create an account for the use of that particular embedded tag and maintain transaction history in the database. All registered user is expected to deposit some minimum amount to their account. Every time a registered vehicle approaches the toll booth, first, the infrared sensors will detect the presence of the vehicle. It will, in turn, activate the radio frequency circuit to read the radio frequency enable tag fixed on the rear-windshield of the vehicle. The transaction will begin; depending upon the balance available toll will be deducted directly from the user's account. The software further updates the details in the centralized database server. It also triggers a mechanism to generate the bill and will be sent to the user as a text message.

3.6.2 System Design of Automatic Vehicle Detection

The designed system using RFID was classified into two modules i.e. the vehicle module which is consisted of a passive RFID tag and the base module consisted of the host computer, the radio frequency reader, the system, and the gate control system. The detection system set its basis on the communication between vehicle-embedded tags and roadside readers:

- Every vehicle will tag with RFID Tag. Whenever the vehicle reaches the coverage area of RFID receiver detects tagged vehicle through radio frequency signals with the help of sensors and the data are then forward to microcontroller situated at the toll station.
- Then all the data corresponding to that particular vehicle will be sent to the database. Microcontroller recognizes the code and data automatically access from a database. At the same time toll payment will also be done.
- If the vehicle has its correct data and valid prepaid account at the toll station, the appropriate toll is deducted from that account and the gate will open to allow the vehicle to pass.
- If the vehicle doesn’t have a correct data and insufficient prepaid account or it is not a daily traveler, alerts are buzz to warn and it will have to pass through a manual check post which will be in another lane.
- The front-end LCD will display the details of the vehicle owner’s account on the screen information such as Owners/Drivers Name, Vehicle ID and License Plate number, Date, Time, and complete description of the owner’s account which is stored in a database. Simultaneously a text message will be sent to the owner of the vehicle.
- As long as the RFID tag information is correct and if the account balance is sufficient, the tollgate barrier will open to pass the vehicle easily.

The general RFID base toll system image in Figure 3.12 and the block diagram of the automatic vehicle detection system is described in Figure 3.13.

Figure 3.13. RFID based automatic vehicle detection

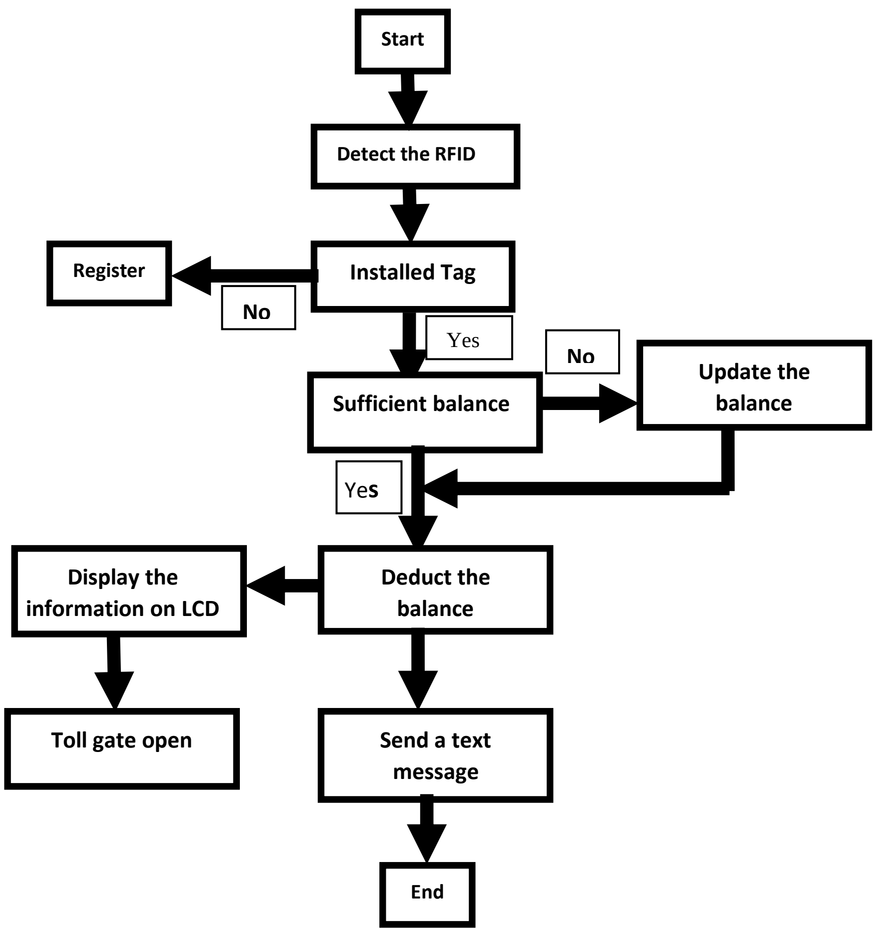

Figure 3.14. Automatic vehicle detection flow chart

3.6.3 Design of Automated Vehicle Identification

- **Antenna and Mounting System: -** Except for tag frequency, the antenna is also a key for effective detection range. Certain kinds of antenna corresponding to the type of adapters. The antennas are mounted over the road and connected to adapters. They are an active part of the detection process.

- **On-site Computing and Data-storing Unit and Local Database Server: -** The on-site calculation and data storage is realized with laptops. The computing and data processing speed of a laptop is fast enough to handle the work. As taken in the real situation, one set of the sensor has a corresponding computing and storing unit. The vehicle's travel information is stored and shared data with other on-site units through the internet on a real-time basis. The calculated and processed performance data (travel time, speed) are archived in the local database server. The following Figure 3.14 the flow chart of the automatic vehicle classification is shown below.

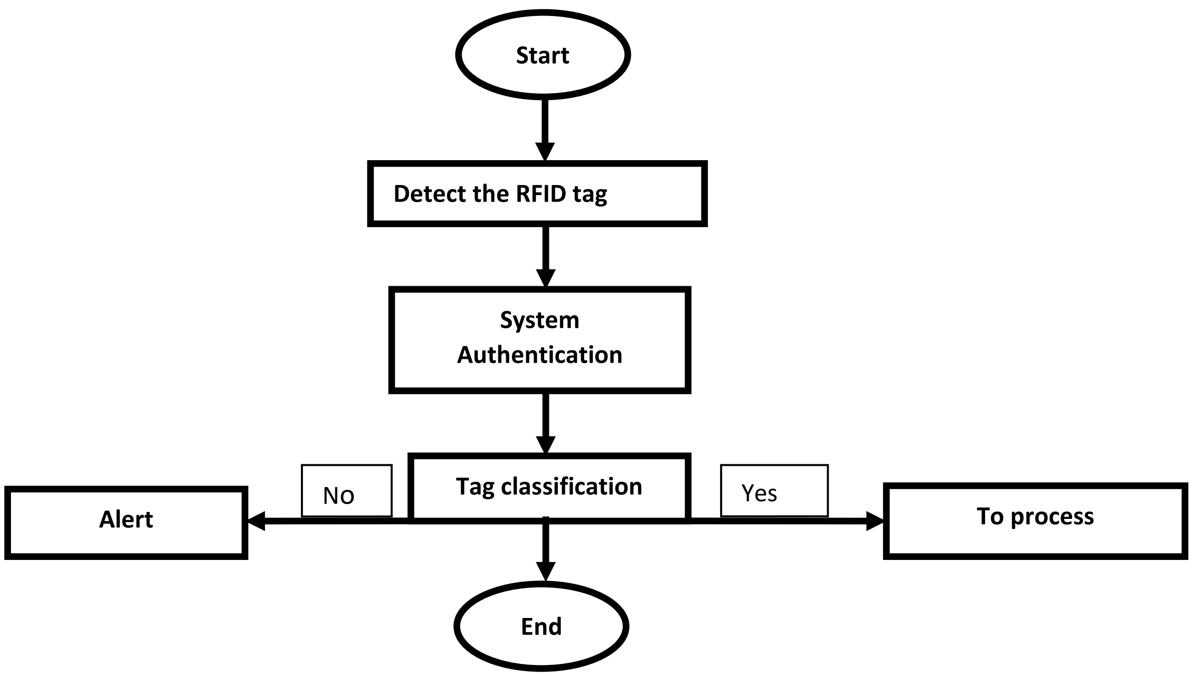

Figure 3.15. The automatic vehicle classification flow chart

3.6.4 Design of Transaction Process

The transaction designs every time a registered vehicle approaches the toll booth, first the Infrared sensors will detect the presence of the vehicle which in turn activates the RFID circuit to read the RFID enable smart card fixed on the windscreen of the vehicle. The transaction will begin, depending upon the balance available toll will be deducted directly or the vehicle will be directed towards another lane to pay tax manually. The software further updates the details in the centralized database server. It also triggers the mechanism to generate the bill and will be sent to the user as a text message.

3.6.5 Design of Violation Enforcement

When used for electronic toll collection, the Video Enforcement System (VES) captures images of the license plates of vehicles that pass through an ETC tollbooth without a valid ETC tag. Although the deployment of these technologies makes the initial cost of installation very high, there exit huge benefits accompanied by such high investment. Figure 3.15 the flow chart of automatic vehicle violation enforcement shown below.

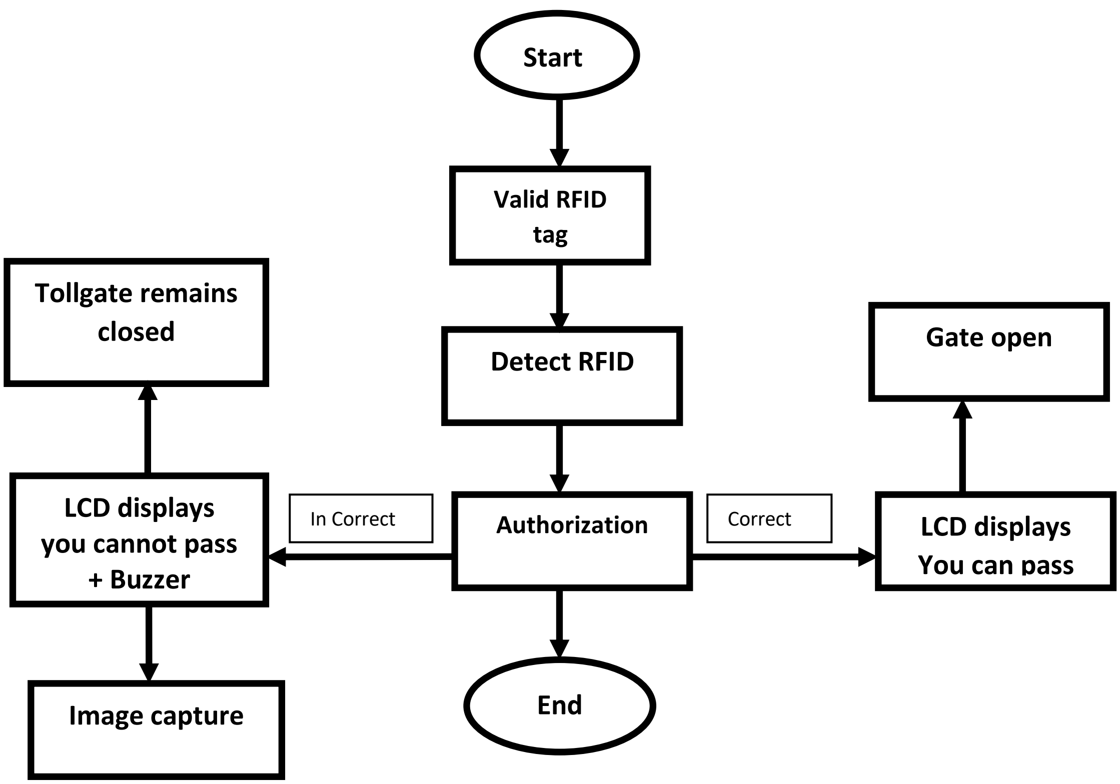

Figure 3.16. Automatic vehicle violation enforcement flow chart

3.6.6 Design of Vehicle Anti-Theft Detection

When a vehicle is stolen the owner might register his complaint to the local Road Traffic Authority (RTA) reached personally with its registration ID and unique RFID tag number.

