‘I – Sense’

AN IOT BASED MOBILE APPLICATION TO DETECT EXPIRED VEHICLE REVENUE LICENSES IN SRI LANKA

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Declaration

I declare that the work presented in this dissertation is my own work and to best of my knowledge acknowledgement is made for all sources of information used in this dissertation. Further, this as a whole or as parts has not been submitted previously or concurrently for a degree or any other qualifications at any University or Institutions of Higher Learning.

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The above Student carried out his /her research project under my supervision.

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Signature of the Supervisor Date

Name of the Supervisor:

Abstract

Sustainable development of a country is dependent upon effective management of its sources of revenue. In Sri Lanka, income from vehicles by means of Vehicle Revenue Licenses play a key role in annual income generation of the country. In addition, law enforcement on expired Revenue Licenses generates a secondary income via a process of assigning fines to offenders.

Problem identified in the domain is the presence of different digital and manual systems to handle separate components of this process, mostly disintegrated form each other. Therefore, currently a gap can be identified between different government sectors involved in the process of handling Vehicle Revenue management. Thereby, a lack of coordination, and improper centralized management of the process has rendered this process to have certain loopholes, which are identified through this project.

As the background research, this project focuses on analyzing various issues in the current system at place for different stakeholders, including local authorities and Vehicle owners as well. Interviews, questionnaires and referencing existing acts and regulations were sued to gather requirements of different stakeholders involved. Thereby, identified aim is to provide a technological solution to centralize the Vehicle Revenue License process. To enhance the effectiveness of Vehicle Revenue License renewal process for Vehicle owners. To enhance the effectiveness of law enforcement against offenders who have failed to adhere to Revenue License regulations in Sri Lanka.

This project is to bridge these gaps between different parties involved in the Revenue Licensing process and increase the efficiency of the process for both drivers and government institutions through I-Sense, IOT based device combined with an application platform. Through the different evaluations and results obtained for the outcome of the project, it is evident that this solution would be effective in making the current Vehicle License renewal process more fruitful and convenient for all the involved parties.

Keywords: Vehicle Revenue License, License renewal, Monitoring vehicle revenue, Law enforcement, IOT device

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Especially grateful for the support provided by Ms. Kumudini Sarathchandra, Module leader. Documentations and resources provided for us were really valuable for the project. Continuous support provide throughout the project is highly appreciated. Her guidance was an immense support, not just individually, but for the whole batch.

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Last but not least, I would extend my heartfelt gratitude to my parents and family who were like shadows behind me, at every step of life. They are the pillars behind the strength I have in dedicating myself to an important and complex task as this and to complete it in a more than satisfactory manner.

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Abbreviations

- ALPR – Automatic License Plate Recognition
- ANPR – Automatic Number Plate Recognition
- CoF – Certificate of Fitness
- DMT – Department of Motor Traffic
- DMV – Department of Motor Vehicle
- DoT – Department of Transport
- ETC – Emission Test Certificate
- HD – High Definition
- HDRBM – Hybrid Discriminative Restricted Boltzmann Machines
- ICTA – Information & Communication Technology Agency
- IoT- Internet of Things
- LPL – license plate localization
- MVC – Motor Vehicle Commission
- NPL – Number Plate Localization
- OCR – Optical Character Reader
- QR – Quick Response
- RFID – Radio Frequency Identification
- RTR – Road Tax Recognition
- RUP- Rational Unified Process
- SoC – Single Board Computers
- UML – Unified Modelling Language
- VLPR – Vehicle License Plate Recognition
- WoF – Warrant of Fitness

Chapter 1: Introduction

1.1 Chapter Overview

This chapter addresses the initiation of the project by elaborating the problem statement. The inability of local authorities to identify the vehicles without having a valid revenue license is analyzed, followed by the aims and objectives as well as the scope of the project.

1.2 Problem Statement

A Revenue License is issued for all vehicles by Department of Motor Traffic in Sri Lanka. The first Revenue License is offered by the Provincial Commissioner of Motor Traffic, Western Province for all the vehicles, with certain exceptions to Motorcycles and Three Wheelers. As this Revenue License is valid only for a one year, from the second Revenue license onwards, prior to expiration of that one-year period, every vehicle owner is required to renew their Revenue License. This is done at the Divisional Secretariat Office that is relevant to the address in official documentations (Issue Revenue License, 2020). Therefore, every year, vehicle owners must go through the process of renewing their vehicle Revenue Licenses. There are many problems related to this process which is discussed in detail.

1.2.1 Forgetting the renewal dates of the Revenue License.

The renewal date of the License is not the end or the beginning of the year, even though it would have been convenient. The expiration day is the day you took your first Revenue License. Currently there is no mechanism of reminding the drivers on the renewal date, hence there is a possibility that drivers tend to forget it. (In discussion with N.W.A.D Dias, SI of Traffic Branch and Officer-In-Charge of Traffic Branch, Sri Lanka Police, Galle)

1.2.2 Inability of pre-identifying the Violators

The key problem identified is the inability of police and local authorities of knowing when a Vehicle Revenue License is expired. There is no proper coordination among the Department of Motor Traffic and the local police. Therefore, Police would not be aware if a vehicle has an expired Revenue License. Hence, as mentioned earlier, Police have to continually conduct random checks on vehicles. This is very ineffective and tiring task for Police officers. Also, most of the vehicles would go unnoticed due to this inefficient system in Sri Lanka. (N.W.A.D Dias, SI of Traffic Branch and Officer-In-Charge of Traffic Branch, Sri Lanka Police, Galle)

1.2.3 Issue in monitoring the revenue gain from Revenue License

Vehicle Revenue Licenses are a vital revenue source of the country. However, since the payment process is not coordinated and there are no fixed dates for payment of this fee, this income cannot be properly monitored. There is no way to identify the income received by the Department of Motor Traffic within a day, week or a month, from Revenue License Renewals. Further, as mentioned above, there may be vehicle owners who have delays in paying the Revenue License fee by months, and they would go unnoticed by Authorities. This is a huge loss and delay of income to the Divisional Secretariat Offices and the Department of Motor Traffic of Sri Lanka. (Akalanka Kariyawasam, Chief public Management Service Officer, Department of motor traffic southern province, Galle)

The reasons for being unable to identify the drivers with invalid Revenue License have been identified in the cause-and-effect diagram which is given below.

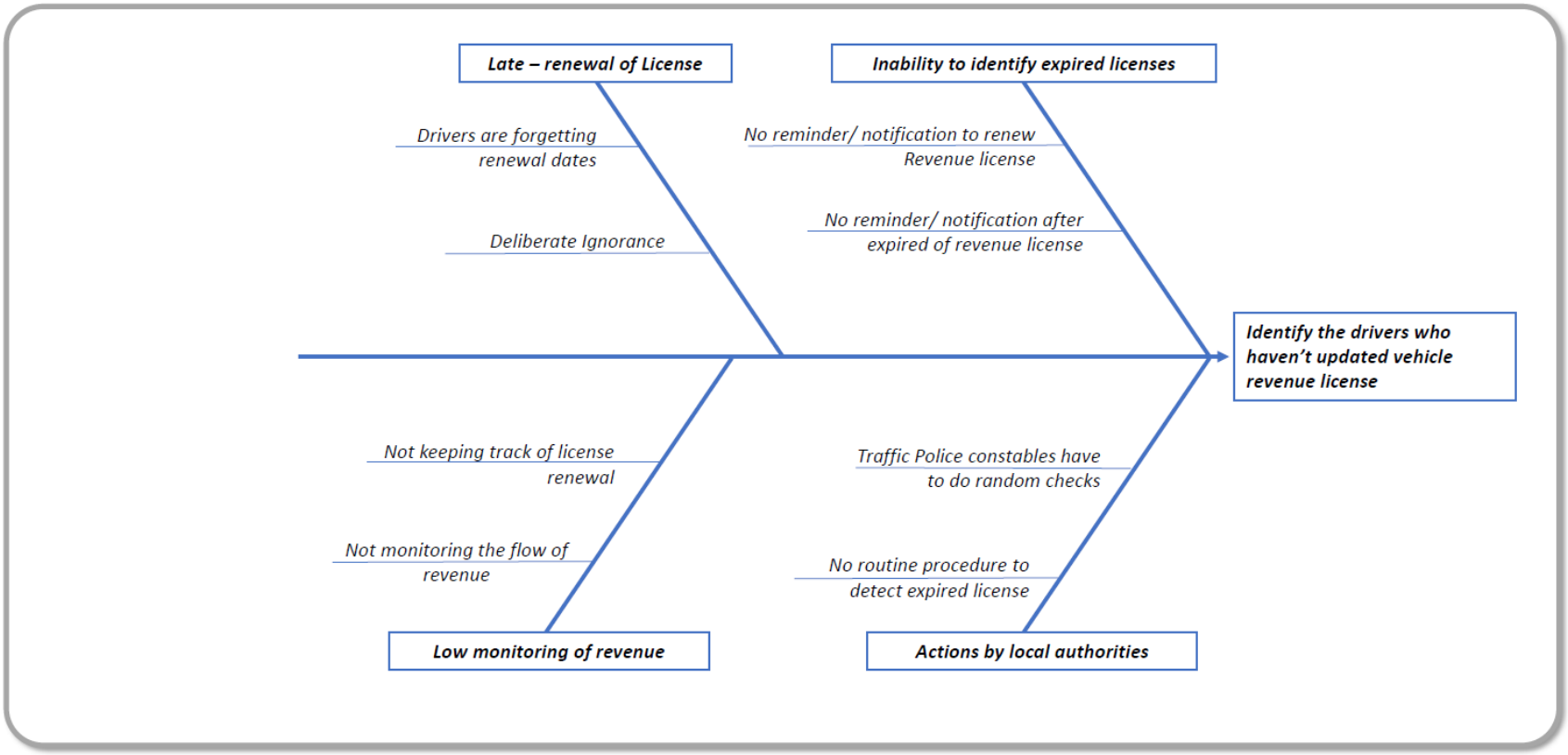

Figure 1-1: Cause and Effect Diagram

The below rich picture showcases the current procedure of issuing and renewing the revenue license as well as process of identifying and enforce the law against the violators in Sri Lanka.

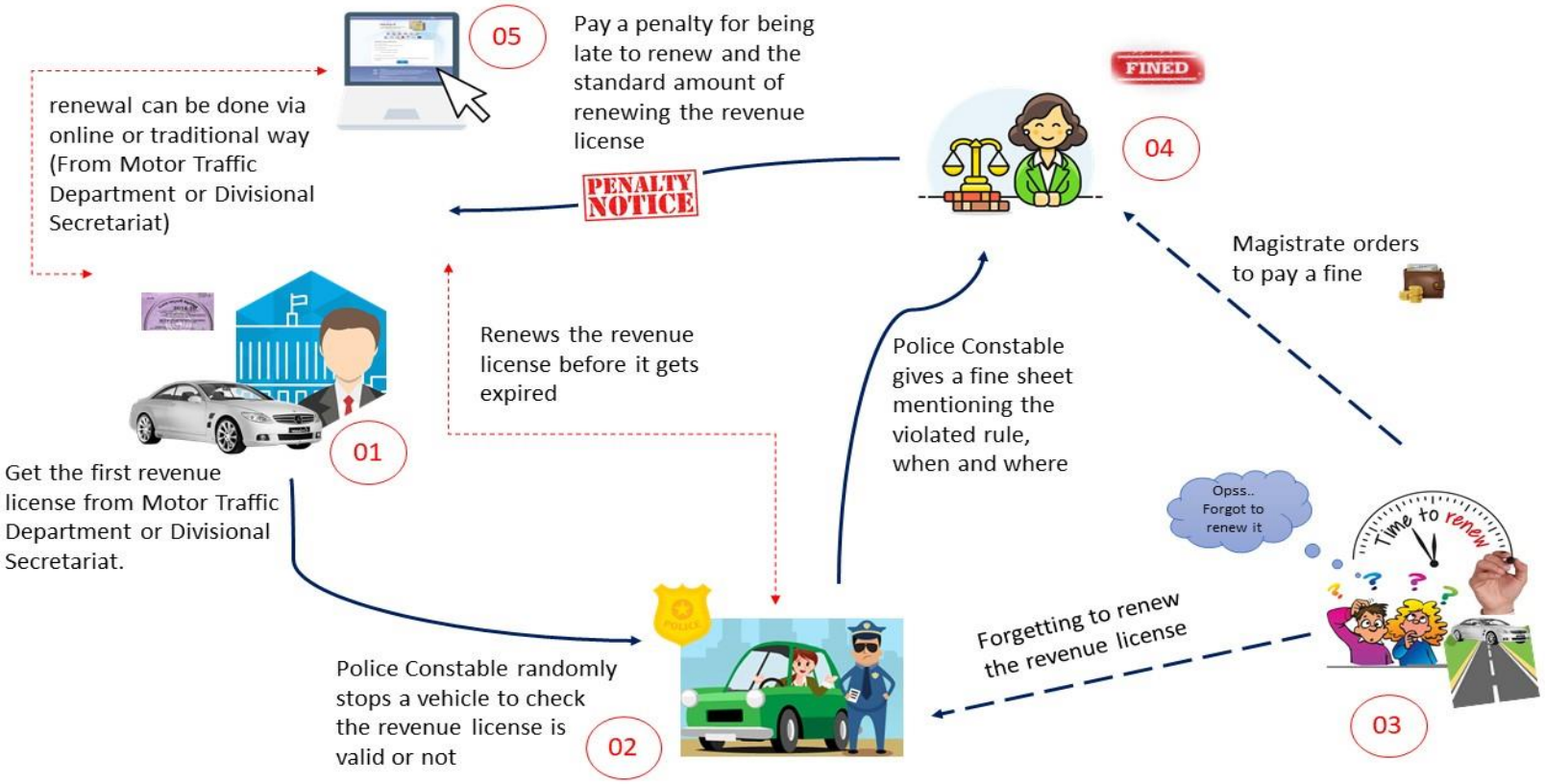

Figure 1-2: Rich Picture

1.3 Aims and Objectives.

1.3.1 Aim

To analyze and identify the vehicles without having a valid Revenue License and to design, develop and evaluate a solution for local authorities to track the vehicles driven without a valid Revenue License and to notify the vehicle owners to renew their Revenue License on time.