Whenever any vehicle owner registers a complaint at the RTA office regarding the theft of the vehicle respective entry is made in the database. Now any vehicle arriving at the toll booth with the same ID as already listed in the stolen vehicle category will be easily identified as the ID assigned with its unique then it automatically stops the vehicle.

- A buzzer will be alarm and also SMS is sent to authorize mobile number, registered police station with specifying RFID number using GSM module.
- LCD will display the stolen vehicle is present.

All the toll plazas will be connected along with the centralized server in the form of LAN. Updates of any sort of transaction will be immediately updated to the local database and a centralized server. Figure 3.16 (A) and (B) show the tag installed on the vehicle and Figure 3.17 shows the technique of detection system of complaint vehicle anti-theft from the database.

A)

B)

Figure 3.17. RFID tag installed on the vehicle

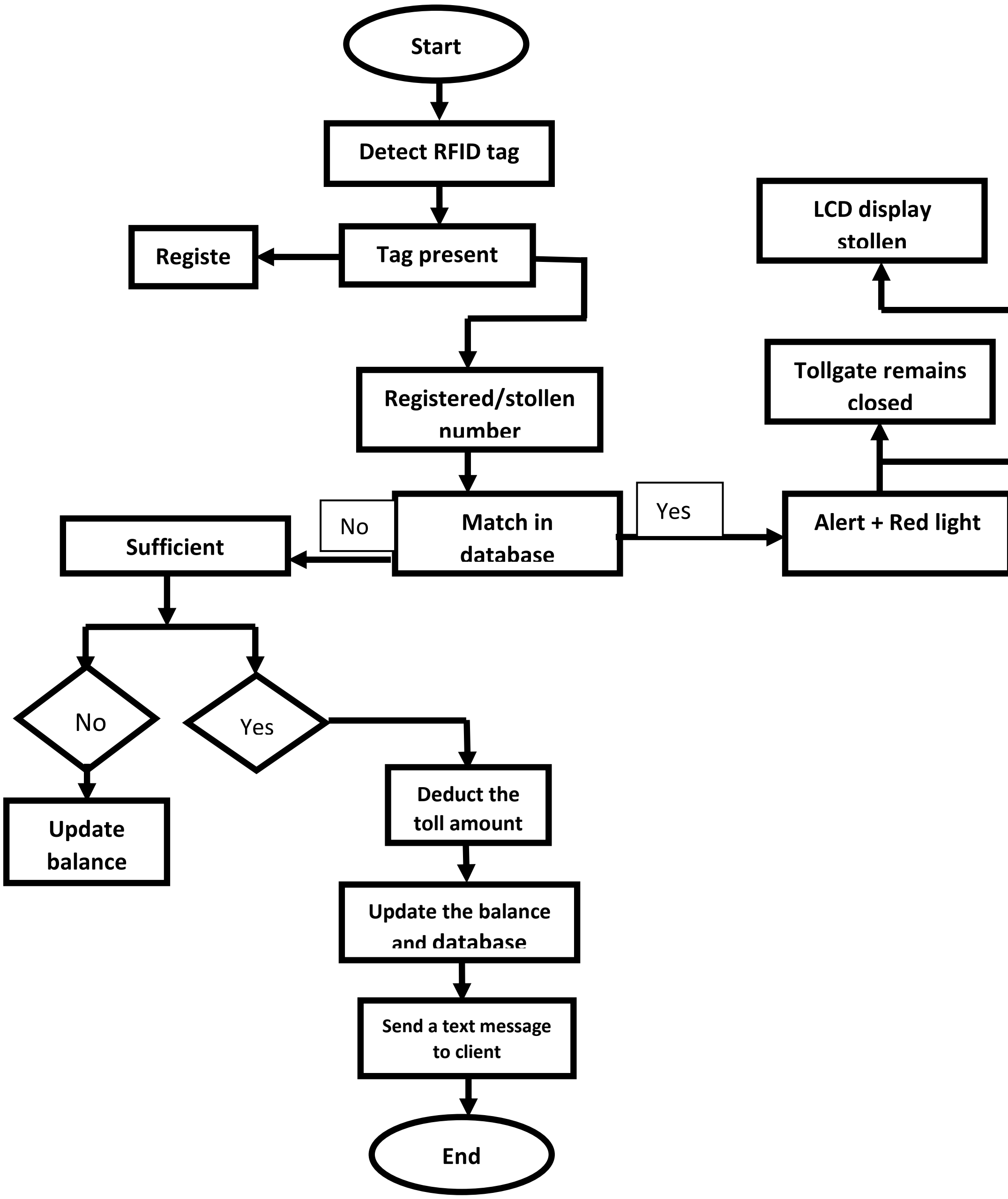

Figure 3.18. Automatic vehicle anti-theft detection

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Introduction to the Design Principles

As per the desired proposal to enhance the automatic vehicle detection and payment system of a low-frequency RFID within a recommended rang and the other components with their correct specification are required. The devices to fulfill the thesis work keep on the correct place and a source voltage for all electronic devices should be regulated accordingly. To control the process of the embedded C language operating system the codes of a program should be written clearly. The vehicle detection experiment with the help of RFID has been done by attached to a real vehicle. Figure 4.1 illustrated the way of detecting a particular vehicle at a given time showed by the flow chart diagram. Whenever the RFID tagged vehicle reaches the RF coverage area and range, the antenna generates an electromagnetic wave then the communication takes place between the vehicle tag and RFID antenna.

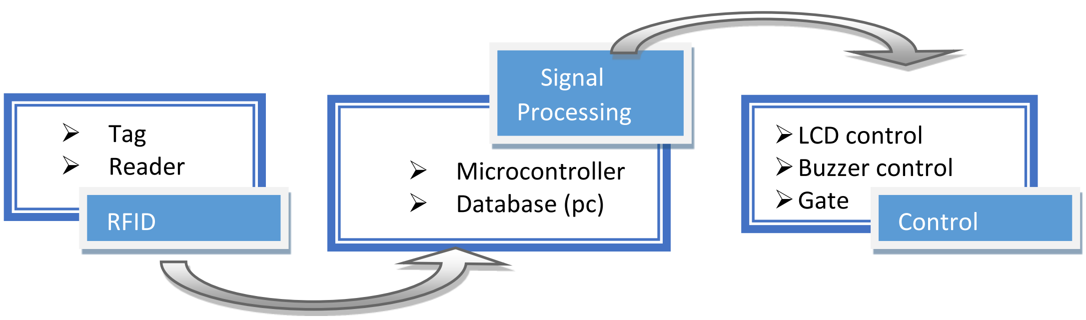

Figure 4.1. Block diagram of automatic vehicle detection

4.2 The Experiment Site and Data Source

4.2.1 Tulu Dimtu Main Tollgate

At Addis Abeba to Adama Expressway (AAE) has 19 entries, of which Adama Main 4 entries and 7 exits, Adama West A 2 entries and 2 exits, Adama B 2 entries and 2 exit from Adama (Nazareth), 3 entries and 3 exits booths from Modjo, 2 entries and 3 exits booths from Dukem, 2 entries and 3 exit booths from Beshoftu (Debrezeyit), Tulu Dimtu 4 entries and 9 exits to Addis Abeba, with one special lane for heavy-duty vehicles and 29 exits vice versa. Figure 4.2 shows the expressway main toll plaza entry at Tulu Dimtu.

Figure 4.2. Tulu Dimtu main toll plaza, Addis Abeba

4.2.2 The Transaction Delay Time (sec)

The Indonesian Highway Capacity Manual (Aly, 1995) defines capacity as the traffic flow to be maintained in a certain highway segment at a certain condition per a certain time of period. For a tollgate, the conditions that can affect tollgate capacity are driver behavior toll tariff, the skill of the toll collector, and the payment or collection mechanism (Golden et al. 1982). Hence, tollgate capacity can be defined as the maximum number of vehicles that can be serviced in a certain period. Tulu Dimtu Toll Plaza, Addis Abeba to Adama Expressway (AAE) calculated tollgate capacity C = 3600/service-time, with service time taken as average 29.8 seconds.

To improve the method of the manual toll transaction system, the calculation of the transaction time and the tollgate capacity should be conducted. This thesis work presents the evaluation of a queueing model and tollgate capacity based on vehicle arrival time and required transaction time.

The following charts are demonstrating an example of the field observation data of the traffic flow and the transaction delay time fluctuation (s) at Tulu Dimtu Main Toll Plaza at Addis Abeba.

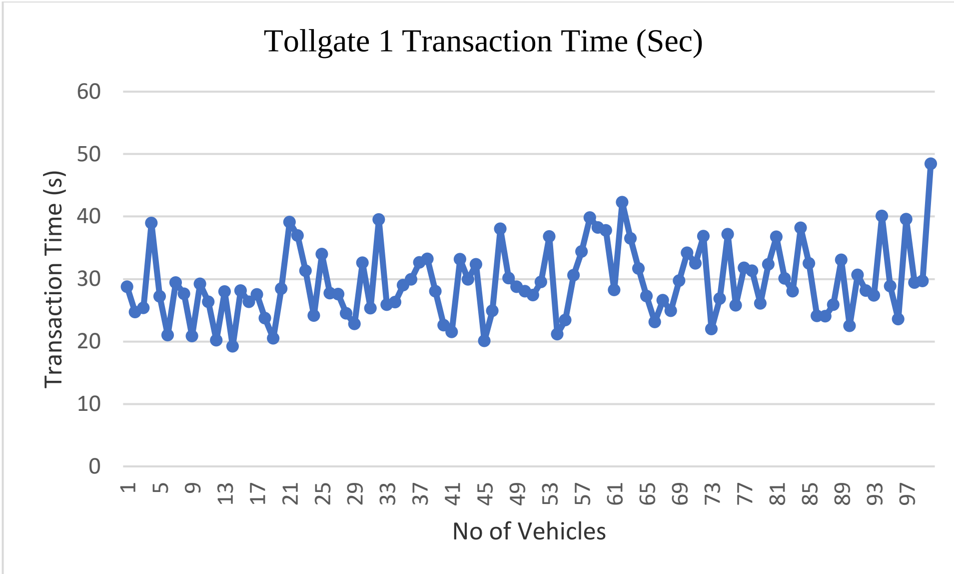

Figure 4.3. Transaction time at Tulu Dimtu Main Toll Plaza toll gate one

In this section, the graph located toll gate one at Tulu Dimtu. A total of 100 vehicles were surveyed for several hours a day (one week). The transaction fluctuation between 19 to 48 seconds. The average transaction is about 29.478 seconds.

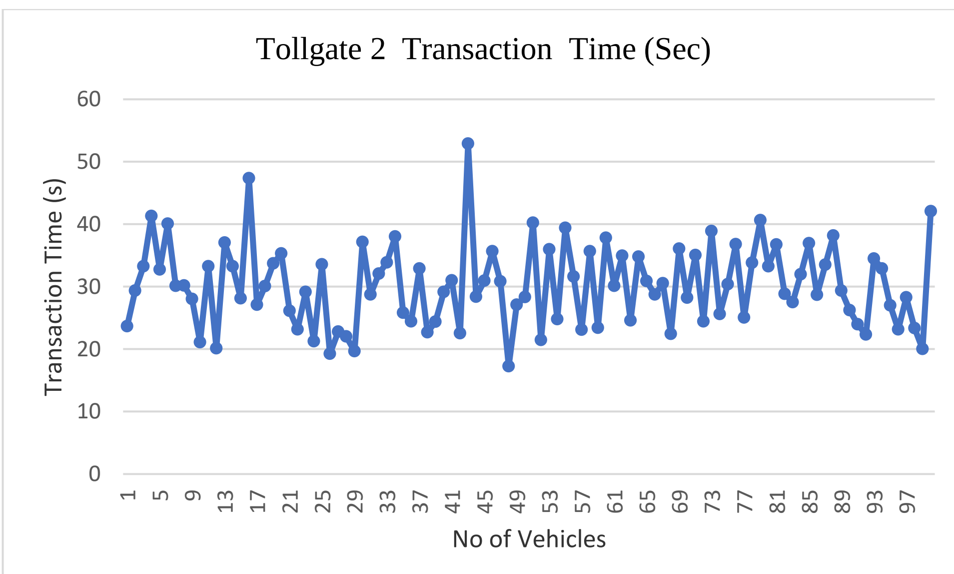

Figure 4.4. Transaction time at Tulu Dimtu Main Toll Plaza toll gate two

In this tollgate the transaction fluctuation approximately between 17 to 52 seconds for 100 vehicles and the average transaction in this gate about 30.2004 seconds.