1.3.2 Project Objectives

ID	Objective
PO1	Carry out initial research on the project idea in order to successfully complete and obtain approval for the Project Initiation Document (PID),
PO2	Conduct research on existing ideas, existing systems which are published and do a check on areas where to improve to be unique.
PO3	Check on the clarity of the information and data gathered to conclude on the idea.
PO4	Identify an appropriate approach and methodology for project management and for the development of the solution.
PO5	Design and conduct an industry survey in order to get an input from the stakeholders of the project.
PO6	Prepare the Software Requirement Specification (SRS) with the help of gathered requirements through literature and industrial survey.
PO7	Design and develop the proposed IT solution based on the feasibilities of platforms where the solution can be deployed.
PO8	Test the developed prototype and make sure most part of the identified key problem and the solution for it has been covered though the prototype. Use different testing techniques – Ex: Blackbox Testing, White Box Testing
PO9	Self-evaluate the developed prototype against the expected outcome of the solution.

PO10	Evaluate the prototype with the help of industry experts, academics and find the future enhancements.
PO11	Submit the finalized Project along with the other documents which are related to the provided solution.

Table 1-1: Project Objectives

1.4 Chapter Summary

One of the key problems that this chapter defined is the inability of the local authorities to pre-identify the revenue license violators and the issue in reminding vehicle owners to renew revenue license before they get expired. The next chapter will discuss the background to the problem.

Chapter 2: Background

2.1 Chapter Overview.

This chapter presents a literature of vehicle revenue license, how it is being issued and renewed, revenue gain by the vehicle revenue license and enforcing the law against violators. Further, theories and technologies which is utilized to identify the revenue license violators will also be addressed with their features.

2.2 Vehicle Revenue License.

2.2.1 Introduction to Vehicle Revenue License

Term "Vehicle Licensing" or "Vehicle Revenue Licensing" refers to a fee that every vehicle owner must pay due to using their vehicles on public roads (VTNZ-Limited, 2020). No matter what type of a motor vehicle you own, prior to drive on roads it is mandatory to obtain a Revenue License as per mentioned in the Motor Traffic Act in every country including Sri Lanka (Department-of-Motor-Traffic-WP, 2020). Further, it is every vehicle owner's responsibility to carry the vehicle license certificate and they must be able to provide proof upon request at any time. (Department-of-State, 2017). By referring to a Revenue License of Sri Lanka, you can know information contains in it such as License Number, Class of Vehicle, Fuel Type, Vehicle Number, Name and address of the owner, Gross (Unladen) Weight of the Vehicle, Number of Seats, Annual fee of renewing the License and Fines paid due to late renewals/ Arrears which has been taken forward, Issued date and the expiry date. Moreover, in Sri Lanka it is a must to paste a copy of the revenue license in windshield while the vehicle owners in countries like USA have to paste a validation sticker on their rear license plate and it might get changed according to the state that the vehicle has been registered and this validation sticker only represents the month and year of expiry. Even if a vehicle which is registered but have not attached the validation sticker on the plate, will be considered as an invalid License Plate in states like Ontario, US (ontario, 2020). When it comes to New Zeeland, every vehicle owner must stick the respective vehicle's "license label" on left part of the windscreen (NZ-Transport-Agency,

2020) and this “license label” includes the majority of details which Sri Lankan Revenue License Includes (Satyanand, 2011). There are countries like Pennsylvania who has been issuing the vehicle registration stickers for some time but has eliminated it after identifying that there is no impact on vehicle registration compliance (Commonwealth-of-Pennsylvania, 2020).

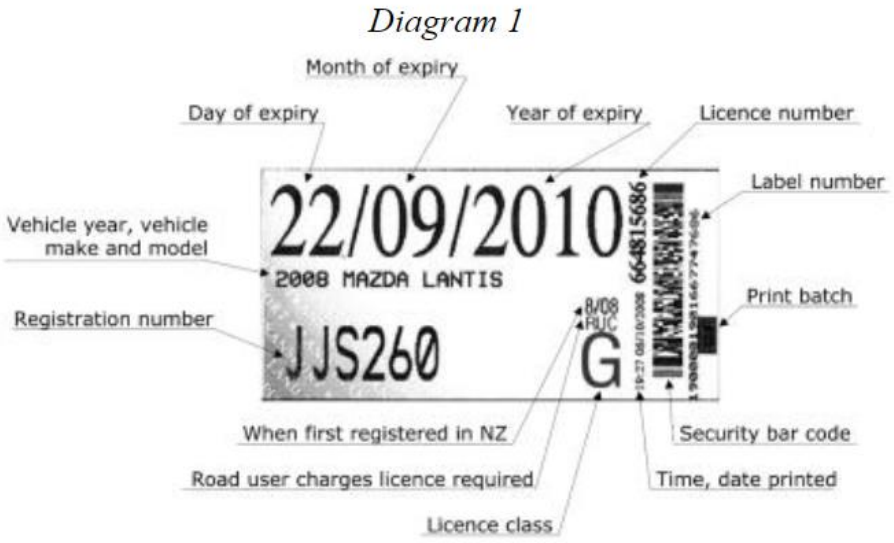

Figure 2- 2 : License Label Diagram of New Zealand

2.2.2 Where to obtain the Revenue License.

Very first vehicle license of any motor vehicle in Sri Lanka except Three Wheelers and Motorcycles are being issued by Provincial Commissioner of Motor Traffic, Western Province. From second license onwards vehicle owners in Sri Lanka have the capability of obtaining it either by physically being into respective Motor Traffic Department or any Divisional Secretariat. As recently Sri Lankan government introduced “eRevenue License System”, now the vehicle owners are eligible to obtain their vehicle revenue license via online. This System was introduced as Whole-of-Government system (UN, 2012) where

more than two government organizations of Sri Lanka are working together in order to provide a better service.

2.2.3 Procedure and Prerequisites of renewing Revenue License.

The prerequisites and procedures to be followed by a vehicle owner in renewing a Vehicle Revenue License may vary from country to country. In Sri Lanka, every vehicle owner must provide following documents in order to obtain the Revenue License (Government-Information-Centre, 2020).

- Certified copy or originals of registration certificate of motor vehicle.
- Obtained Revenue License in previous year.
- Valid vehicle insurance policy certificate.
- Fitness certificates for Commercial Vehicles.
- Passenger Service permits for Omni Bus.
- Valid Emission Test certificate (ETC).

Above requirements will get changed according to the country that a person lives in. In New Zealand it is required to have either WoF or CoF prior to renew the Vehicle License instead of the ETC. These two certificates' states whether a particular motor vehicle is safe and eligible to drive or not. As a developed country, states in USA such as New Jersey requires very limited number of documents to be taken to the MVC (New-Jersey-Motor-Vehicle-Commission, 2020).

Reminding the vehicle owners prior to expire their Vehicle License is an opportunity that certain DMVs in foreign countries has given to the vehicle owners and this is something Sri Lankan Motor Traffic Department has failed to do. Waka Kotahi, the transport agency of New Zealand is keep sending emails and mails by post, four weeks prior to expire any particular vehicle license. If still a vehicle owner forgets or neglects to renew the license the transport agency of New Zealand will keep sending reminders in six weeks and six months after the expiration. In Sri Lanka the status of the vehicle license can be checked either by sending a SMS to 1919 or visiting the official website of DMT (ICTA, 2014).

In Sri Lanka, vehicle owners are capable of either physically being in to a DMT or visit the official website to renew their vehicle license. Comparing to the other countries like USA, Australia, New Zealand certain DMVs have enabled the vehicle owners to renew the Vehicle License over the internet, via self-service Kiosks, walk-in to an Emission Station or either by Fax or Mail.

2.2.4 Revenue gain by Revenue License

It is bit hard to obtain the specific numbers, but by the end of 2016, it was estimated that there are nearly 1.4 billion motor cars including other vehicles such as busses and trucks (Chesterton, 2018). Research Department of Statista reveals that majority of the motor vehicles are being used by United States of America and they are growing the number of motor vehicles by nearly 17 million in every year (Statista, 2020). In Sri Lanka total number of registered vehicles were increased from 367,303 and by the end of 2019 vehicle population of Sri Lanka exceeded 8 million (Ministry-of-Trasnport, 2020).

New Registration

Year	2015	2016	2017	2018	2019
Motor Cars	105,628	45,172	39,182	80,742	38,232
Motor Tricycle	129,547	56,945	23,537	20,003	15,490
Motor Cycles	370,889	340,129	344,380	338,433	284,301
Buses	4,140	2,685	3,331	2,963	1,613
Dual purpose vehicles	39,456	26,887	16,742	17,116	13,459
Motor Lorries	6,602	7,229	11,432	8,914	5,223
Land Vehicles-Tractors	10,517	10,285	8,821	7,459	5,696
Land Vehicles-Trailers	2,128	3,996	4,228	3,063	1,970
Quadricycle	-	-	-	645	1,318
Motor Home	-	-	-	02	1
Total	668,907	493,328	451,653	479,340	367,303

Figure 3-2 : Island Wide New Registrations Sri Lanka

In Sri Lanka, renewing a Revenue License is not the only source of income which is gain by Revenue License. Revenue gain from new registrations of vehicles, penalties which are collected for being late to renew the Revenue Licenses, issuing duplicates for the misplaced, distorted, or differed license also adds a significant amount to the revenue. This

was identified during the interview conducted with Akalanka Kariyawasam, Chief Public Management Service Officer, Department of Motor Traffic, Southern Province, Galle.

In Sri Lanka, the revenue gain from vehicles may vary from its vehicle type, weight, and the fuel type. Annual Revenue License renewal fee categorized by above mentioned criteria are given in the below tabular.

Motor Vehicle	**Tare (Unlade) Weight**	**Renewal Fee (Rs.)**	
		Petrol	**Diesel**
Motor Car Ambulance Hearse	001-762	2000	3100
	763-1016	2200	4000
	1017-1270	3000	6000
	1271 above	4000	8000
Motor Lorry Special Purpose Vehicle	0001-2000	1500	3000
	2001-5000	2000	4000
	5001-10000	2500	6000
	10001-15000	3000	7000
	15001-20000	4500	10000
	20000-25000	4600	12000
	25001-30000	6000	14000
	30001-above	7000	15000
Land Vehicles	0001-1778		450
	1779-2032		900
	2033-2510		1100
	2511-3048		1300
	3049-3500		1550
	3501-5080		1650
	5081-15240		2400
	15241-25400		2750
	25401-above		3300

Table 2-1: Annual Revenue gain from Motor Vehicles in Sri Lanka

Methods of revenue which are gaining from vehicles such as SLTB buses, Omni Buses and private motor coaches are charged according to number of passenger seats which are available in those vehicles. Further, renewal fee of motorcycles and three wheelers are

fixed, and they are respectively Rs.700 and Rs.750. In Sri Lanka, all the Revenue Licenses of vehicles which belongs to Sri Lanka government, Provincial Councils and foreign diplomats will be issued for free of charge.