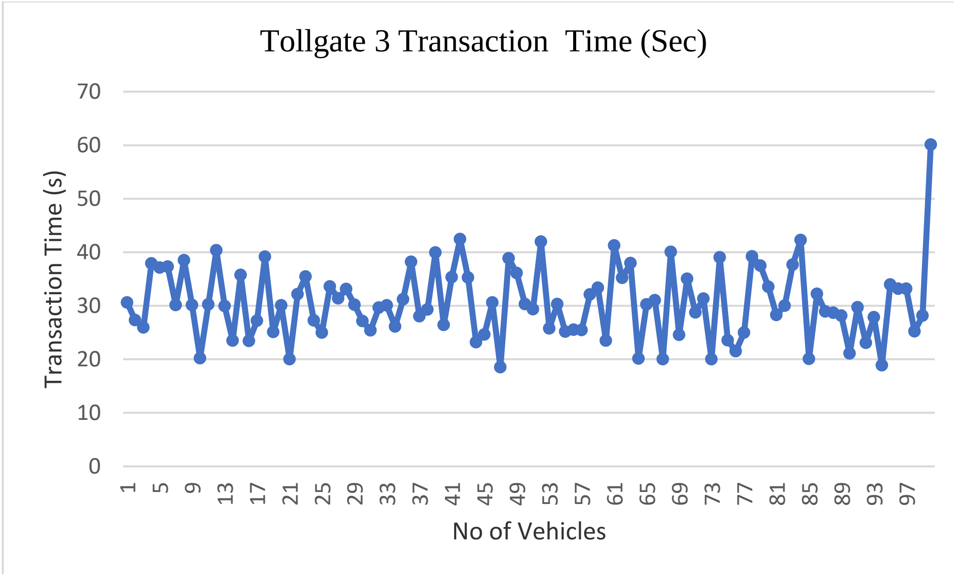

Figure 4.5. Transaction time at Tulu Dimtu Main Toll Plaza toll gate three

In this toll gate the transaction fluctuation between 18 to 60 seconds for 100 vehicles. The average transaction is about 30.5251 seconds.

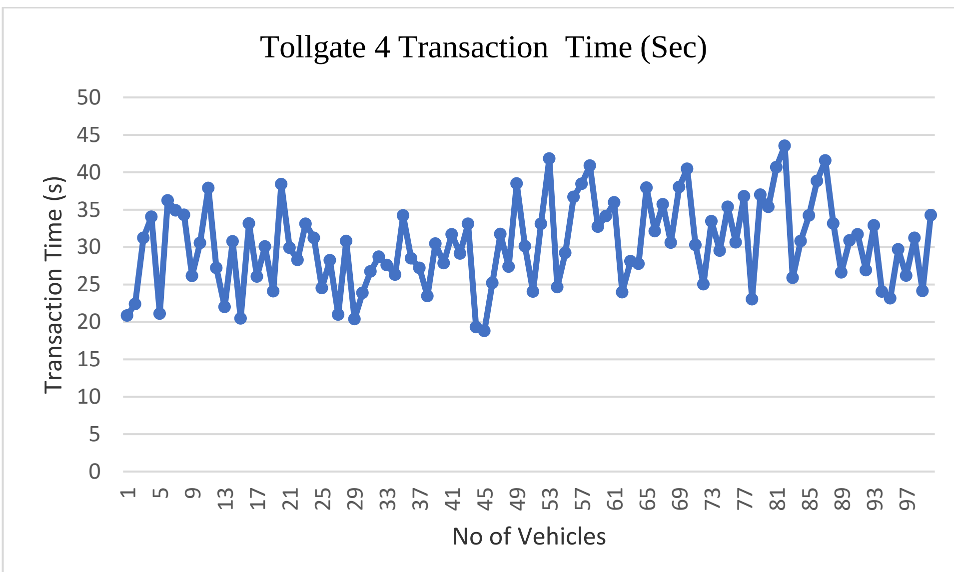

Figure 4.6. Transaction time at Tulu Dimtu Main Toll Plaza toll gate four

The toll gate four transaction fluctuation approximately between 18 to 43 seconds for 100 vehicles and the average transaction in this gate about 30.3252 seconds.

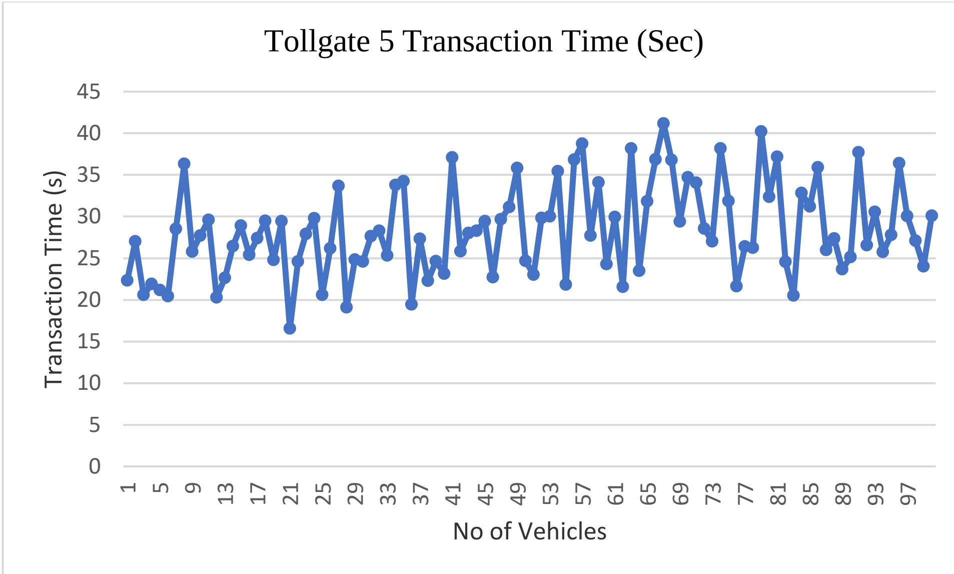

Figure 4.7. Transaction time at Tulu Dimtu Main Toll Plaza toll gate five

In tollgate 5 the transaction fluctuation between 16 to 41 seconds and the average transaction was about 28.3546 seconds.

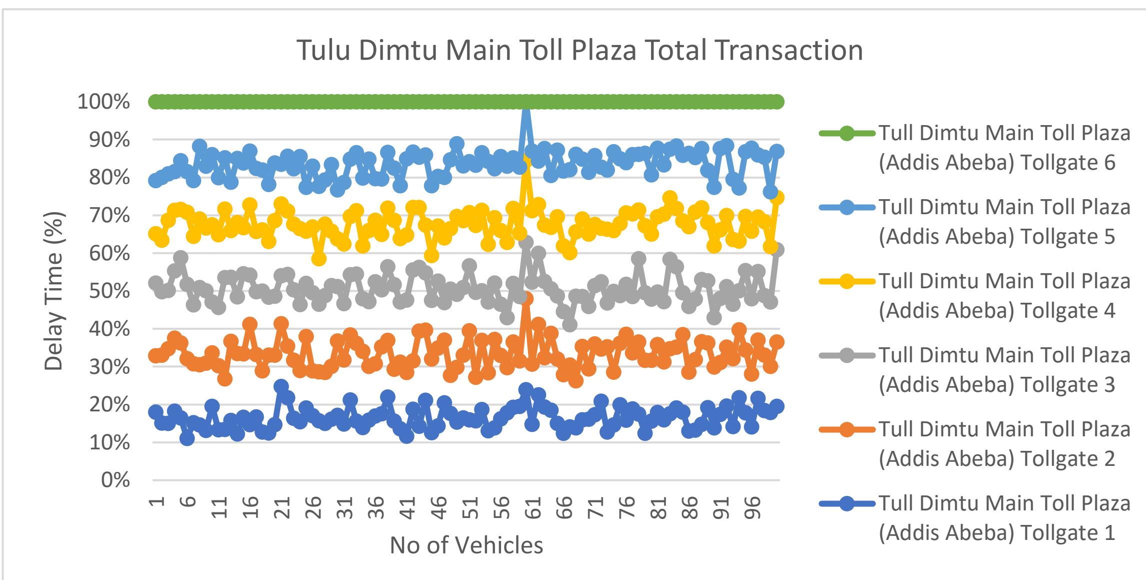

Figure 4.8. Total transaction time at Tulu Dimtu Main Toll Plaza at all tollgate

Figure 4.8 and Figure 4.9 are showing the total transaction at Tulu Dimtu Main Toll Plaza, and the transaction fluctuation was about 16 to 60 seconds on both toll gates for 100 vehicles respectively. A total of 600 vehicles were surveyed for 45 days. The average transaction was about 29.8 seconds.

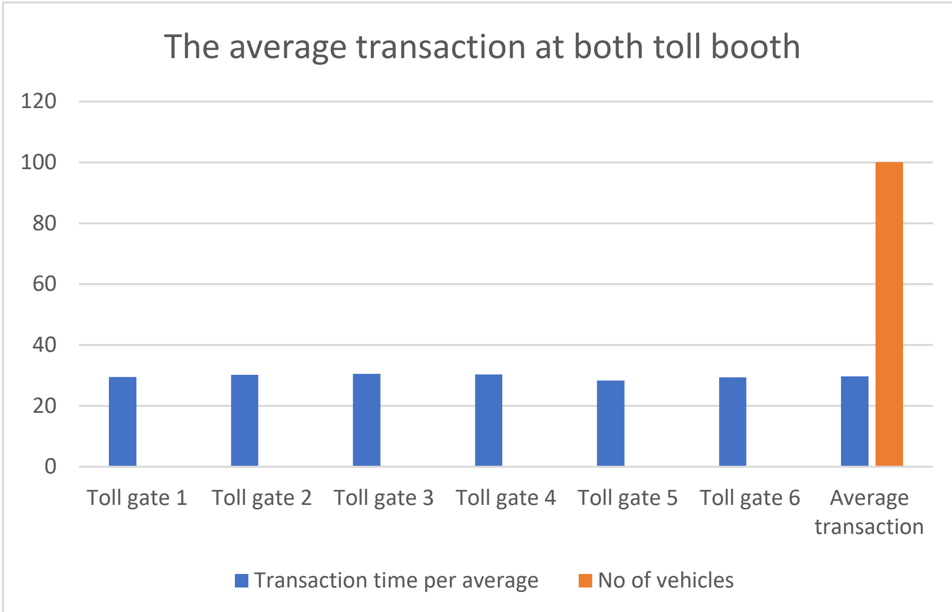

Figure 4.9. Average Transaction at the main toll plaza

The total number of vehicles passes through a plaza each month at Tulu Dimtu Main Toll Plaza tabulated in Table 4.1.