In USA, the annual or biennial registration fee may vary from state to state, where majority of the state's charge flat rate while other states consider the criteria like weight, value, age of a motor vehicle (NCSL, 2020). The following map presents how the Revenue License fee get differed from other states according to the criteria that they consider on.

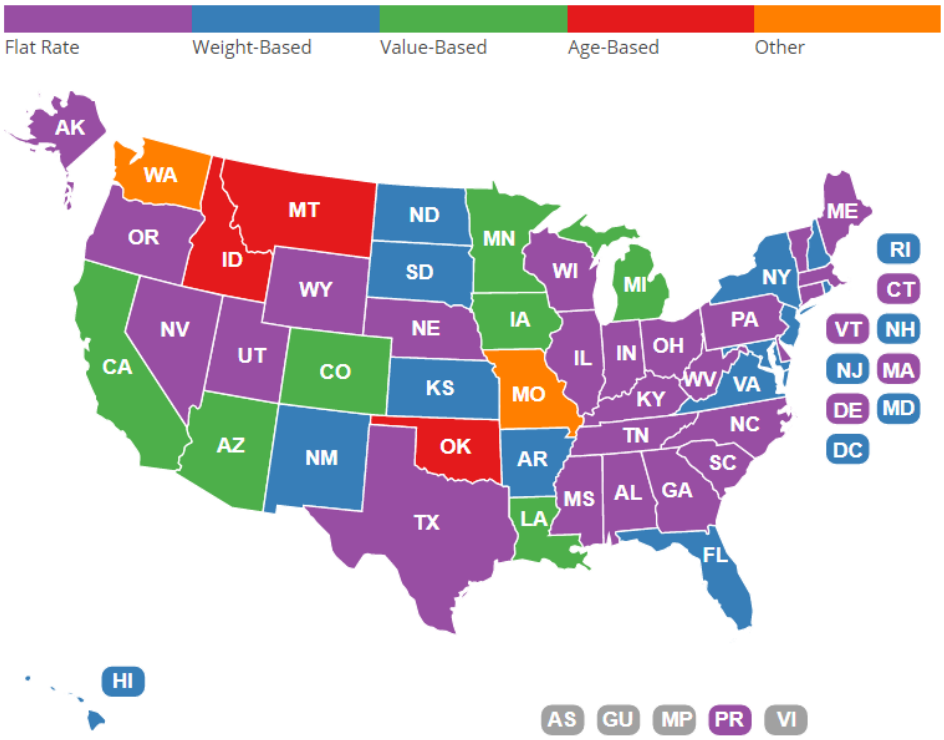

Figure 2-4: Considerations of issuing, renewing a vehicle license and its fee.

2.2.5 Enforce the law against offenders.

In Sri Lanka law enforcement is carried out by the authorities on different violations related to Revenue Licenses by the local authorities. A person is termed to commit an offence if the person is driving an unregistered vehicle or using it on the road which is not licensed

in accordance with part 17 of the Act, Land Transport (Motor Vehicle Registration and Licensing) Regulations 2011 of New Zealand (Satyanand, 2011). There are additional clauses in the act which makes a driver liable to offenses. If these clauses are not satisfied, then the offender would be either fined or appropriately punished, based on type of offense (Satyanand, 2011). There are similar conditions of enforcing law against offenders in Sri Lanka, based on Penal Code of the country. There are fines imposed on late registrations, late vehicle taxes etc. according to the USA laws (Satyanand, 2011).

There are manual systems of law enforcement that is used in Sri Lanka. However, in other countries there are suggested and in use systems of law enforcement against offenders, through digital, smart systems.

A vehicle violation enforcement and noticing system, which has obtained a patent in USA, is expects to allow identification of vehicles and retrieves the vehicle information pertaining to the identified vehicles (Marchasin, et al., 2010). With the manual enforcement of law against offenders, there are some key issues that arise, such as missing out of some key offenders, inefficient enforcement of law against rule breakers etc.

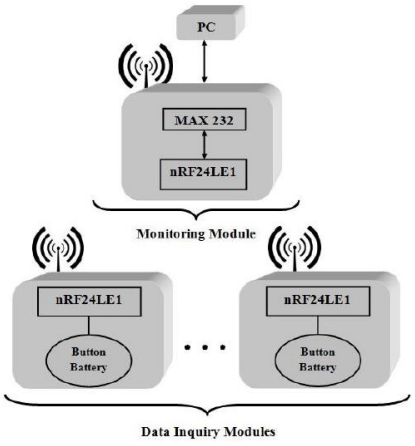

Figure 2-5: Electronic Vehicle sticker system – USA.

Therefore, A Low Power Electronic Sticker for Vehicle Identification System using Proprietary Active RFID Wireless Protocol, is a research on a system which facilitates

easier detection of offenders by the local authorities (Karabacak, et al., 2013). This research is based in USA, which is therefore designed to suit the existing system of the USA.

Further, when an offender is needed to be tracked, there are systems designed to support the Police on that process. Patented innovation in USA, System for Registering and Tracking Vehicles is focused on this purpose of tracking offenders (Kovach, 2005) .

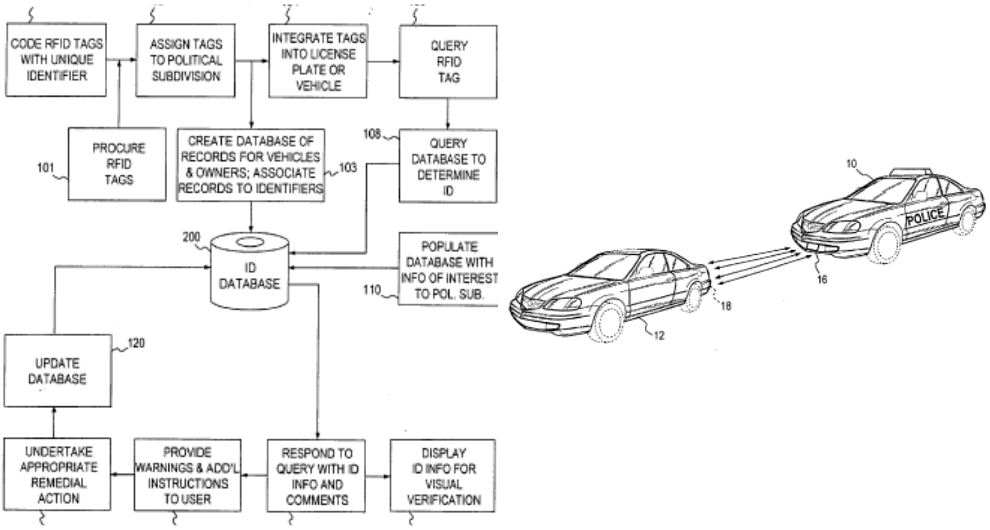

Figure 2-6: System for vehicle registering and Tracking – USA.

There are many different recognition systems and detection systems which are innovative solutions for the problem of detection of frauds, offenders and other issues related to vehicle licensing. One such system is Rf Electronic License Plate and Information System for Vehicle Tracking, a patented product in USA for overall detection of different types of vehicle related regulations. This is a Radio Frequency based tracking system, build with the integration of roadside receivers and information system architecture (Estus, et al., 2003). This system overview is shown in fig.6, as designed by the inventors of this system.

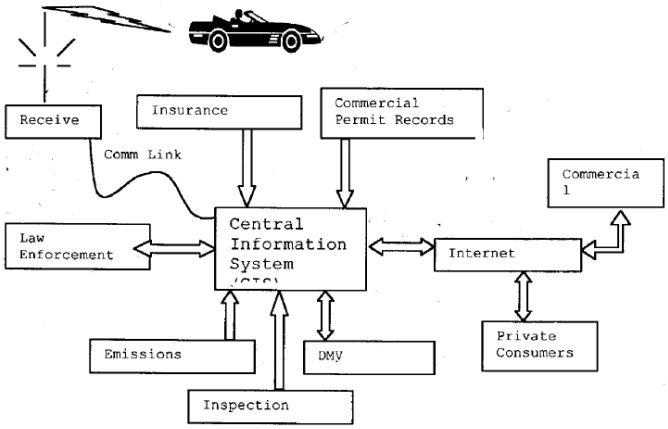

Figure 2-7: Rf Electronic License Plate and Information System.

After the research sited above (Estus, et al., 2003) , there have been many different, advanced systems developed by other innovators and authors over the years. Out of these, some of the key researchers are elaborated in the next section of the Literature review, in order to obtain a technological insight of the existing solutions.

2.3 Theories/ models used to identify traffic violations.

Different vehicle related licensing policies around the world are met with innovative technological concepts, with the aim of improving user experience, efficiency, and effectiveness in implementation of such policies. There are many systems such as ALPR, ANPR and other key technologies which are used in vehicle licensing and tracking systems. These are highly advanced solutions, to support the local authorities in ensuring the laws and regulations are met.

License plate detail processing is a key focus area of research, which has paved way for some patented innovative products to be developed in the USA. Electronic license plate and information processing system is one such technological solution (J.Lukawitz & Stevens, 2011). It is presenting a system for identifying specifically associated vehicles, as well as for the purpose of acting as a media in publishing messages associated with the vehicle.

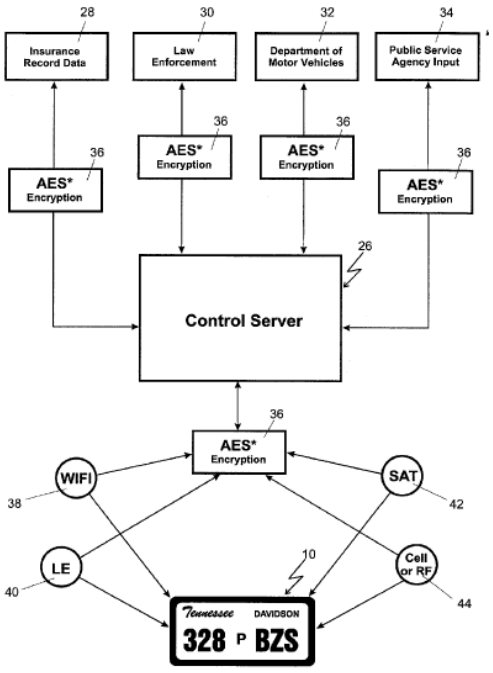

Figure 2-8: Electronic Vehicle plate system in USA.

ANPR or Automatic Number Plate Recognition systems are used for the purpose of mass surveillance. They are used for many different purposes such as automated traffic surveillance tracking, secured automation process in gas stations etc. (Ananth, 2016). This process is mostly used in Developed countries like USA. However, this particular research focuses on deployment of the ANPR based solutions for developing countries.

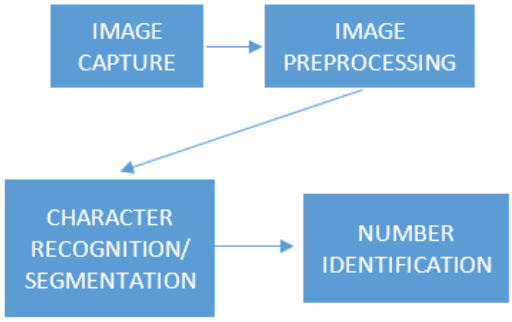

Figure 2-9 Deployment of ANPR systems.

ALPR systems, also similar in context to ANPR, stands for Automatic License Plate Recognition. ALPR systems consists of three stages as license plate localization (LPL), character segmentation and optical character recognition (OCR). In this particular research, an improved LPL algorithm is proposed, with a high and accurate detection rate.

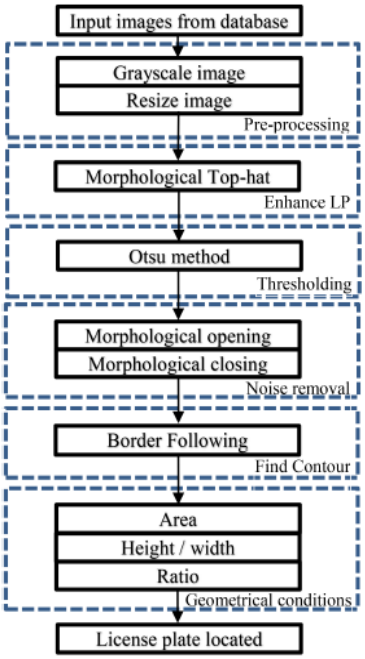

Figure 2- 10 : Improved LPL Algorithm

This system is designed for low-cost devices such as Raspberry Pi (Yepez & Seok-Bum Ko, 2018). ALPR systems when properly utilized and implemented, can be used for different purposes. But ALPR systems require a high-performance workstation to work. However, with this new LPL suggested, ALPR would be implemented in low computational power devices (Yepez & Seok-Bum Ko, 2018).