Table 4.1. Total number of vehicles pass through plaza each month

Year	Months												
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
2019	723, 095	700, 428	721, 296	674, 743	738, 760	688, 790	754, 302	756, 286	714, 668	687, 065	699, 111	759, 448	34,671, 459

Source: Ethiopian Toll Road Enterprise

The electronic toll collection is more efficient than the existing toll collection systems as it gives good management at toll plaza as well as it can save fuel. Hence, the study describes an efficient toll collection system.

4.2.3 Feasibility Study

Consider at 6 manual toll plazas (19 entries and 29 exits) totals 34,671,459 vehicles in the year 2019 are tracked. The average value of this becomes 718,170 vehicles and 23,939 vehicles are pass-through toll plaza per day

$$= \frac{total\ number\ of\ vehicles}{one\ month}$$

$$= \frac{718,170}{30} = 23,939\ vehicles\ per\ day$$

$$= \frac{23,939}{24} = 997\ vehicles\ per\ hour$$

$$= \frac{number\ of\ vehicles}{number\ of\ tollbooth}$$

$$= \frac{997}{6} = 166.2\ vehicles\ per\ lane$$

Suppose the manual toll system is efficient and time taken average transaction time is about 29.8 seconds for one vehicle. Now if 997 vehicles pass a toll plaza, then the time is taken to 1 vehicle with 29.8 seconds average stop time taken in a month:

$$29.8 \times 30 = 894 \text{ seconds}$$

$$\text{Yearly total time took } 894 \times 12 = 10,728 \text{ seconds} = 2.98 \text{ hours} \approx 3.00 \text{ hours}$$

Therefore, on average, each vehicle that passes through a toll plaza has to wait for 3.00 hours keeping them engine turned on. The figure is amazing as if on an average 997 vehicles pass through a toll plaza each day, then yearly 23,939 vehicles pass the toll plaza, so each year 23,939 vehicles wait for 3.00 hours.

$$\text{No. of vehicles passing yearly: } 23,939 \times 30 \times 12 = 8,618,040$$

$$\text{No. of vehicles passing 48 tolls: } 23,939 \times (365 \times 29) = 253,394,315$$

Table 4.2. Numbers of vehicles passed through toll plaza per day

Vehicle	Days	Toll Booth
23,939	1	1
8,618,040	30×12	1
253,394,315	30×12	29

The above table indicates that each year about 8,618,040 vehicles just stand still for about 3.00 hours in engine start condition creating pollution and burning fuel. Consider that in 1 lit fuel is used in 3.00 hours. So, the total amount of fuel used by all the vehicles:

$$253,394,315 \times 1 = 253,394,315 \text{ Liters}$$

Table 4.3. Fuel consumption

Vehicle	Fuel consumed	Amount
1	1 Lit	20,00 ETB
253,394,315	253,394,315 Lit	8,273,318,400 ETB

Assuming cost of 1liter of fuel = 20.00 ETB total cost of fuel consumed by 413,665,920 vehicles = 253,394,315 Lit$\times$20 = 5,067,886,300 ETB

The above is the money wastage under the consideration that the vehicle stops for 29.8 seconds at the toll plaza, and 23,939 vehicles pass through the toll plaza each day and there are 29 exits at toll plazas. The approximate CO_2 emission per liter of diesel fuel is 2.68kg, and for petrol, it is approximately 2.31kg. LPG produces around 1.51kg per liter (Fuel CO_2 calculator (Https://www.drivingtests.co.nz/resources/, 2016) which results in air pollution. These figures are all at a minimum average.

4.2.4 Evaluation and Result of Designed System

The evaluation of ETC was too much different from the existing system. The location where the arrival of vehicles was recoded 1 meter before the antenna. For 15 vehicles the average delay time was 5.6 seconds. When this survey was conducted, all five tags are used at various times and vehicles. Figure 4.10 clearly shows an example of the field observation data of vehicle arrival at the automated system.

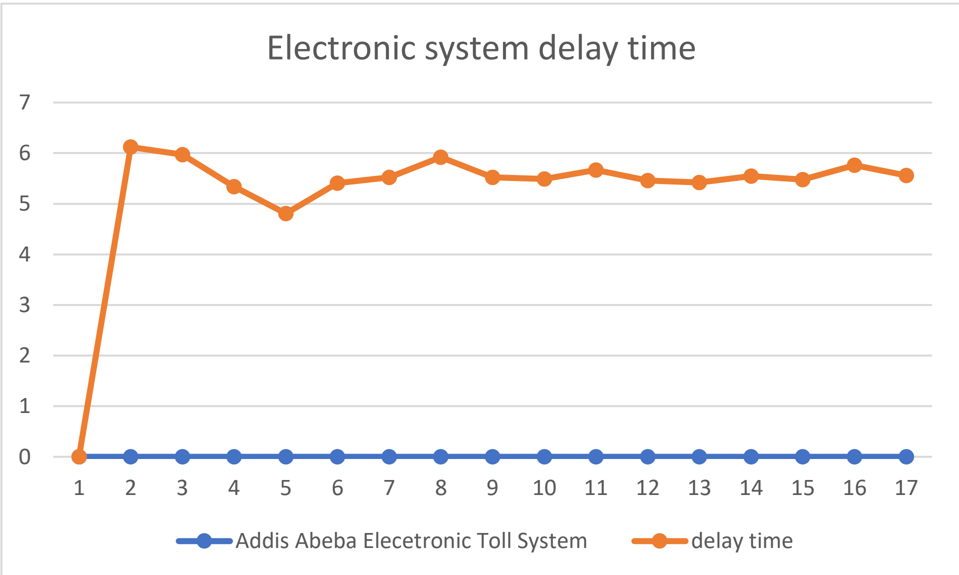

Figure 4.10. Automated system delay

4.2.5 Arrival Level (λ)

The level of arrival is the number of vehicles that arrive at manual tollgate at a certain time (vehicle unit per hour). In some scientific research, a Poisson distribution model more suitable for modeling the arrival pattern of vehicles under uncongested road vehicle traffic flow conditions.

$$p^n = \frac{(\lambda)^n e^{(-\lambda)}}{n!} \tag{4}$$

Where:

p(n)= probability of arrival of n vehicle within the time range

λ= vehicle arrival level at a certain time point

e= natural number (e=2.718)

4.2.6 Service Level (μ)

Aftabuzzaman, (2007) stated in his scientific research the measure of traffic congestion can be classified into four broad categories; i.e. basic measure, ratio measures, level of service measures, and indices. Basic measures are related to delay estimation. Delay can be defined as the additional time experienced by a road user in comparison to the free flow travel or the acceptable travel time. The concept of the level of service was developed (Manual, 1985). The level of service of a facility is determined by traffic flow characteristics such as vehicle density, volume to capacity ratio, and transaction delay. The following Table 4.4 shows the level of service analysis and volume to capacity ratio.

Table 4.4. Level of service analysis and volume to capacity ratio

Level of service	Description	Volume/capacity
A	Free- flow condition with unimpeded maneuverability, stooped at, stooped delay at the signalized intersection is minimal	0.00 to 0.60
B	Reasonably unimpeded operations with restricted maneuverability, stopped delays are not bothersome.	0.61to 0.70
C	Stable operations with somewhat more restrictions in making mid-block lane changes than LOS B. Motorists will experience appreciable tension while driving.	0.71 to 0.80

D	Approaching unstable operations where small increases in volume produce substantial increases in delays and low average speeds.	0.81 to 0.90
E	Operations with significant intersection approach delays and low average speeds.	0.91 to 1.10
F	Extremely low speeds caused by intersection congestion, high delay, and adverse signal progression.	Greater than 1.0

Based on Owolabi et al. (2016) the level of service measured the average capacity/volume and congestion as tabulated in Table 4.5 below.

Table 4.5. Average capacity/volume congestion

No	Average traffic volume/capacity ratio	Technical interpretations
1	Less than 0.6	No congestion
2	0.6 to 0.8	Slight congestion
3	0.8 to 1.0	Congestion
4	1.0 to 1.2	Sever congestion
5	Greater than 1.2	Extreme congestion

The level of service (μ) is the number of vehicles that can be served at one or several service points (vehicle unit per hour). Service time is the time required to serve a vehicle (minutes per vehicle). The value of ρ is the ratio of arrival level (λ) to service level (μ), with the condition that its value has to be less than 1 (Tamin, 2008).

$$\rho = 1 + \frac{\lambda}{\mu} < 1 \quad (5)$$

Where:

λ= arrival level

μ= service level capacity

If ρ>1, then the arrival level is higher than the service level, which indicates a longer queue at toll lane. Therefore, ρ must be less than 1.

The length of the vehicle queue and the required service time, as well as the number of additional gates required to shorten the length of queuing, can be analyzed based on the number of vehicle arrivals, the transaction time, and the number of existing gates.

To measure the capacity of a given toll system, the following formula is used (Karsaman & Weningtyas, 2015).

$$\mu = \frac{3600}{wp}$$

Where:

μ= level of service

wp= service time

For instance, the arrival level of 997 (166 vehicles for 6 lanes) vehicles per hour and the average transaction time is taken 29.8 sec per vehicle for each manual toll booth. The gate capacity calculated by the following method:

$$\rho = \frac{166}{29.72}$$

$$= 5.6\ vehicles\ per\ lane$$

As per the above equation, the value of ρ is greater than one. This indicates the existing system has extremely too much long queue (8.2 vehicles per lane).

The average queue length if using a manual system

$$\rho = \frac{\lambda}{\mu}$$

$$= \frac{997}{121}$$

$$= 8.2\ vehicles$$

The average capacity

$$\mu m = \frac{3600}{29.72}$$

$$= 121\ vehicles\ per\ hour$$

The level service calculation of the automated system

$$\mu e = \frac{3600}{5.6}$$

$$= 642.9\ vehicles\ per\ hour$$

The queue length if using an automated system

$$\rho = \frac{15}{642}$$

$$= 0.024\ vehicles$$

∴ Therefore, it is advisable to implement an ETC system gradually rather than the existing system considering an initial cost and total benefit analysis to account.

4.2.7 Evaluation Scenarios

In the development of automated vehicle detection and payment system using an RFID, the different outcome at the gates should be taken into consideration for effective evaluation. Detecting range is a fixed value in the simulation study. This variable determines the length of the measurement link. The reasonable detection range has been pre-determined.

4.2.8 Service Time Survey and Result Analysis

In this section, a comprehensive result analysis of the study at Tulu Dimtu transaction points is given. The following Table 4.6 shows all the average transaction fluctuation at both toll booth.

Table 4.6. The total average transaction

Tulu Dimtu Main Toll Plaza Total Average Transaction							
Tollgates	Toll gate 1	Toll gate 2	Toll gate 3	Toll gate 4	Toll gate 5	Toll gate 6	Average transaction
Average Trans	29.478	30.2004	30.5251	30.3252	28.3546	29.4277	29.72
No of vehicles	100	100	100	100	100	100	

4.3 The Results of the Field Study

The result of the queueing parameter calculation was based on the arrival level and the transaction time at all toll plaza. Traffic queue can be measured in various ways depending on the purpose of analysis. To measure a queue, some parameters indicate the intensity of traffic congestion. As itemized by (Mohan & Ramachandra, 2012), measures of traffic congestion can be categorized into four broad groups: basic measures, ratio measures, level of service measures, and indices. Basic measures are related to delay estimation.

Based on the field survey and the study analysis, the capacity of the manual transaction system significantly lower than the minimum service standard (450 vehicles per hour), and the proposed ETC system was much higher than expected in the capacity of a toll plaza. Each transaction at each tollbooth and the average transaction are almost the same. Figure 4.11 shows the similarity of the transaction at each tollgate.

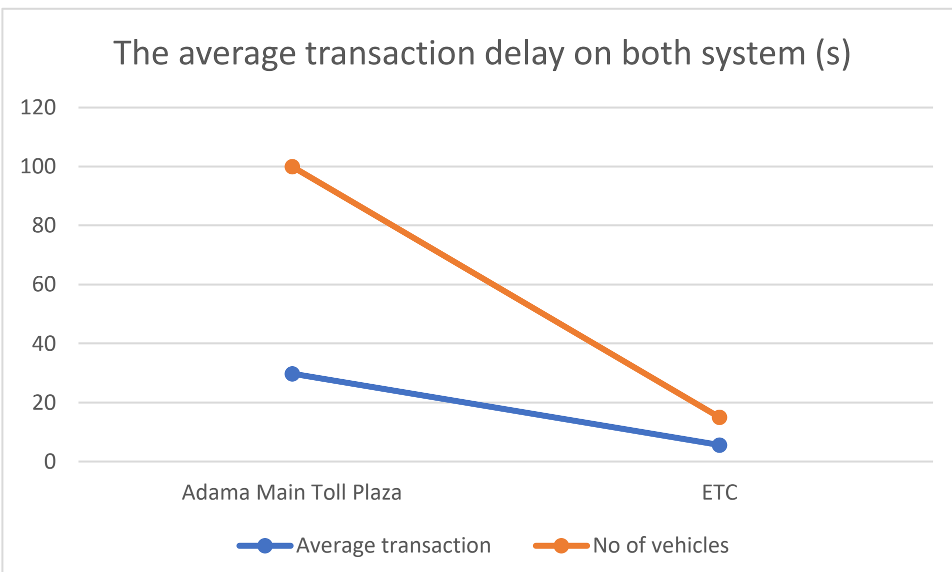

Figure 4.11. Transaction fluctuation on both system

4.4 Operating Frequency

RFID device work on a different range of frequency from 125 kHz to 5.8 GHz. The selection of operating system range is depending on the bases of application and the requirements. To prepare a prototype 13.56 kHz radiofrequency was selected due to having a better ability to read near the antenna, cost orientation, and availability.

4.5 A Prototype of Electronic Vehicle Detection and Payment System

When a vehicle comes close to the toll plaza the GSM module will become active and simultaneously the RFID tag read all the data of the vehicle. All the data of the specific vehicle have been sent to both the GSM module and the PC through the program design to verifying the balance account of the vehicle owners.

If the account balance is sufficient, the barrier opens and a text message sent to the registered cell phone based on the IDE programming language. LCDs to the driver “you shall pass”. When the green LED lit, the servo motor opens the gate barrier and closes after the vehicle pass.

If the account balance of the owner is insufficient or the vehicle not yet registered, he/she may pay manually as per the location of the manual toll gate, or if the vehicle tagged incorrect RFID tag the LCDs to the driver “You cannot pass”. These have to be done within 5.6 seconds means the toll plaza works like a non-stoppable way. The following Figures 4.12, 4.13, and 4.14 are illustrated the output of the automated system set up with an RFID tag.

Figure 4.12. The automatic toll collection system

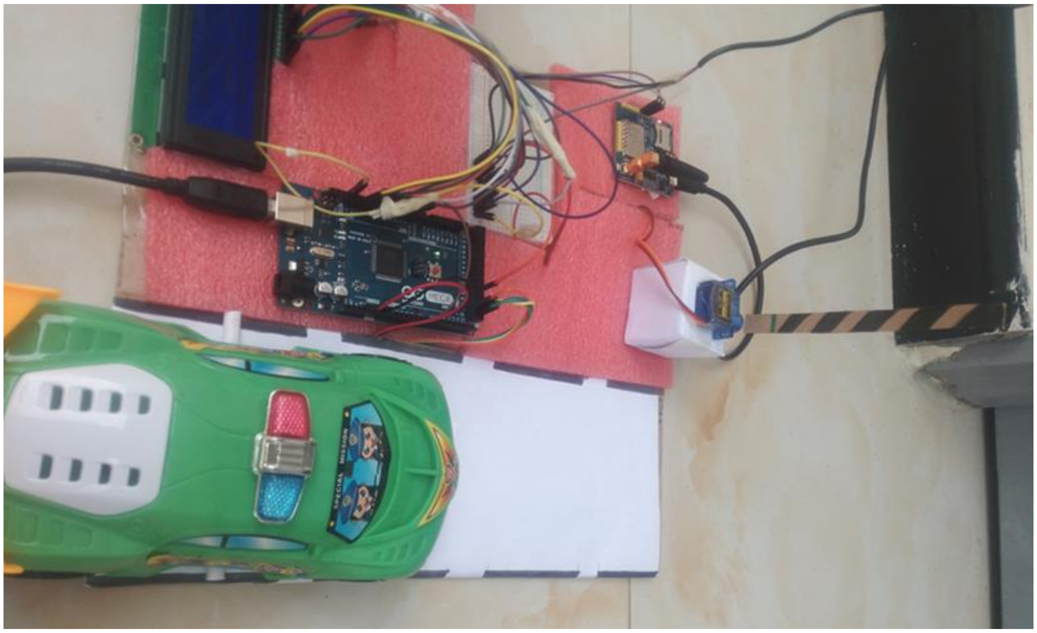

Figure 4.13. The output of the proposed model

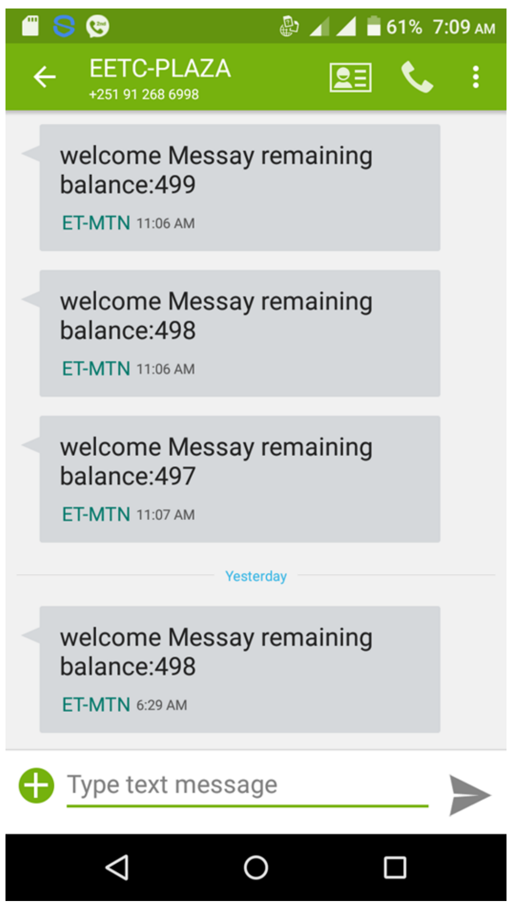

Figure 4.14. Received text message from the system

4.6 Circuit Diagram of the Automated System

The microcontroller is considered as a CPU in this thesis work prototype. The major function of a microcontroller for this application are:

1. Read the RFID unique number from the reader
2. Send the correct data and information to the LCD
3. Send the command to motor or buzzer as per the program designed for

The external electric source for the Arduino board should be 5volts form USB or other regulated power sources. This regulated power supply used to power the microcontroller and the other components built on the board. A 3.3 (max 50 mA) volt supply generated by the onboard regulator.

RC522 is a high integrated RFID card that works on non-contact 13.56 MHz communication as low cost and compact size, read-write chip. The chip is an advanced modulation system that fully integrated at 13.56 MHz with all kinds of non-contact communication. The module also uses 3.3-volt power and can communicate directly with any board by connecting through SPI protocol which ensures reliable work with good reading distance. The integration of Arduino UNO with the RFID module illustrated below in Figure 4.15.

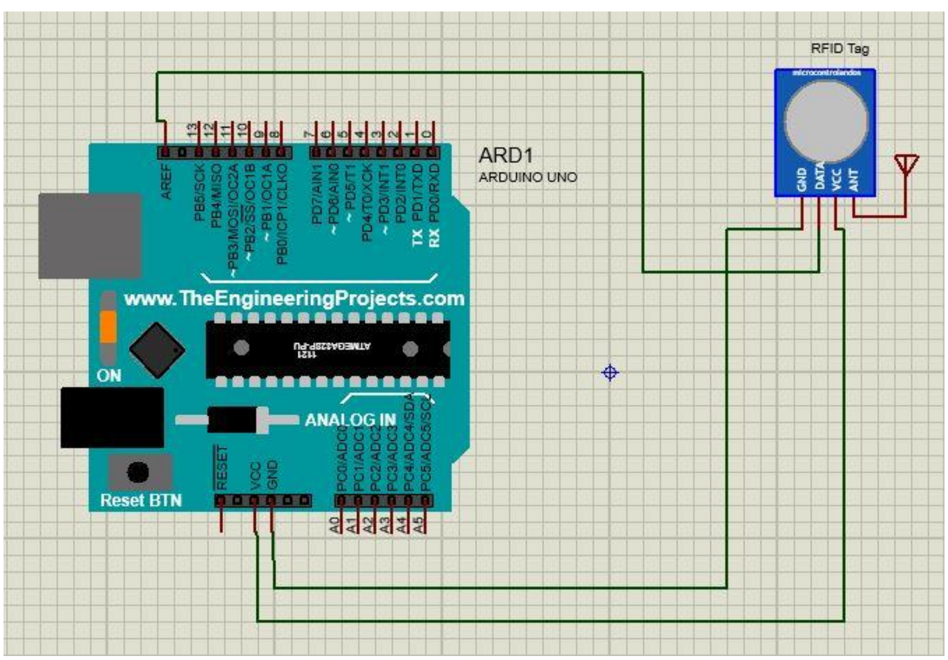

Figure 4.15. RFID module Connection

The Arduino can be powered from a 9V wall adapter. There is a buzzer and LED to indicate either the vehicle registered correctly or not, or have a sufficient balance or insufficient balance. The LED circuit design illustrated below in Figure 4.16.

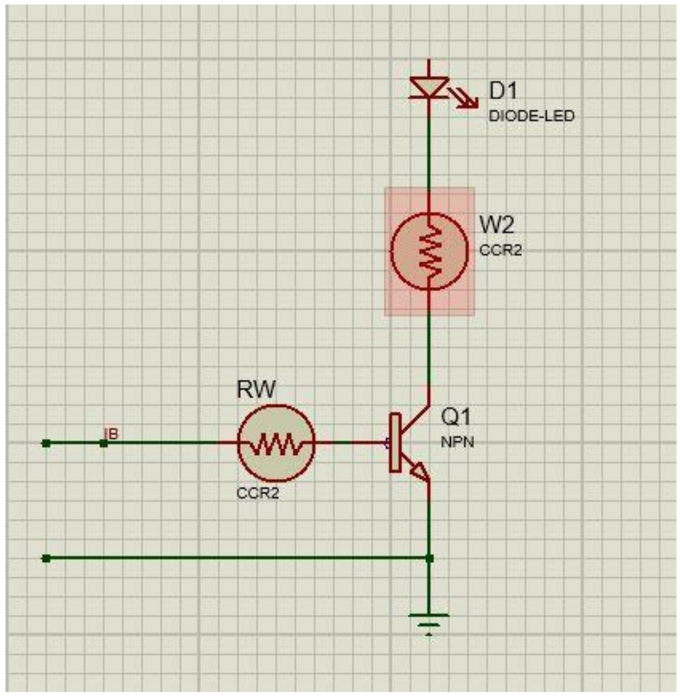

Figure 4.16. Transistor controlled LED

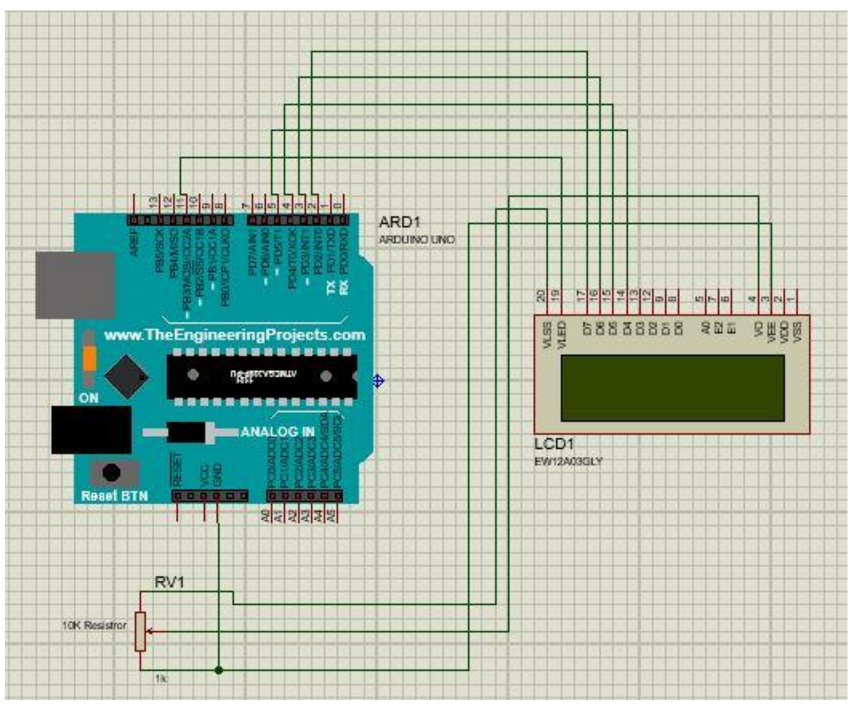

Figure 4.17. Arduino to LCD connection

The automated vehicle detection and payment system circuit diagram of servo motor, microcontroller, and RFID reader is illustrated in Figure 4.18 and Figure 4.19.