The research, Image Recognition Technique of Road Tax sticker in Malaysia proposes a new image recognition technique (Alharaki & Zeki, 2013).

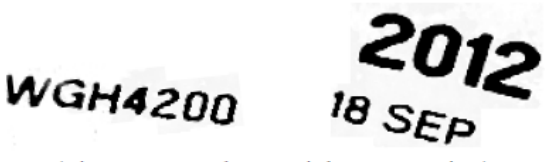

Figure 2-11: Vehicle tax sticker format extracted - Malaysia.

This is designed with the expectation of validating car Road Tax information. This RTR System is expected to have greater efficiency for vehicle monitoring system at Toll Gates in Malaysia (Alharaki & Zeki, 2013). RTR or Road Tax Recognition systems are used in the countries, that are in need of optimizing their law enforcement regarding the vehicle revenue. In Malaysia, this system is used for the implementation of a highly accurate detection of different tax related offences by drivers, done intentionally and unintentionally. Therefore, it also serves as a system of warning the drivers for expiration of tax stickers and renewal on due dates (Alharaki & Zeki, 2013). But the drawback of this system would be that it is not focused on warning the drivers when the expiration dates are close. Instead, the system is directly linked with local authorities to punish the offenders.

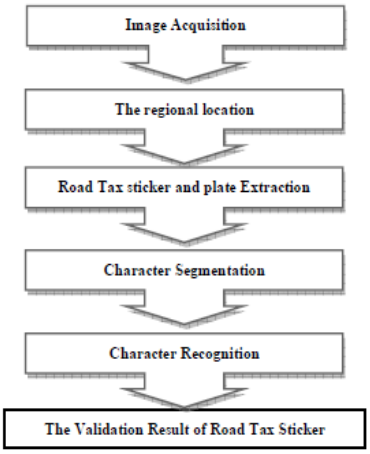

Figure 2-13: Sticker validation system in Malaysia.

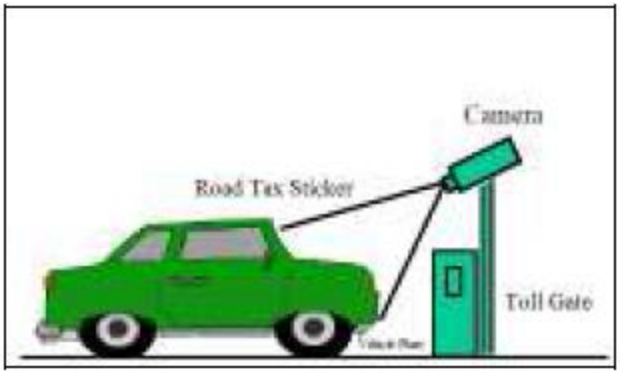

Figure 2-12: Road Tax Sticker system in Malaysia

In Saudi Arabia, a more complex system of License Number plating exists, due to population and other reasons. Therefore, it is difficult to use the normal ALPR systems in that country (Alzubaidi, et al., 2019).

Figure 2- 14 Complicated vehicle plates in Saudi Arabia.

Therefore, an affordable and portable device, which capture and identify vehicle plates real-time has been designed. This device is based on SoC (Single board Computing).

A Smart Vehicle Registration Certificate Prototype has been developed using RFID. This system is aimed on Indonesian system of vehicle traffic control. (Widiasari, et al., 2018) Indonesian system of registration is not remote or wireless, which is the key target of this research. This system is based on RFID. A smart label is developed with the object identification system, to be attached to the vehicle. It has the capability to collect vehicle registration details wirelessly.

It is highly problematic in some countries to find the overdue taxpayers related to vehicles, without a manual checking by the local police (Chen & Cheng, 2009). Rough sets fusion model which is Delphi based is introduced by a group of researchers in Taiwan, which is aimed to extract License Tax rules of the government.

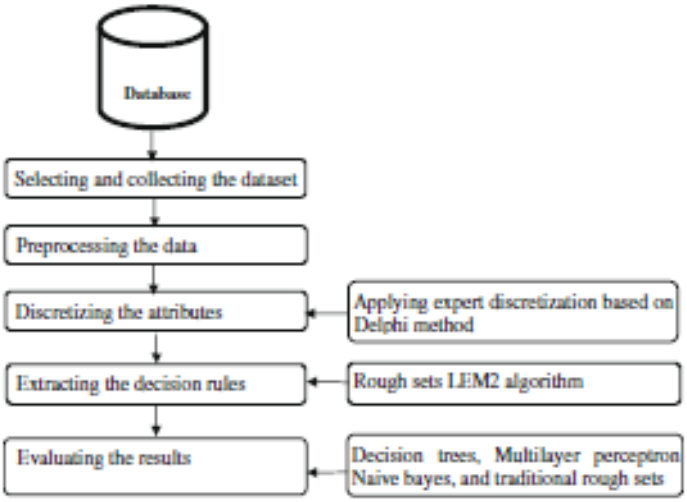

Figure 2-15: proposed Delphi based system – Indonesia.

Digitalization of obtaining the different certificates and renewal license is a key factor in the e-governance process. When the government structure is digitalized, it is more convenient and efficient for the citizens to obey the rules and regulations in a country (Li, 2010). Therefore, different e-licensing, digital ALPR systems, online license renewal systems are very important innovations for the particular countries.

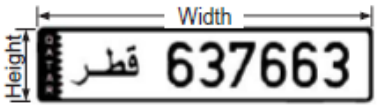

Fig. 2. Qatari NP

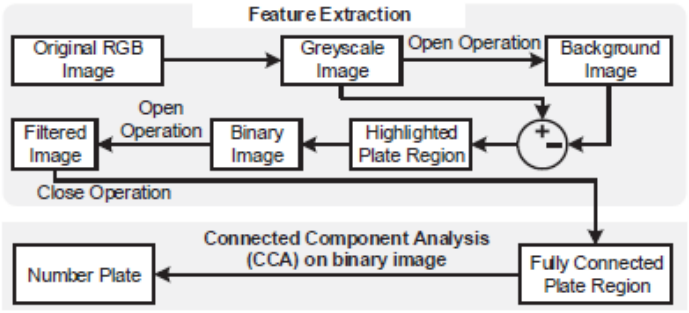

Figure 2-16 Proposed SD NPL algorithm - Qatari Number plate.

In Qatari based research, an HD ANPR system has been suggested, so that HD cameras can be used for the automatic number plate recognition. Their argument is that the existing ANPR are not supportive of HD real time number plate recognition. Therefore, a new set of algorithms are proposed for more effective Number plate localization (NPL) (Hommos, et al., 2016).

There are several research cited and detailed above related to ANPR, ALPR systems of different countries, based on different technologies. There are researches that have compared such technologies, analyzed the effectiveness, and identified the most effective methodologies (K.B.Sathya, et al., 2017). There are three parts of an ALPR system as Number plate localization, OCR and vehicle plate recognition. In figure 2-16, a summarized evaluation of the different technologies used for every component of the VLPR systems is included (K.B.Sathya, et al., 2017) .

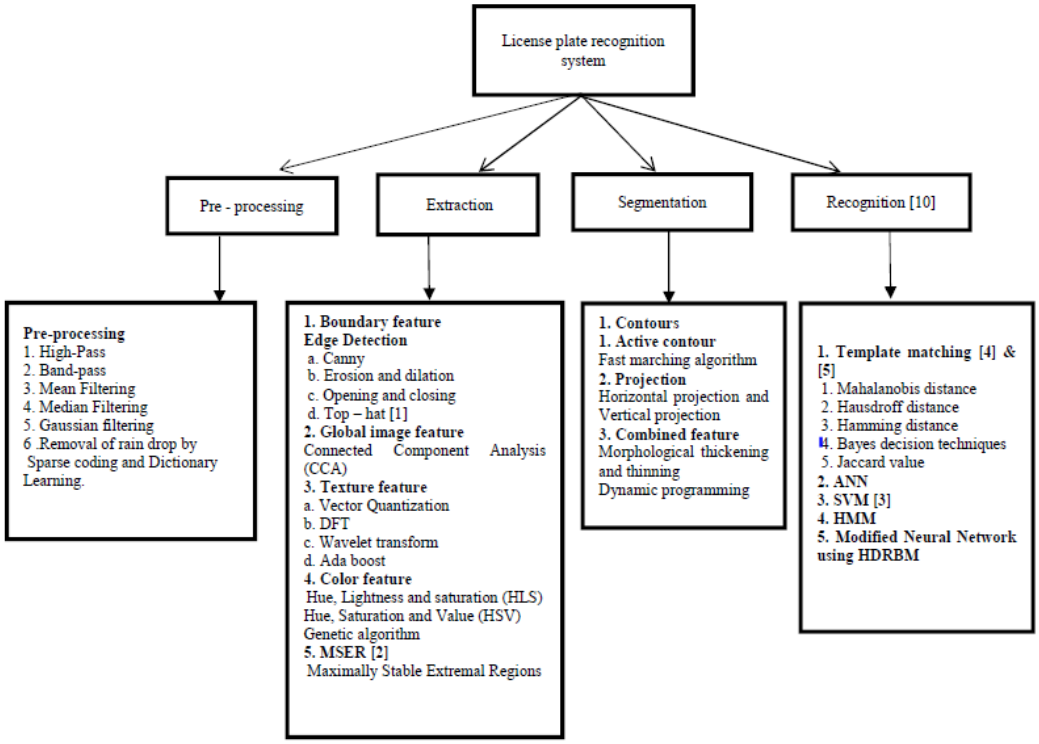

Figure 2-17: Taxonomy of VLPR systems.

After the evaluation of different possible approaches, there is a methodology proposed for a more effective VLPR. The challenges posed by existing different methodologies can be overcome by this technique (K.B.Sathya, et al., 2017). This methodology is shown in figure 2-17.

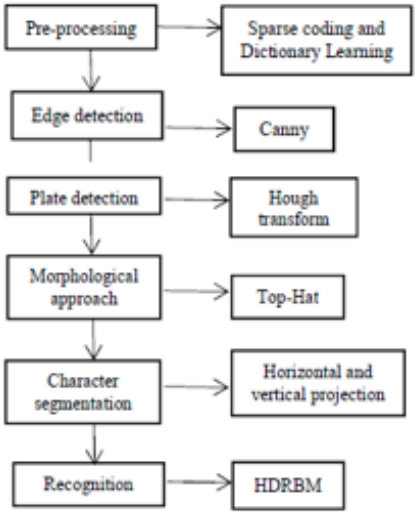

Figure 2-18: Efficient VLPR System

As included in figure 2-17, researchers have identified most suitable technologies for each of the components of an efficient VLPR system. For the pre-processing of images, Sparse coding and Dictionary Learning is to best to be used. For the edge detection Canny system, for the plate detection Hough transform, Morphological approach would be Top-Hat, Character Segmentation through horizontal and vertical projection and recognition through Hybrid Discriminative Restricted Boltzmann Machines (HDRBM).

Therefore, through different literature cited the literature review consists of few key points to be highlighted. First the different types of vehicle licensing that is used in different countries and regions could be identified. This has discussed varies from region to region based on the laws of the country and the governance structure. Then the licensing and taxing payments were discussed and elaborated based on details again from many different countries and regions in the world.

Then the way offenders are fined and punished, when vehicle licensing related crimes are done was discussed, with literature available from sri Lanka and other countries. Here it could be identified that there are digital tools in identifying and alarming the local authorities about possible offends related to vehicle licenses. Therefore, finally, several such systems were analyzed and compared to identify research gaps and other key factors.

2.4 Review of existing projects/ Applications.

Existing solutions were critically evaluated prior to initialize the development for identifying, track and enforce the law against revenue license offenders. As there are no existing method which is focused on pre identifying and tracking "Revenue License Violators" the proposed solution was critically evaluated against the existing systems which is out there to identify the motor traffic offenders. Comparison of existing applications against the proposed solution has been shown in the below tabular.