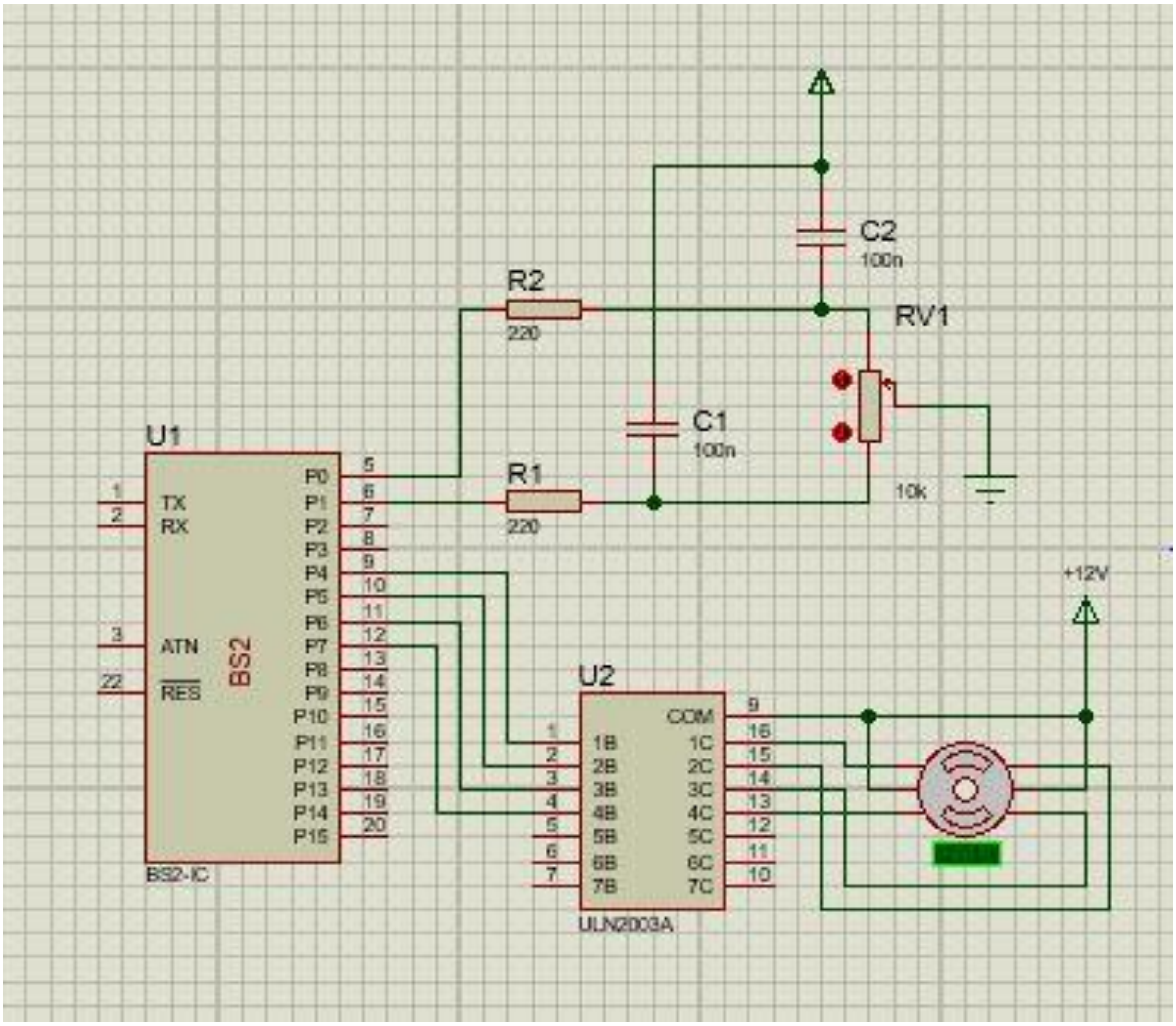

Figure 4.18. Automated toll system schematic diagram

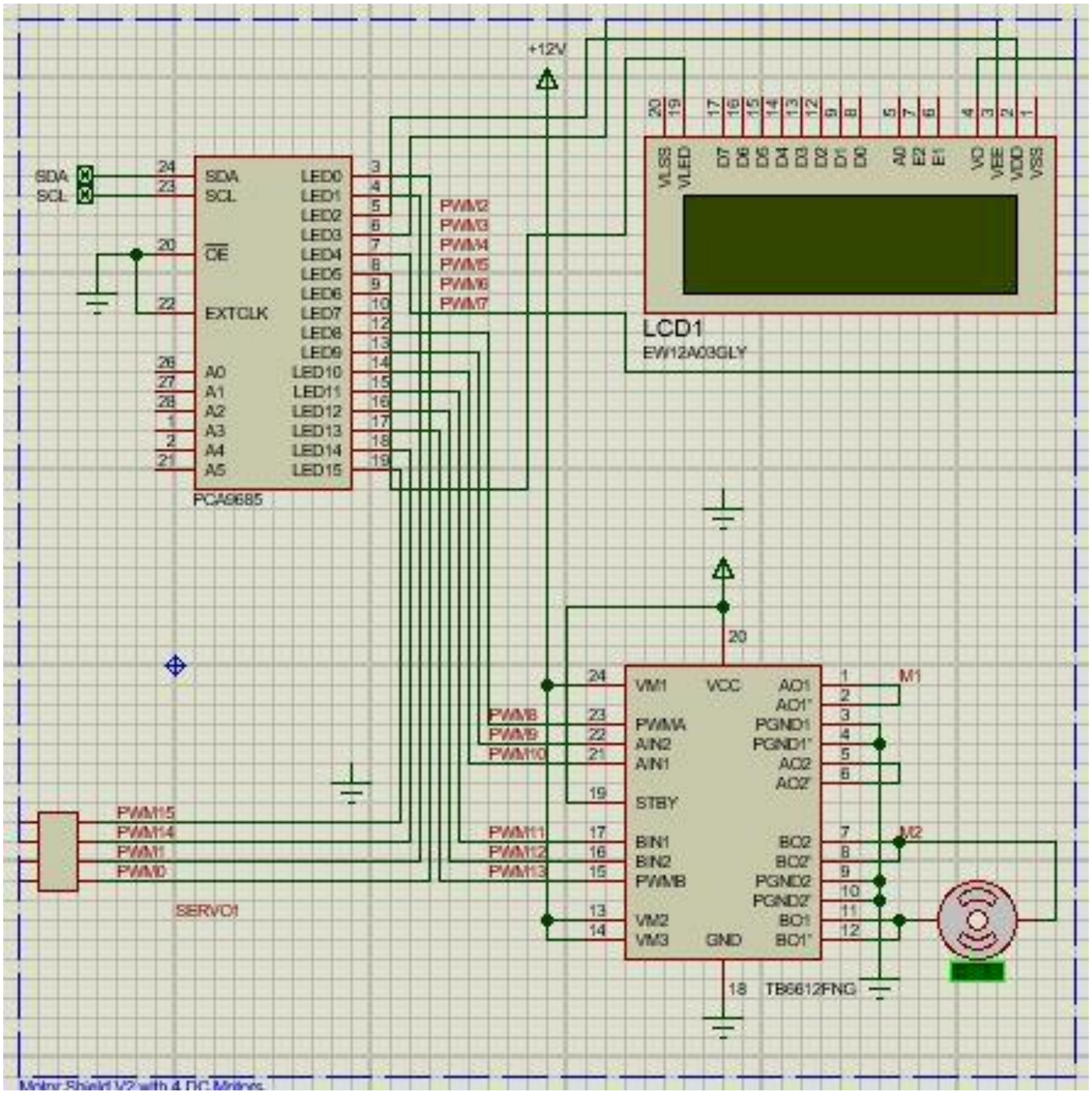

Figure 4.19. The ETC wiring diagram

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1 Summery

As it has been indicated in the introduction part, the main objective of this thesis work was to design and development of electronic vehicle detection and payment system using RFID technology at Addis Abeba to Adama expressway. Using an ETC has advantages over the existing system, such benefits are increasing toll capacity, fuel-saving, lower operating cost, vehicle theft detection, tracking over speeding, pollution of an environment, and wastage of paper are itemized detailed. The designed system mainly used Arduino UNO, GSM module, passive RFID tag and module, and the Liquid Crystal Display.

The reliable and sufficient quantitative data are collected beginning the field survey at Tulu Dimtu main toll plaza. The arrival level and service level of the existing system have been conducted and analyzed.

To design automated vehicle detection, vehicle identification, vehicle anti-theft system, the transaction process, and violation enforcement Arduino IDE with C language is preferred. And the electrical circuit diagram has been designed by PROTEUS PRO 8 DEMONSTRATION software. The study evaluated the design and development of vehicle detection and payment system using RFID and microcontroller on a kid's toy car to show the system prototype.

Based on the actual field survey and observation measurement analysis, the following main findings are obtained.

- As long as the RFID tag is available on the vehicle, the effectiveness of the tollgate will be guaranteed and significantly improved the service level capacity.
- Expanded the capacity of the automated systems without building more infrastructure.
- The designed system allows the driver to pass through the system at 20 km/h.
- The average delay time during transactions decreased from 29.8 to 5.6 seconds.

5.2 Conclusion

The grounds of this thesis work were the need for assessment of the design and develop a vehicle detection system at a toll plaza. Based on a quantitative and qualitative analysis of the existing toll transaction at a toll plaza, it can be concluded that a service level and capacity performance are important factors to consider when designing and developing a new system. The result indicated that the designed system is achieved the service level more than the minimum standard level of vehicles per hour.

By analyzing both the arrival level, service level, and capacity performance of the existing toll system in 2019, this thesis has shown how the designed system to be executed directly or indirectly like a big scenario. Based on field observation and measurements, it was found that the average delay time of the existing system was 28 to 30 seconds, while in the automated system the delay time decreased to 5.6 seconds and the capacity was 642.9 vehicles per hour with 0.024 vehicles queue.

The study process, therefore, designed an appropriate program to establish whether the implementation of the technology feasible in the situation and to explain the possible problems. Since this thesis is the first-ever duty of the groundwork technology in Ethiopia, the design and development be faced with during the study and recommendations here will pave way for create the circumstances to enable further studies to be done.

After doing a study on this thesis it is initiate that the introduction of the ETC system can be more advantageous to achieve the goals of ETRE in 2020. With this a low-cost technology implementation it will dramatically decrease time consumption, fuel savings and reduce air pollution, traffic congestion, improves the government revenue, making the transaction process easier and faster, increasing toll booth service rates, and leave a personal contact to avoid the current pandemic global disease COVID-19. The traffic-free toll system will add a good impression to road users and they can enjoy the travel on this road by a short time.

The study demonstrated that the system has sent a short text message to the vehicle’s registered cell phone and he/she knows how much money is deducted by the system. The development can be completed to advance a multi-vehicle amount deducted and send a text message at a period of the multi vehicles. These were the major achievements met in the study among the other objectives.

The designed system is the non-contact, non-line-of-sight nature of the technology. Tags can be read through a change of natural phenomena such as rain, fog, and sun. Hence, this development can be very much useful and can be implemented in real-time applications. The detection range of the vehicle and the location of the antenna was predetermined by the frequency. Passive radio frequency has a good ability to detect an object near to the antenna. The amplification of passive radio frequencies detection range will explore in future studies.

5.3 Recommendations

To provide the right solution by resolving the road traffic congestion, to give safer transportation system, and to minimize traffic destruction on human life and property at the expressway, the enterprise should undertake the following recommendations which are obtained based on the thesis outcome;

- The transport sector stakeholders should work together to make sure all the transportation systems facilitate a healthy transportation system. Especially the driving institutes should give serious attention to their trainees to optimizing vehicle speed and service qualities.

- Driving on the expressway means meaningfully it is related to vehicle speed. According to the Code of Ethiopia, the declared maximum allowed speed on the expressway was 100 km/hr. So, the declaration must be obeyed.

- The Ethiopian Toll Road Enterprise has to build several speed breakers more than 5 to10 meters far from each toll booth and the fence should be more secured.

- To provide the right fleet management and to enhance violation enforcement the surveillance cameras must be placed at a specific distance from the vehicle license number plate.

- To control the vehicle’s maximum speed through the expressway the radar cameras should be installed at a certain point.

- As a temporary solution for the road users, if the enterprise provides a set of mobile garages together it will help the traffic.

- The enterprise has to give attention to optimizing the level capacity of transaction time and evaluate the performance.

In this busy world, this thesis work gives preference for time and efficiency, to fulfill this achievement we are kindly requesting to implement the automated toll collection system.

5.4 Future work

The technology used in electronic toll collection system can be further improved for security and safety such as:

1. **Over Speeding Vehicle:** The ZigBee module can be modified to transmit speed details. The RFID antenna installed at every location will track the speed of the vehicles. If any vehicle exceeds the defined limit the vehicle number will be stored. This system can be used to track the vehicles as ZigBee transmitter transmits VIN which will be detected by the nearby RFID reader. Thus, preventing serious crimes. This system provides efficient and better ways that improve the driving experience and provide safety to paddlers.

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Appendices

Appendix I

The required materials specification

AT mega 2560 Microcontroller

Microcontroller	ATmega 2560
Operating Voltage	5V
Input Voltage (recommended)	7-12V
Input Voltage (limit)	6-20V
Digital I/O Pins	54 (of which 15 provide PWM output)
Analog Input Pins	16
DC Current per I/O Pin	20 mA
DC Current for 3.3V Pin	50 mA
Flash Memory	256 KB of which 8 KB used by bootloader
SRAM	8 KB
EEPROM	4 KB
Clock Speed	16 MHz
LED_BUILTIN	13
Length	101.52 mm
Width	53.3 mm
Weight	37 g

MFRC522 RFID Module:

Voltage:	DC 3.3V
Operating Current n:	13-26mA
Idle Current:	10-13mA
Sleep current:	<80uA
Peak current:	<30mA n
Operating Frequency:	13.56MHz
Supported card types:	mifare1 S50, mifare1 S70, mifare Ultralight, mifare Pro, mifare Desfire
Dimensions:	40mm n× n60mm n

Module Interface SPI Data Transfer Rate: Max. 10Mbit/s

Card reading distance： 0～30mm Mifare1 card

16x4 Character LCD Display:

Status	Not Recommended for New Design
Replacement LCD	164G
Display Format	16×4
Character Matrix (w×h)	5×8
Character Size (w×h)	2.95×4.735 mm
LCD Controller and Driver IC	Sitronix ST7066U and ST7065C
Module Size (w×h×d)	87×60×11 mm (14 mm max with LED backlight)
View Area (w×h)	61.8×25.2 mm
Pixel Size	0.55×0.5 mm
Driving Method	1/16 Duty, 1/5 Bias
Operating Temperature	-20 ~ 70°C

program and software used

IDE version 2014a

Windows Operating System (WOS) 10

2.5 GHz Intel "Core i7" Processor HP

8 GB RAM

SOFTWARE REQUIREMENTS

LPCXpresso IDE

MC Programming Language: Embedded C

Arduino IDE

Servo SG-90:

Operating Voltage	+5V typically
Torque	2.5kg/cm
Operating speed	0.1s/60°
Gear Type	Plastic
Rotation	0°-180°
Weight of motor	9gm

Package includes gear horns and screws

GSM Features:

Quad-Band	850/900/1800/1900 MHz
Dual-Band	900/1900 MHz
GPRS multi-slot class	10/8
Compliant to GSM phase	2/2+
Class 4(2W)	Class 1 (1W)

Control via AT commands (GSM 07.07, 07.05 and SIMCOM enhanced AT Commands)

Low power consumption:	1.5mA (sleep mode)
Operation temperature:	-40°C to +85 °C

Appendix II

Transaction time fluctuation at the manual toll plaza

Tulu Dimtu Main Toll Plaza (Addis Abeba)						
No of Vehicles	Tollgate 1	Tollgate 2	Tollgate 3	Tollgate 4	Tollgate 5	Tollgate 6
1	28.72	23.67	40.58	20.83	22.31	33.18
2	24.69	29.37	27.32	22.39	27.01	42.64
3	25.37	43.26	25.94	31.21	20.61	32.03
4	48.93	51.31	47.92	44.06	21.89	39.37
5	37.23	32.73	47.1	21.1	21.18	25.75
6	20.98	60.06	47.32	36.21	20.43	35.01
7	39.4	40.12	30.12	34.92	28.52	60.19
8	27.6	30.17	48.5	34.3	36.31	22.21
9	20.87	28.01	40.12	36.15	25.77	26.76
10	39.23	21.1	40.17	40.56	27.71	20.85
11	26.34	33.26	30.25	37.9	29.61	39.45
12	20.17	20.12	50.35	27.23	20.28	22.3
13	27.99	47.5	39.96	21.98	22.62	37.59
14	19.22	43.26	23.47	30.78	26.43	23.5
15	38.12	28.12	45.72	20.46	28.89	27.19
16	36.32	47.33	23.42	33.14	25.42	23.24
17	27.52	27.1	27.2	26.04	27.4	28.82
18	33.7	40.08	39.16	40.08	29.47	33.48
19	20.51	33.73	25.12	24.1	24.77	35.76
20	28.43	35.32	40.07	38.4	29.44	31.12
21	39.12	26.13	40.2	29.91	16.54	26.03
22	36.95	23.12	32.18	28.3	34.59	24.34
23	31.32	29.13	35.44	33.1	27.9	33.7
24	34.12	21.27	27.23	41.23	29.78	22.62
25	43.95	33.55	24.98	24.53	20.61	40.19
26	37.7	19.23	33.57	28.22	26.16	27.55
27	27.56	22.81	31.38	20.99	33.68	39.14
28	24.5	22.01	33.12	30.8	19.1	33.63
29	42.81	19.67	30.17	20.38	24.83	23.38
30	32.57	37.12	27.12	23.87	24.61	43.99
31	25.32	28.72	25.39	26.76	27.65	36.23

32	39.52	42.07	29.66	28.69	28.27	28.17
33	25.86	43.87	40.7	27.6	25.32	32.16
34	26.29	38.02	26.14	26.31	33.78	37.93
35	29.01	25.82	31.2	34.21	34.26	27.63
36	29.9	24.4	38.19	28.5	19.44	35.78
37	32.64	32.88	28.02	27.21	27.32	37.83
38	53.23	22.7	29.29	23.47	22.3	20.13
39	28.02	24.37	39.94	30.45	24.64	31.25
40	22.57	29.16	26.41	27.87	23.14	36.75
41	21.5	31.01	35.32	31.68	37.1	27.8
42	43.14	22.51	42.42	29.12	25.84	23.43
43	29.94	52.9	35.29	33.13	28.01	40.63
44	32.32	28.36	23.19	19.29	28.29	21.49
45	20.09	30.92	24.64	18.81	49.44	35.19
46	24.92	45.63	30.62	25.2	22.71	34.1
47	38.02	40.81	18.49	31.75	29.69	37.14
48	40.15	17.26	38.84	27.4	31.13	26.1
49	28.72	27.11	36.12	38.49	35.82	20.78
50	28.05	28.3	30.31	40.14	24.68	28.72
51	27.41	60.2	29.37	24.05	23.03	26.98
52	29.51	21.47	41.95	43.09	29.83	31.27
53	36.82	35.97	25.74	51.84	40.01	26.48
54	21.16	24.79	30.31	24.63	35.46	25.51
55	23.41	39.38	25.16	29.22	21.81	29.81
56	30.59	31.62	25.54	36.68	36.82	27.25
57	34.41	23.08	25.45	38.47	38.74	32.85
58	49.83	35.66	32.08	40.87	27.71	30.51
59	48.21	23.42	33.33	42.74	34.1	33.68
60	38.75	37.83	23.46	44.13	24.3	31,62
61	28.23	30.11	41.25	45.96	29.93	24.74
62	52.26	34.95	45.22	43.97	21.55	29.37
63	56.51	24.57	37.98	48.12	48.19	23.31
64	31.65	34.8	40.15	27.76	31.49	33.29
65	27.25	30.88	30.26	37.95	41.84	43.21
66	23.08	28.72	31.05	42.13	46.87	33.88
67	26.58	30.55	20.04	35.71	41.19	43.58
68	24.88	22.43	60.07	40.61	36.8	24.92

69	29.74	36.08	24.55	38.03	29.39	28.14
70	34.17	28.2	35.01	50.44	44.71	59.37
71	32.48	35.03	28.75	30.27	34.06	26.51
72	56.83	24.42	31.32	25.03	28.57	30.41
73	21.97	38.89	20.01	33.46	27.03	31.06
74	26.87	25.59	39.01	39.51	38.19	41.4
75	37.13	30.35	23.53	45.39	31.85	28.03
76	25.79	36.8	21.5	30.63	21.65	60.04
77	31.75	25.02	24.99	36.79	26.41	23.53
78	41.29	33.82	39.21	23.03	26.24	24.71
79	36.7	40.62	37.46	47.02	50.21	28.59
80	32.35	33.25	33.53	35.39	42.36	39.96
81	36.74	36.73	28.27	40.67	37.16	25.02
82	40.6	28.85	29.98	43.53	24.57	31.3
83	28.02	27.51	37.65	25.87	20.52	19.94
84	38.16	31.94	42.26	30.8	32.84	23.24
85	32.47	36.94	20.08	34.23	41.23	25.52
86	34.8	28.69	32.2	38.84	35.89	25.11
87	24.01	33.51	28.94	41.57	25.99	26.48
88	25.86	38.19	38.71	33.16	27.35	21.6
89	33.06	29.36	28.18	26.6	23.68	31.13
90	22.47	26.21	41.12	30.87	25.14	36.63
91	30.62	43.97	29.72	31.69	37.7	21.68
92	38.12	42.34	23.04	26.9	26.54	16.58
93	27.37	34.5	27.83	32.89	30.56	39.49
94	60.09	32.89	38.89	44.07	35.74	41.7
95	38.87	27.01	33.96	33.14	37.8	21.35
96	43.56	43.15	43.19	39.71	46.42	40.44
97	39.56	38.28	33.15	36.19	60.07	25.69
98	29.42	23.33	25.23	31.23	27.11	33.33
99	29.69	40.03	38.17	24.13	24.03	39.22
100	48.43	42.08	60.09	34.26	60.08	42.44