2.4.1 Comparison the features against existing (published) applications.

	Published Solutions				**Proposed Solution**
	Traffic Violation Detection by Hikvision (Web based)	**LOGIPIX (Web based)**	**SmartCop (Web / iOS/ Android)**	**VehiScan by Vehant Technologies (web)**	**I-Sense**
User Registration.		✔		✔	✔
Real time offender tracking.	✔	✔	✔	✔	✔
Report offenders to respective parties. (Police Officers)	✔	✔	✔	✔	✔
Notify violator's vehicle details.	✔		✔	✔	✔

Share live location of an offender's vehicle.					✔
Notify the amendments regarding motor traffic law.			✔		✔
Remind vehicle owner prior to expire vehicle revenue license.					✔
Notify vehicle owner regarding the offence.					✔
Allow offender/ vehicle owner to Pay fine.					✔
Provide Offence History.		✔			✔
Generate Reports.		✔	✔	✔	✔

Table 2-2: Comparison of functionalities against existing solutions.

2.5 Review of tools and techniques.

Following tools and techniques were utilized in order to carry out successful research and develop the proposed solution.

2.5.1 Fact-finding Techniques.

Technique	Description
Background Reading	Online resources such as websites, conference papers, statistical reports, journal articles were referred to get a thorough background knowledge. This could be considered

	as the most effective technique of finding the elementary information which were based to initialize the project.
Literature Review	Accessing and reading number of journal articles were used as a fact-finding technique. This was helpful to identify the related products and applications which has been implemented so far to solve the addressed problem.
Questionnaires	A well-designed questionnaire was circulated among vehicle owners and local authorities in order to retrieve their perspectives on the problem. This technique was helpful to gather large number of data and compare the feedbacks though it was cost effective.
Interviews	Piloting one-to-one interviews with senior employees (in both Galle Police Headquarters and Southern Province Motor Traffic Department) were used as a technique of obtain the thoughts of them. Further, gathered information by conducting interviews were used to improve the solution and clarify on ambiguous

Table 2-3: Fact finding techniques.

2.5.2 Project Management Techniques.

Technique	**Description**
Work Breakdown Structure (WBS)	This could be considered as a productive technique which is used for project planning. Breaking the whole project in to smaller tasks were helpful to increase the manageability and approachability. Well organized structural view gives a clear impression of the things which will be covered throughout the project. Experience gain by using previously was a reason to choose this technique.

Grantt Chart	This was used to schedule the project tasks. Further, this technique indicates the tasks to be done with their respective time period/ deadlines. Familiar of the technique was a reason to choose this.

Table 2-4: Project Management techniques.

2.5.3 Design and Development Techniques.

Technique	Description
Use Case Diagram	This technique was used to represent the interaction between the features of the proposed applications and respective actors (Both internal and external) who are involved with the feature. Further, this UML diagram clarifies both generalized and specialized function performed by each actor.
Class Diagram	Class diagram will be illustrated based on object-oriented approach. This technique is used to represent the attributes, classes, operations, and relationship among classes. Further, this technique is used to visualize the system structure in a descriptive way.
Activity Diagram	This technique was used to represent the flow of control in the proposed system. Further, steps in the Use Case Diagram will be illustrated in more elaborated way while bringing the dynamic aspects of the proposed solution.
Wireframes	Motive of utilizing this technique is to visualize the interfaces of proposed solution. Moreover, this technique was used to fulfill the UI requirements prior to develop the proposed solution.

Table 2-5: Design and development techniques.

2.5.4 Tools.

Purpose	Tool(S)	Justification
Project Management	Microsoft Project	Experience and familiarity of using this tool since level 5 was a reason to select.
Documentation	Microsoft Word	Capability of editing, formatting, way easier than the existing word processing software's was a key reason for choosing this tool. Moreover, Microsoft Office 365 Provides to work online and it make sure your data is being always saved in driv0e is quite an advantage specially when documenting a project.
Referencing	Mendeley Mybib	"Mendeley" was used to manage and store the accessed journal articles in a one place, while "Mybib" was used to cite the online resources such as websites in Harvard Referencing Style.
Data Collection	Google Forms	This was chosen due to its flexibility and accessibility. Ability to view in an infographic view on gathered information was also a reason to choose this tool.
Data Analysis	Microsoft Excel	Due to ease of access and visualize the data (Through charts and graphs) which are gathered from surveys was the main reason of choosing Microsoft Excel.
System Design	Astah	As this tool is available for free of charge and the experience of using this since Level 4 was a reason of picking this tool.

		Prior to select Astah, its easiness of use was also considered.
Wireframes	Adobe XD Balsamiq Wireframes Justinmind Prototyper	Both Adobe XD, Balsamiq Wireframes and Justinmind Prototyper were chosen due to hands on experience of using them.
Database	Mongo DB	Mongo DB is knows as one of the most reliable and stable databases. Moreover, it provides free hosting as it is a fully managed cloud database. So, these reasons were considered prior to select the database as Mongo DB.
Prototyping	InVision Studio	InVision is a software which is made to build only the prototypes. Hence it enables more advance features such as transitions and animations in order to build interactive prototypes.
Programming Language	Java	Programming Knowledge which were gain in level 4 was reason to choose Java as the scripting language.
IDE (Integrated Development Environment)	Android Studio	Android Studio IDE was chosen to develop the mobile application as it a free product but comes along with advance features such as advance debugging.

Table 2-6: Tools.

2.6 Summary.

This chapter presented the background of obtaining, renewing vehicle revenue licenses, and enforcing the law against vehicle license offenders. Further, theories, models, and similar applications that are used to identify the violators were discussed. Intended tools and techniques which are to be used in proposed solutions were reviewed and justified. The following chapter will focus on requirements elicitation while identifying the stakeholders.

Chapter 3: Requirements

3.1 Chapter Overview

This chapter presents the identified stakeholders of the project, analysis of the functional and non-functional requirements of the proposed system. Latter part of this chapter presents a discussion on legal, social, and ethical issues that are related to the findings of the proposed solution.

3.2 Stakeholder analysis

The identified stakeholders of the proposed system have been presented via an onion model in and each stakeholder's roles have been described in Table 3-1.

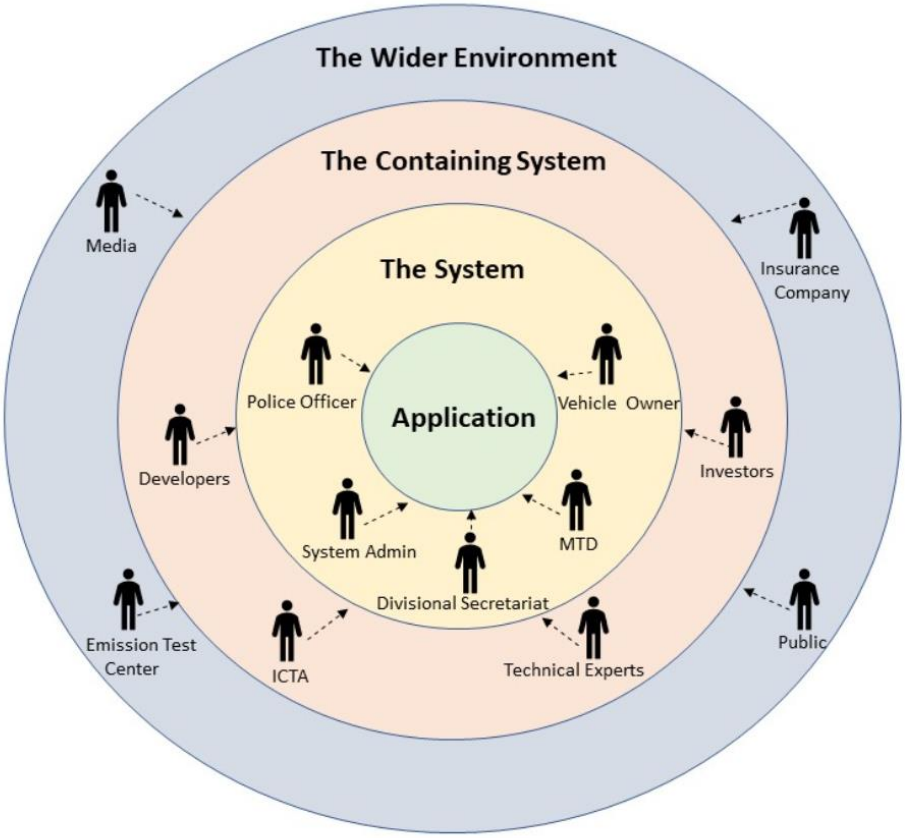

Figure 3-19: Onion model diagram of stakeholders

Application: This layer represents the solution that is being implemented. i.e., I-Sense	
The System: This layer represents the stakeholders who are directly interact with the application layer	
Stakeholder	**Viewpoint/ Interest**
Police Officer	Police officer will interact with the application to both enforce the law against a revenue license violator or to find the location of a vehicle which moves without having a valid revenue license.
Vehicle Owner	Vehicle owner will interact with the application to provide the necessary information on revenue license which will help them to receive a reminder prior to expire the revenue license. Apart from that fines or amount of registration renewals also can be paid through the application by a vehicle owner.
System Admin	System admin will interact with the application to allow the users to register to the application and authenticate the users.
MTD (Motor Traffic Department)	Motor Traffic Department (MTD) will utilize the proposed application to gather required certificates such as emission test certificate and insurance certificate from a user and issue a revenue license once paid.
Divisional Secretariat	Divisional Secretariat will utilize the proposed application to gather required certificates such as emission test certificate and insurance certificate from a user and issue a revenue license once paid.

System Admin	System admin will utilize the application to validate the provided certificates by a particular user, verify the money transfers and allow the Motor Traffic Department or Divisional Secretariat to issue a revenue license.
The Containing System: This layer represents the stakeholders who indirectly interact with the system but plays a role to control the system.	
Developers	Develop the application, perform regular tests to minimize errors, keep the application up-to-date and maintain the application are the main tasks which will be performed by the developers.
Technical Experts	Responsible for making effective decisions when choosing hardware components to build the IoT device.
ICTA	Information and Communication Technology Agency (ICTA) of Sri Lanka is the head ICT agency in Sri Lanka who is accountable for all ICT projects that are initialized by the government. As this solution is proposed for government, ICTA will act a major role when it comes to the implementation stage.
Investors	The individual or parties who have an interest and capable enough to financially support to make this project happen are identified as investors.
The Wider Environment: This layer represents the operational environment and includes. Stakeholders which contain in this layer have less interaction compared to the previous layers, but they are still important.	

Media	Media will be used to make awareness programs of the solution and reach out for a large audience immediately.
Insurance Company	Motor Traffic Department and Divisional Secretariat validates the Insurance Certificate provided by a vehicle owner when he/she requests via online. Hence, Insurance Companies should send all the certificates which they have issued in a day to the MTD.
Emission Test Center	Motor Traffic Department and Divisional Secretariat validates the Emission Test Certificate provided by a vehicle owner when he/she requests via online. Hence, Emission Test Centers should send all the certificates which they have issued in a day to the MTD.
Public	The response of the public and their willingness to adopt is important for the existence of the solution.

Table 3-1: Viewpoints of stakeholders.

3.3 Requirement Gathering

Questionnaires which were distributed among the vehicle owners and police officers, *Interviews* which were conducted with the relevant parties are the utilized requirement gathering techniques. Following is the requirement elicitation plan.

Objective	**Technique**	**Subject(s)**	**Time**
Background of the project	Background research	Journal Articles Published research papers	4 Weeks

Identify the current enforced rules and regulations regarding the revenue license.	Interview	Police Officer x 2	2 hours
Inability to identify the revenue license violators	Interview	Police Officer x 2 Officer, Motor Traffic Department	2 hours
How the current system works and its shortcomings	Interview	Officer x 2 Divisional Secretariat	3 hours & 30 mins
Awareness of rules enforced regarding revenue license, e-revenue license, and willingness to shift to the proposed system.	Questionnaire	Vehicle Owners x 54	1 week

Table 3-2: Requirement Elicitation Plan.

3.3.1 Sample Description

A questionnaire was distributed among randomly selected 70 vehicle owners (refer Appendix XX) and received 54 valid responses. The sample covered 77.8% of males and 22.2% of females out of which, 55.6% were Full-time employees, 16.7% not employed and 24.1% of self-employees. Of the 16.7% unemployed vehicle users, they owned it through family, or a previously owned vehicle maintained with minimal care. In summary, Figure 3-3 illustrates the employment status of the sample population taken into consideration. As the questionnaire results were obtained in a urban population based around Colombo, the data collected can be considered as quite the same as in key urban cities around most parts of Sri Lanka, where the vehicle use is at the highest in numbers.