Average transaction time table (s)

Tulu Dimtu Main Toll Plaza Total Average Transaction							
Tollgates	**Toll gate 1**	**Toll gate 2**	**Toll gate 3**	**Toll gate 4**	**Toll gate 5**	**Toll gate 6**	**Average transaction**
Average Trans (seconds)	29.478	30.2004	30.5251	30.3252	28.3546	29.4279	29.8
No of vehicles	100	100	100	100	100	100	600

Electronic system time delay table

Electronic Toll System																
Delay time(s)	**6.12**	**5.97**	**5.34**	**4.81**	**5.41**	**5.52**	**5.92**	**5.52**	**5.49**	**5.67**	**5.46**	**5.42**	**5.55**	**5.48**	**5.76**	**5.6**
no of vehicles	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	

Comparison table

Parameters	**Existing system**	**Automated system**
Service time (s)	29.8 seconds	5.6 seconds
Queue length	8.2 vehicles	0.024 vehicles
Toll capacity	121 vehicles/hour	642 vehicles/hour

Appendix III

Programming code

```
#include <SPI.h>
#include <MFRC522.h>
#include <Servo.h>
#include <SoftwareSerial.h>
#include <LiquidCrystal.h> // includes the LiquidCrystal Library

#define SS_PIN 53 // RFID Reader ss pin
#define RST_PIN 5 // RFID Reader rest

LiquidCrystal lcd(6, 7, 8, 9, 10, 11); // Creates an LC object. Parameters: (rs, enable, d4, d5,
d6, d7)

//Create software serial object to communicate with the GSM Module

SoftwareSerial mySerial(3, 2); //GSM U_Tx & U_Rx is connected to Arduino #3 & #2


Servo myservo;

MFRC522 mfrc522(SS_PIN, RST_PIN);   // Create MFRC522 instance.
char *Authorized[]={ "60 xx xx xx", "10 xx xx xx", "E0 xx xx xx", "A0 xx xx xx", "60 xx xx
xx"}; // regisered RFID Cards
int D_Balance = ;
int L_Balance = ;
int S_Balance =;
int K_Balance = ;

void setup()
{
  mySerial.begin(9600);
  lcd.begin(16,4);
  SPI.begin();

  mfrc522.PCD_Init();
  myservo.attach(44); // Servo connetctd to pin 44
  lcd.print("Welcome"); // inital welcome display


}

void updateSerial()
{
```

```
  delay(500);
  while (Serial.available())
  {
    mySerial.write(Serial.read());//Forward what Serial received to Software Serial Port
  }
  while(mySerial.available())
  {
    Serial.write(mySerial.read());//Forward what Software Serial received to Serial Port
  }
}


void show_home()
{
  lcd.print("Welcome");
  }

void loop()
{
  // Look for new cards
  if ( ! mfrc522.PICC_IsNewCardPresent())
  {
    return;
  }
  // Select one of the cards
  if ( ! mfrc522.PICC_ReadCardSerial())
  {
    return;
  }
  //Show UID on serial monitor
  String content= "";
  byte letter;
  for (byte i = 0; i < mfrc522.uid.size; i+)
  {

     content.concat(String(mfrc522.uid.uidByte[i] < 0x10 ? " 0" : " "));
     content.concat(String(mfrc522.uid.uidByte[i], HEX));
  }

  content.toUpperCase();
  if (content.string(1) == Authorized[0])
  {
    lcd.clear();
    lcd.print("Authorized access");
    lcd.setCursor(2,1);
    lcd.print("Welcome ");
```

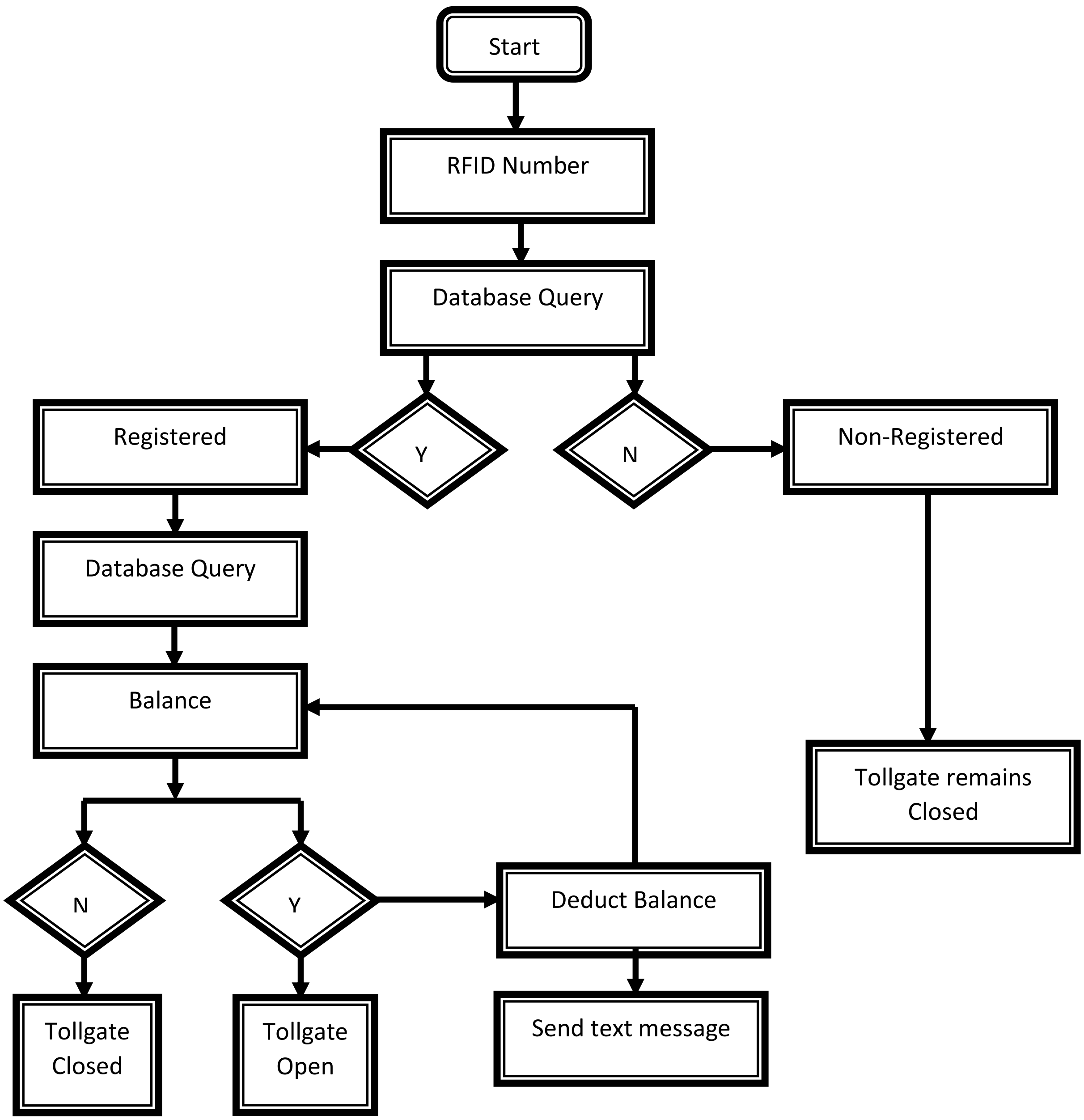
```
  myservo.write(0); // take the servo to 0 degree
  delay(3000);
  myservo.write(90); // return the servo to original position(90 degree)
  lcd.clear();
  Serial.println("AT"); //Once the handshake test is successful, it will back to OK
delay(1000);
int balance = xx;
    String text;
    text = String(xx);

mySerial.println("AT"); //Once the handshake test is successful, it will back to OK
updateSerial();

mySerial.println("AT+CMGF=x"); // Configuring TEXT mode
updateSerial();
mySerial.println("AT+CMGS=\"\"");c
updateSerial();
mySerial.print("Welcome xxx remaining balance is :" + text ); //text content
updateSerial();
mySerial.write(26);
}

else if(content.substring(1) == Authorized[1])
{     lcd.clear();
      lcd.print("Authorized access");
  lcd.setCursor(2,1);
  lcd.print("Welcome");
  myservo.write(0); // take the servo to 90 degree
  //Serial.println();
  delay(3000);
  myservo.write(90); // return the servo to original position(90 degree)
  lcd.clear();

  int balance = xxx;
    String text;
    text = String(xxxx);
mySerial.println("AT"); //Once the handshake test is successful, it will back to OK
updateSerial();

mySerial.println("AT+CMGF=x"); // Configuring TEXT mode
updateSerial();
mySerial.println("AT+CMGS=\"\"");
updateSerial();
mySerial.print("Welcome remaining balance is:" + text); //text content
updateSerial();
mySerial.write(26);}
```

```
else if(content.substring(1) == Authorized[2])
{
  lcd.clear();
  lcd.print("Authorized access");
  lcd.setCursor(2,1);
  lcd.print("Welcome");
  myservo.write(0); // take the servo to 90 degree
  //Serial.println();
  //delay(3000);
 // myservo.write(90); // return the servo to original position(90 degree)
  //lcd.clear();
  int balance = -xxx;
    String text;
    text = String(xxx);
   mySerial.println("AT"); //Once the handshake test is successful, it will back to OK
updateSerial();
mySerial.println("AT+CMGF=x"); // Configuring TEXT mode
updateSerial();
mySerial.println("AT+CMGS=\"\"");
updateSerial();
mySerial.print("welcome xxx remaining balance:"+ text); //text content
updateSerial();
mySerial.write(26);
  myservo.write(90); // return the servo to original position(0 degree)
  lcd.clear();

}

else if(content.substring(1) == Authorized[3])
{
  lcd.clear();
      lcd.print("Authorized access");
  lcd.setCursor(2,1);
  lcd.print("Welcome ");
  myservo.write(0); // take the servo to 90 degree
  //Serial.println();
  delay(3000);
  myservo.write(90); // return the servo to original position(90 degree)
  lcd.clear();

delay(1000);
int balance = xxx;

    String text;
    text = String(xxx);
```

```
  mySerial.println("AT"); //Once the handshake test is successful, it will back to OK
 updateSerial();

 mySerial.println("AT+CMGF=x"); // Configuring TEXT mode
 updateSerial();
 mySerial.println("AT+CMGS=\"\"");
 updateSerial();
 mySerial.print("Welcome remaining balance is: "); //text content
 updateSerial();
 mySerial.write(26);}
 else if(content.substring(1) == Authorized[4])
 {
  lcd.clear();
  lcd.print("Authorized access");
  lcd.setCursor(2,1);
  lcd.print("Welcome ");
  myservo.write(90); // take the servo to 0 degree
  //Serial.println();
  delay(3000);
  myservo.write(90); // return the servo to original position(90 degree)
  lcd.clear();
  Serial.println("AT"); //Once the handshake test is successful, it will back to OK
 delay(1000);
 int balance = -xxx;
 String text;
 text = String(xxx);
  mySerial.println("AT"); //Once the handshake test is successful, it will back to OK
 updateSerial();

 mySerial.println("AT+CMGF=x"); // Configuring TEXT mode
 updateSerial();
 mySerial.println("AT+CMGS=\"\"");
 updateSerial();
 mySerial.print("welcome remaining balance is:" + text); //text content
 updateSerial();
 mySerial.write(26);}


else   {
 lcd.clear();
  lcd.print(" Access denied");
  delay(3000);
 }
 show_home();
}
```

Appendix IV

ETC System Algorithm



Appendix V

Evidence photography