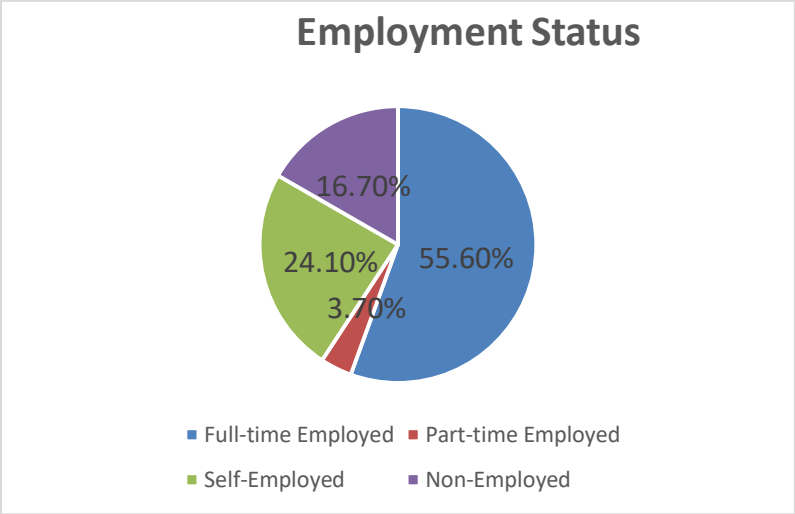

Figure 3-20: Employment Status

Figure 3-4 exhibits the type of motor vehicle which belongs to the participants of this questionnaire. As there is a possibility of having more than one vehicle by a citizen, the following chart may represent the vehicle owners who have the ownership of two or three type of motor vehicles among the varieties of motor bicycle, motor car, motor van. As per the responses received, 40.7% out of 54 participants own a motor bicycle while 74.1% participants own a motor car and 7.4% own a motor van. Numbers gathered up displayed a drastic difference between motor cars, motorcycles and other vehicle types with a dominant percentage for the said categories. These numbers can statistically be supported based on the numbers collected in 2018, with a percentage close to 60 (SRI LANKA SOCIO ECONOMIC DATA 2018, n.d.), being either a motor car or a motorcycle. Hence, the target audience approached here can be considered as quite a reflection of the majority vehicle owners.

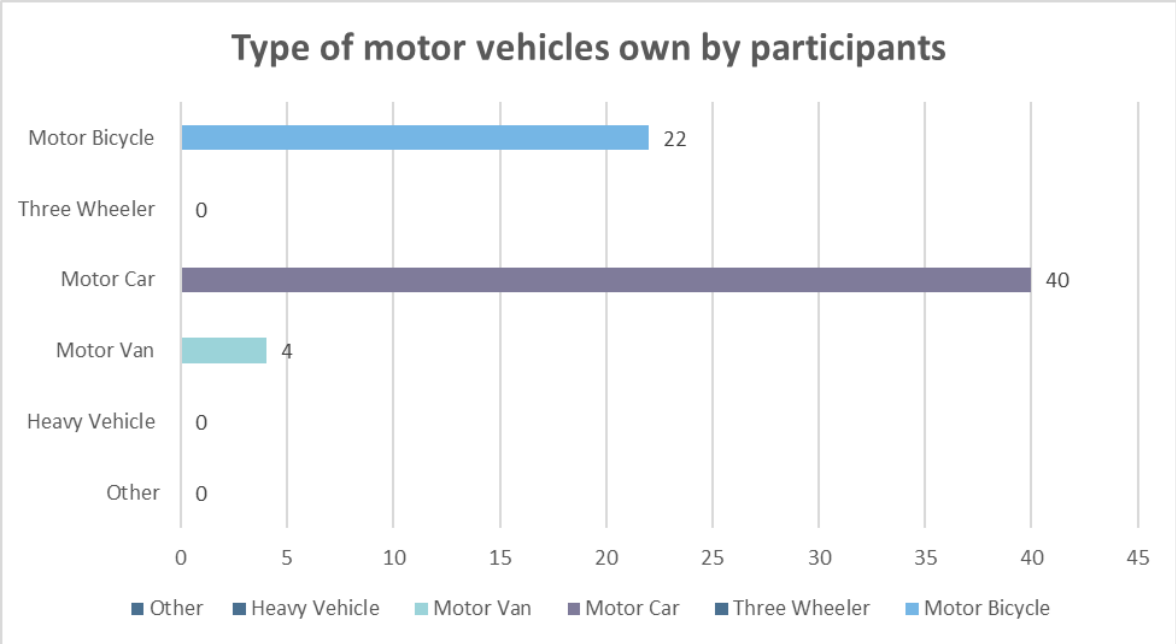

Figure 3-21: Type of motor vehicles own by participants.

Interviews were conducted with the following domain expert to gain in depth understanding of the problem. Interviews were conducted with five individuals occupied in the government departments who have a complete knowledge on how license renewal is done, and services accompanied. Below are the details of each Interviewee. Refer Appendix for interview notes for further information.

Interviewee	**Date and Time**
Akalanka Kariyawasam Chief Public Management Service Officer Department of Motor Traffic Southern Province	13th October 2020 2.30 PM
N.W.A.D Dias Sub Inspector, Traffic Branch Galle Police Station Southern Province	12th October 2020 2.00 PM
Janaka Officer in Charge, Traffic Branch Galle Police Station Southern Province	12th October 2020 2.45 PM

Nelum Senadiratne Assistant Divisional Secretary Dehiwala Divisional Secretariat Western Province	1st February 2021 11.00 AM
Thushari Liyanage Enforcement Officer Dehiwala Divisional Secretariat Western Province	1st February 2021 11.30

Table 3-3: Details of Interviews.

3.3.2 Analysis and findings

3.3.2.1 Awareness and Legitimacy

In the distributed questionnaire, questions were included to analyze the awareness and legitimacy of the vehicle owners regarding the vehicle revenue license. The statistics below display how knowledgeable the sample set was on what documents they should have with them along with the Driver's license and awareness they have on the other supporting documents they should carry along with it. Among the respondents 88.9% know that they should carry revenue license with them whilst driving.

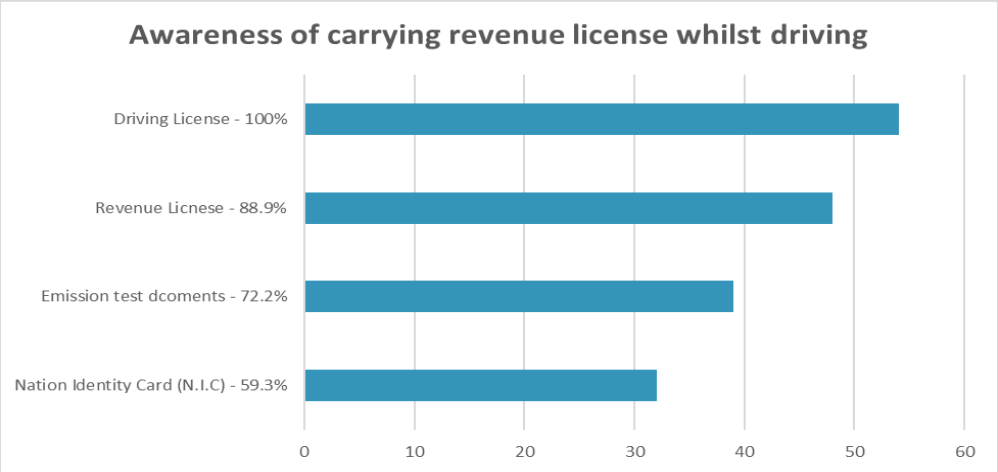

Figure 3-22: Awareness of carrying revenue license whilst driving.

Irrelevant to the numbers displayed in the graph, under the motor traffic act, both driving without having a vehicle revenue license and driving without having a expired, invalid revenue license are considered as offenses that are punishable. This is further discussed in Motor Traffic (Amendment) Act, No. 21 of 1981. https://www.lawnet.gov.lk/motor-traffic-amendment-6/

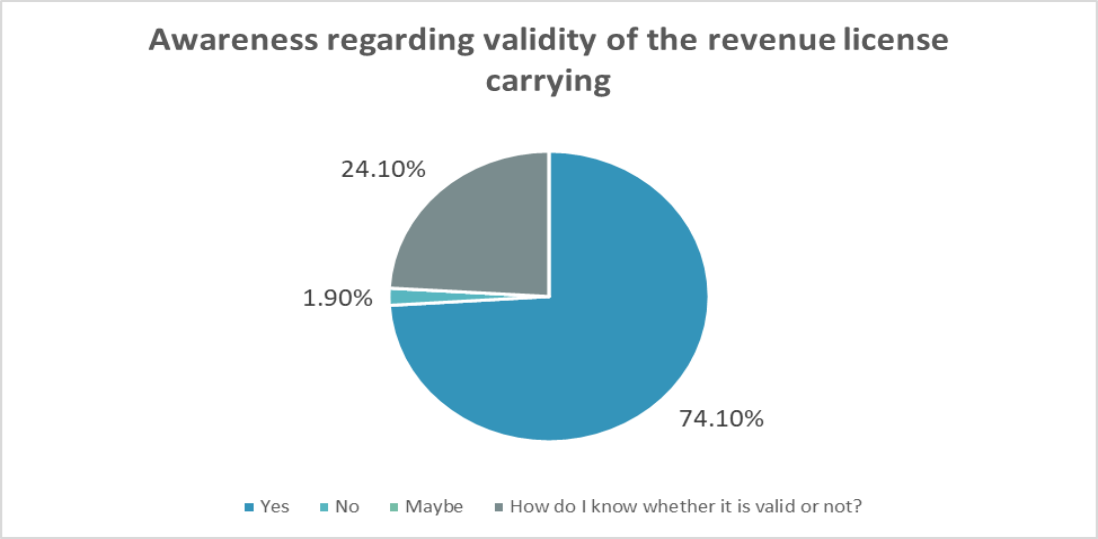

Figure 3-23: Awareness regarding validity of the revenue license carrying.

Figure 3-6 showcases that 74.10% of vehicle owners are aware of the validity of the revenue license that they carry when they drive while more than 25% of vehicle owners are not aware of the validity of the revenue license that they carry. As per N.W.A.D. Dias (Sub Inspector, Traffic division, Galle branch),

‘’ *A revenue license expires one year after the date that it was issued. We consider that one year period as the validity period of a particular revenue license and from the next day after the expiration day onwards, no driver shall drive the vehicle without updating it. By any chance if we could catch someone who has broken the law of revenue license, we do have all the rights to issue him or her a fine sheet and the relevant amount that the offender should pay will be decided by the court.”*

Hence, it becomes quite evident, if a driver willing or not holds an invalid revenue license it can lead him or her to be in a challenging position against the law. Also, as the questionnaire suggests, the 25% of the respondents are not sure of the validity of the revenue license they carry during any randomly selected day of the year.

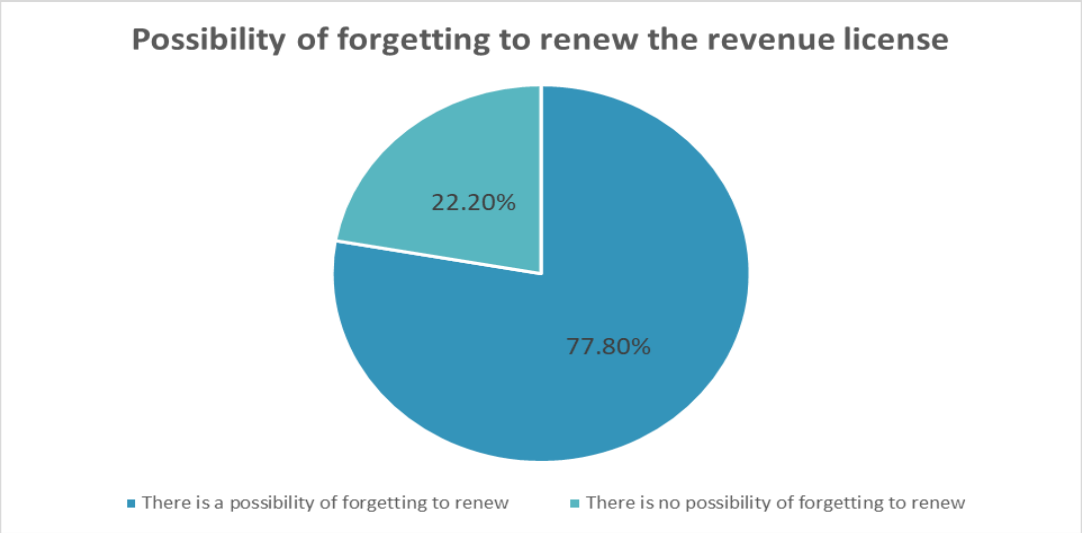

Figure 3-24: Possibility of forgetting to renew the revenue license.

As figure 3-7 exhibits, 77.80% of vehicle owners assume that they might forget to renew their vehicle revenue license while 22.20% make sure that they are somehow capable to renew their vehicles before they get expired. As the majority of respondents are occupied, the chances are they might not find a time during the week to renew the revenue license just when needed. Added to this, chances are unless you are frequent traveler one might end up not renewing the license for possibly weeks. A minority 22.2% of the population taken into consideration in the questionnaire are confident of the fact they keep themselves alarmed of when they need to renew the license. This, again is a number is less than ¼ of the entire population subjected to answer the questionnaire. Therefore, ideally a solution keeps users reminded renewing the license would be of utmost importance, so they can

conveniently utilize their time to renew the license as well as to avoid facing unnecessary legal implications.

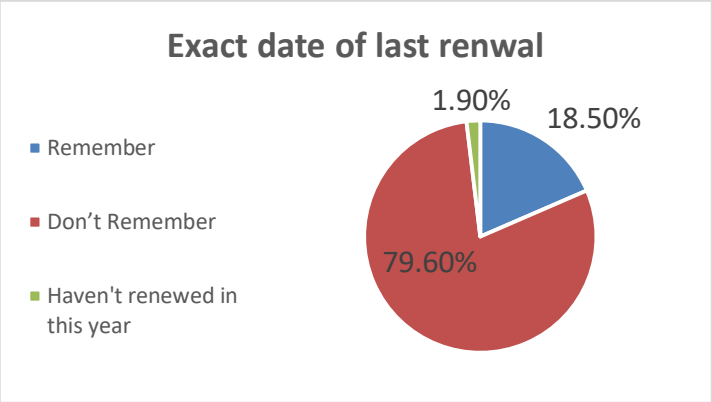

Figure 3-8: Exact date of last renewal

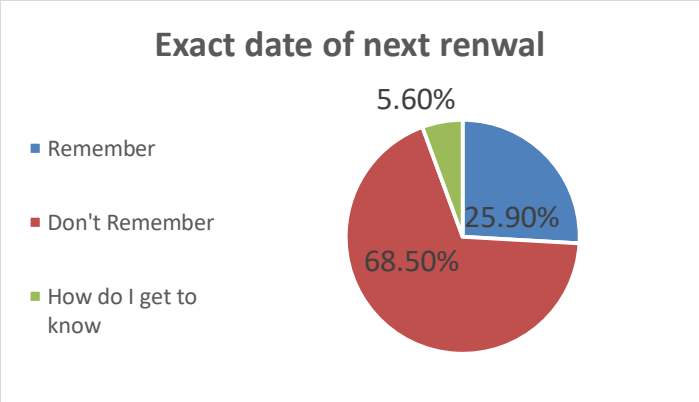

Figure 3-25: Exact date of next renewal

As Figure 3-8 presents, close to 80% of the participants confirm that they do not remember the last renewal date of their vehicle's revenue license while figure 8 showcases that 74% of vehicle owners who participated for the survey, do not remember the exact date that they are supposed to renew their vehicle revenue license. Therefore, it is proven that majority of the vehicle owners may forget to renew vehicle revenue license before it gets expired. The problem addressed here is similar to what is discussed above, and the idea here is the fact they need a precise time in the reminder would be the best solution rather having a reminder to happen on a completely different time of the year than expected.

‘’ *We do not say that it is impossible to keep the last renewal date or expired date of a particular revenue license in mind. If someone can remember one of those two days; only if the last renewal was done on or before the deadline, that will help them to get rid of this problem. But as we have noticed, there is a huge possibility of forgetting to renew by the vehicle owners before the revenue license get expired. No matter how technology has been improved, nothing can stop the people from being busy but there is a law which is common to all of us which we all must obey to it.”, (*N.W.A.D. Dias, Sub Inspector, Galle Police Station)

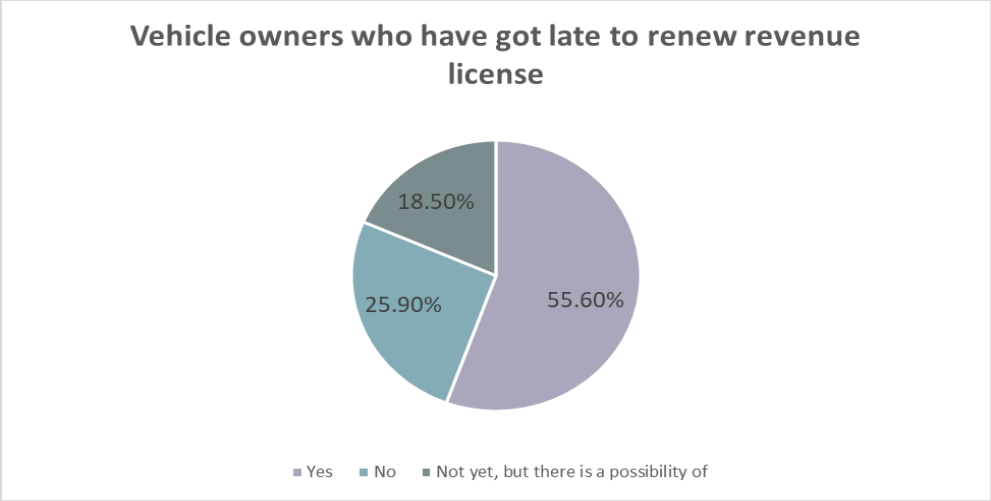

Figure 3-26: Vehicle owners who have got late to renew their revenue license at least once.

Figure 3-10 exhibits that 81.50% of the sample either have got late or they believe that there is a possibility of getting late to renew their vehicle revenue license. Additionally, out of above 81.50% of vehicle owners 79.2% of them (Refer Figure 11) believe that it may happen or may have happened due to forgetting the exact renewal date of their vehicle revenue license while 20.8% of them think that they did not have enough time to renew it. Therefore, it is again proven that forgetting to renew vehicle revenue license before reaching expiration is quite a big problem that majority of the vehicle owners face. Thoughts of vehicle owners regarding their reason for being late to renew the vehicle revenue license is graphically presented below.

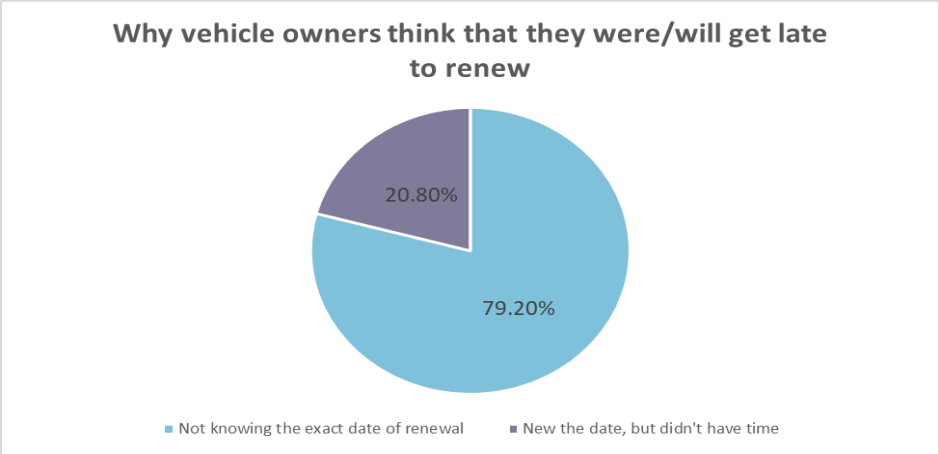

Figure 3-27: Why vehicle owners think that they were/will get late to renew.

Traffic police constables must stop a moving vehicle to inspect whether a particular driver carries valid documents including driving license, emission test certificate, insurance certificate and revenue license besides as it is the only way that it can be done. When questioned "Have you ever been stopped by a constable to check your revenue license?". 70.4% (as mentioned in Figure 12) of the respondents confirmed that they have been stopped more than once and 14.8% of participants have been stopped at least once. The issue here is the Police department

Enforcement officer of Dehiwala Divisional Secretariat, Thushari Senanayake mentioned the following during the interview. "*Neither the Motor Traffic Department nor we have the details of vehicle owners who have an expired revenue license. I do consider as it as a major problem we do have. Anyway, Whether the offenders are caught by the police or not, when they come back here to get it renewed, we can collect the fine them. But that is not what it should be."*

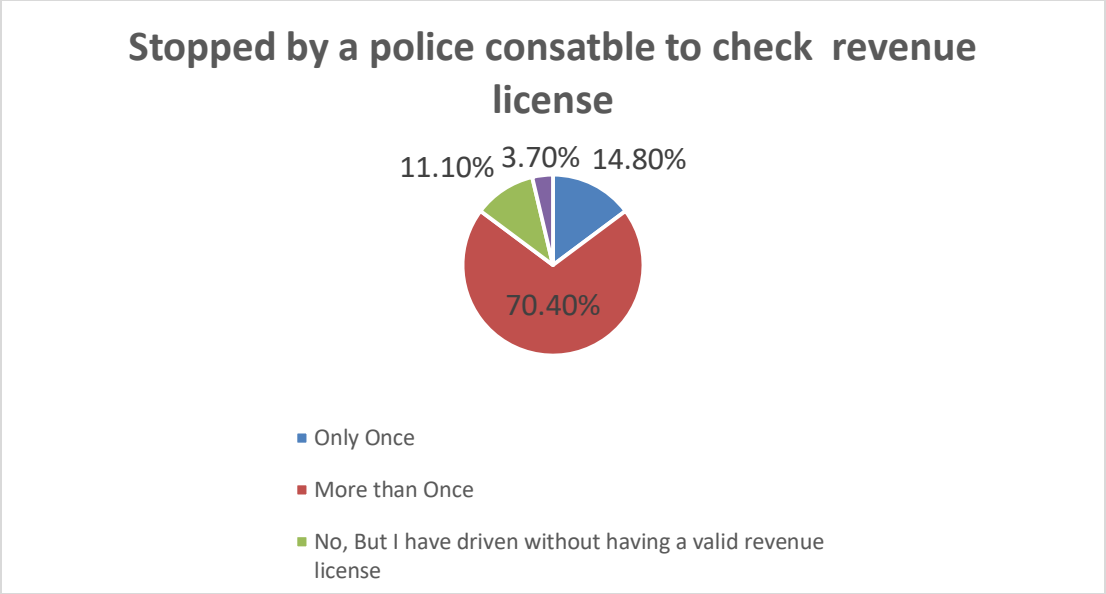

Figure 3-28: Vehicle owners who have stopped by a police constable.

A key revelation from the interviews, as stated above, is how the drivers are tracked in the aspect of not getting their revenue license updated on time. The usual procedure as mentioned by Officer-in-Charge, Traffic unit, Galle, Janaka, is by directly approaching the driver and checking for their documents physically. To be on a techier situation and to have this process more credible and efficient, a tech-based approach to monitor the drivers who are willingly or unwillingly skip a step to get the license renewed can be tracked and any action could be taken based on the data collected.

Based on the inputs on both Thushari Senanayake and Officer-in-Charge, Traffic unit, Galle, Janaka, it is evident, from the receiving end of a lawmaker, it is more credible to have a more accurate and credible dataset and a data collection point to address this issue and based on the driver discipline in this aspect, to bring them under the guard of the country's law.

Figure 3-13 illustrates more than half of participants (57.4%) admit that they have driven a motor vehicle which does not have a valid revenue license and not being caught by the police. 18.6% respondents state that they have never committed and would never commit

such illegal while another 24.1% say that they have not done yet but may be tempted to do so in the future.

The result for this particular question is quite vulnerable, for both law-keepers and the drivers, because an overwhelming majority of the respondents have either driven a vehicle with no revenue license without getting caught by the Police or they can be tempted to commit such as act. Again, irregular use of data and how the process is monitored is highlighted, as there is a gap between how the law is put in action for the drivers who penetrate the law. A proper approach on how the data can be collected to understand the drivers in specific, the geographical area in which these acts take place can be monitored and a firm approach could be intact, if the data can be aligned to a single point of truth. With the visible loopholes in the laws, chances are high with a feasible implementation in place to address these issues.

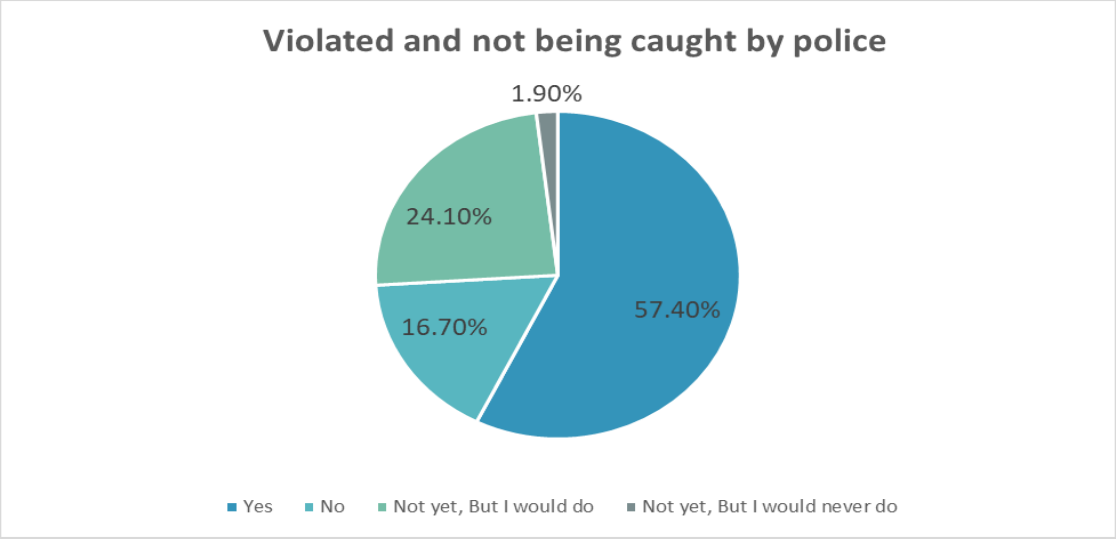

Figure 3-29: People who have driven a vehicle without updating the revenue license but not being caught by the police.

3.3.2.2. Mobile Solution Preferences

As proposed solution consist of two mobile applications, two different questionnaires were circulated among vehicle owners and police officers who would utilize it. The responses retrieved from the questionnaire which was distributed among vehicle owners has been graphically represented in the following chart.

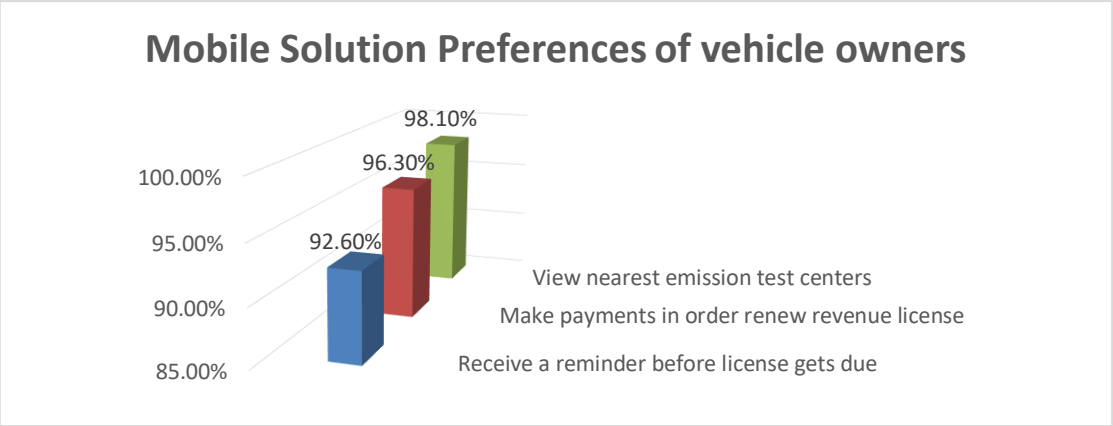

Figure 3-30: Mobile Solution Preferences of vehicle owners

As per figure 3-14, 92.6 % participants have expressed their willingness, as shown in figure 3-14, to use a mobile application to receive a reminder before their revenue license get due, while only 7% of respondents did not express their interest on it. For further comprehension, two other features of the mobile application were added to the questionnaire to analyze the preference of vehicle owner's of utilizing it.

As graphically represented in figure 3-14, 96.30% of total participants display their interest to use a mobile application which has the capability of make a payment and renew their vehicle revenue license and 98.10% of participants express their willingness to have a feature to find nearest emission test centers which are situated around them via the same mobile application.

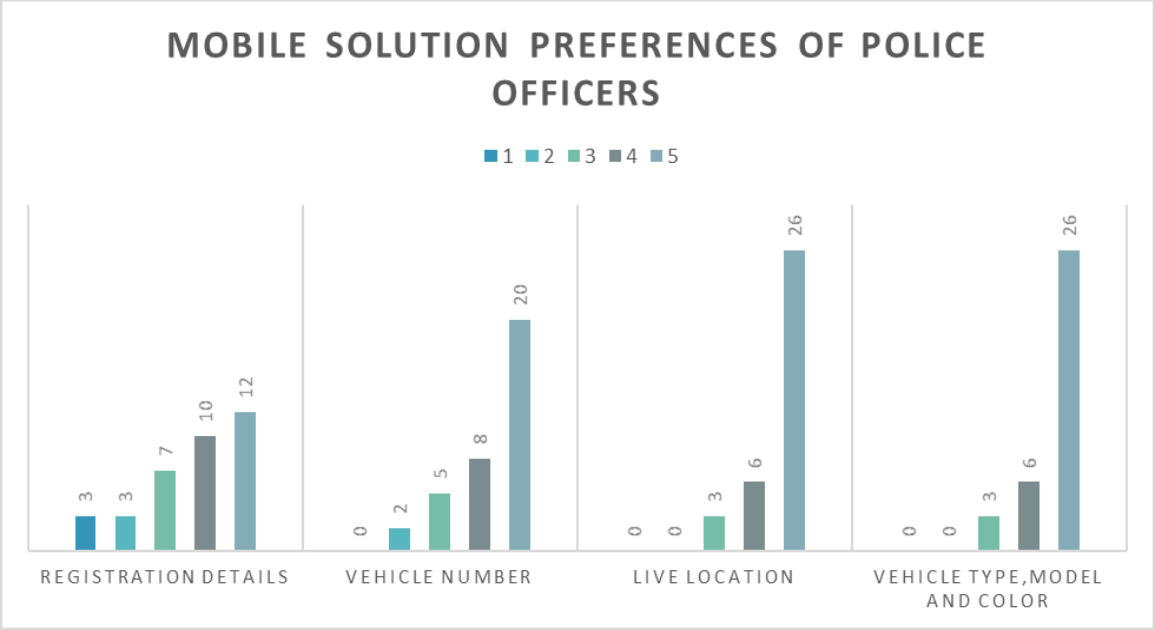

Figure 3-31: Mobile solution preferences of police officers

As per the figure 3-15 exhibits, 62.85% police officers were willing to have at least registration details of the offenders while 80% of the total participants showed their willingness to receive the vehicle numbers of offenders. Other than above two factors, 91.42% of participated police officers displayed their enthusiasm in viewing the live location of an offender as well as the vehicle type, model, and the color of the offender's vehicle in a graphical view. In terms of the affinity of Police Officers parting up the side agreeing to the fact, it is a good sign a practical application of this scale can be utilized to smoothen up the processes of maintaining the activities of offenders with less hassle than now.

3.4 Modelling requirements and relevant diagrams

3.4.1 Use Case Diagram

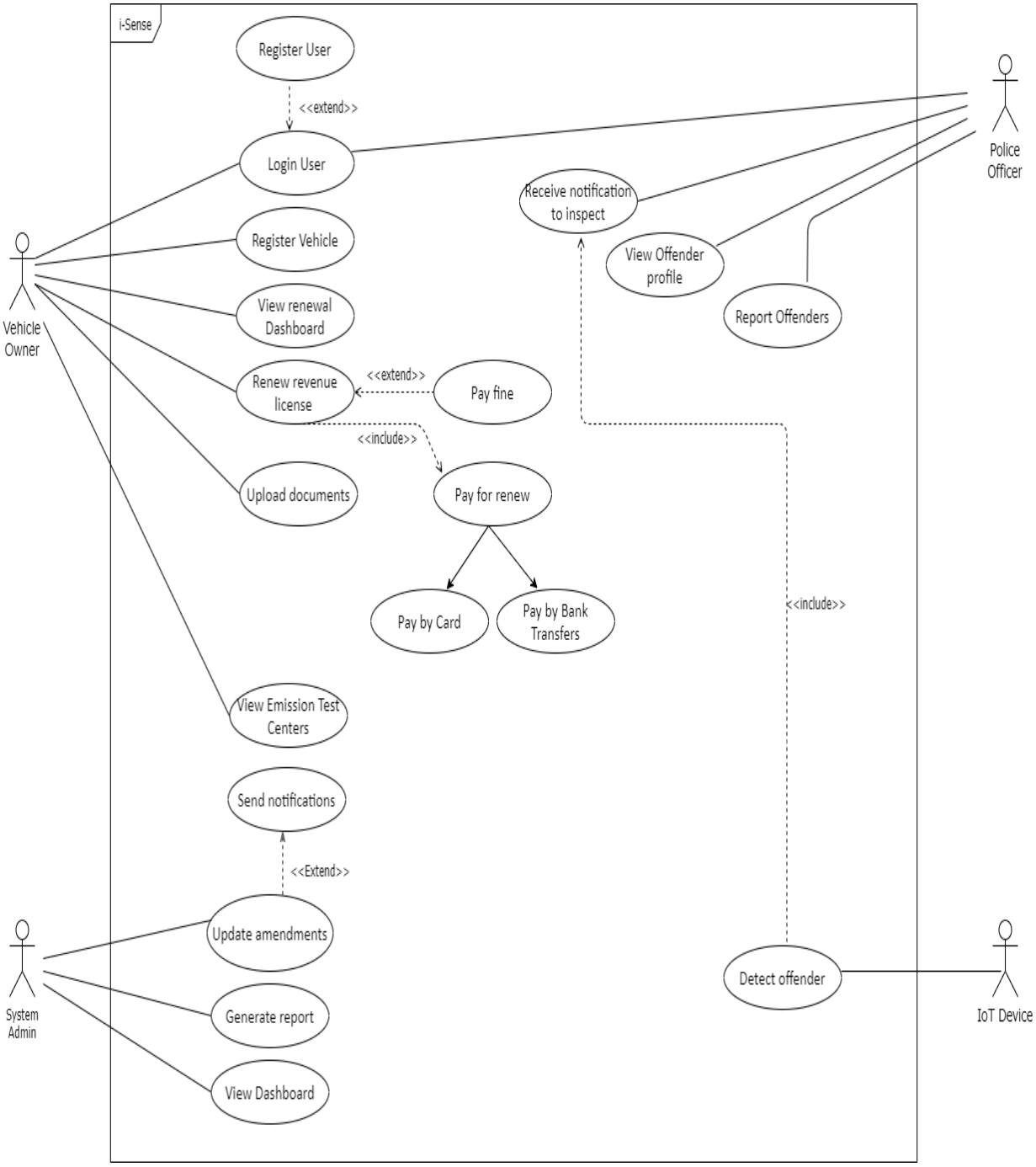

Figure 3-16: Use case Diagram

3.4.2.1 Renew revenue license.

Use Case	Renew revenue license	
Actor	Vehicle Owner	
Brief Description	This use case presents how a vehicle owner can renew the vehicle revenue license prior to expire it or once it gets expired.	
Purpose	This use case allows vehicle owners to renew their vehicle revenue license.	
Pre-conditions	1.Vehicle owner must be logged in to the system providing valid credentials. 2. Vehicle owner must have a valid Emission Test Certification and Insurance Certification.	
Main Flow	**Actor Action**	**System Response**
	1. Upload the required documents. E.g., Insurance Certificate, Emission Test Certificate	2. Verify uploaded documents.
	3. …	4. If all documents are valid, check the status (Expired or not) of the current revenue license.
	5. …	6. Calculate and display the total amount. (Note: Total amount = Annual Registration Fee + Fine for late renewal)
	7. Choose a card which has been added to the system before or enter a new card number.	8. …
	9. Enter the OTP.	10. Verify the OTP.
	11. Confirm the payment.	12. Generate a payment receipt once after receiving the payment successfully.
Alternative Courses	1. If the uploaded documents are invalid, prompt a message to re-upload valid documents. 2. If credentials are incorrect, allow the user to change them after three attempts.	
Post-conditions	Revenue licensed renewed.	

Table 3-4: Use case diagram for Add vehicle.

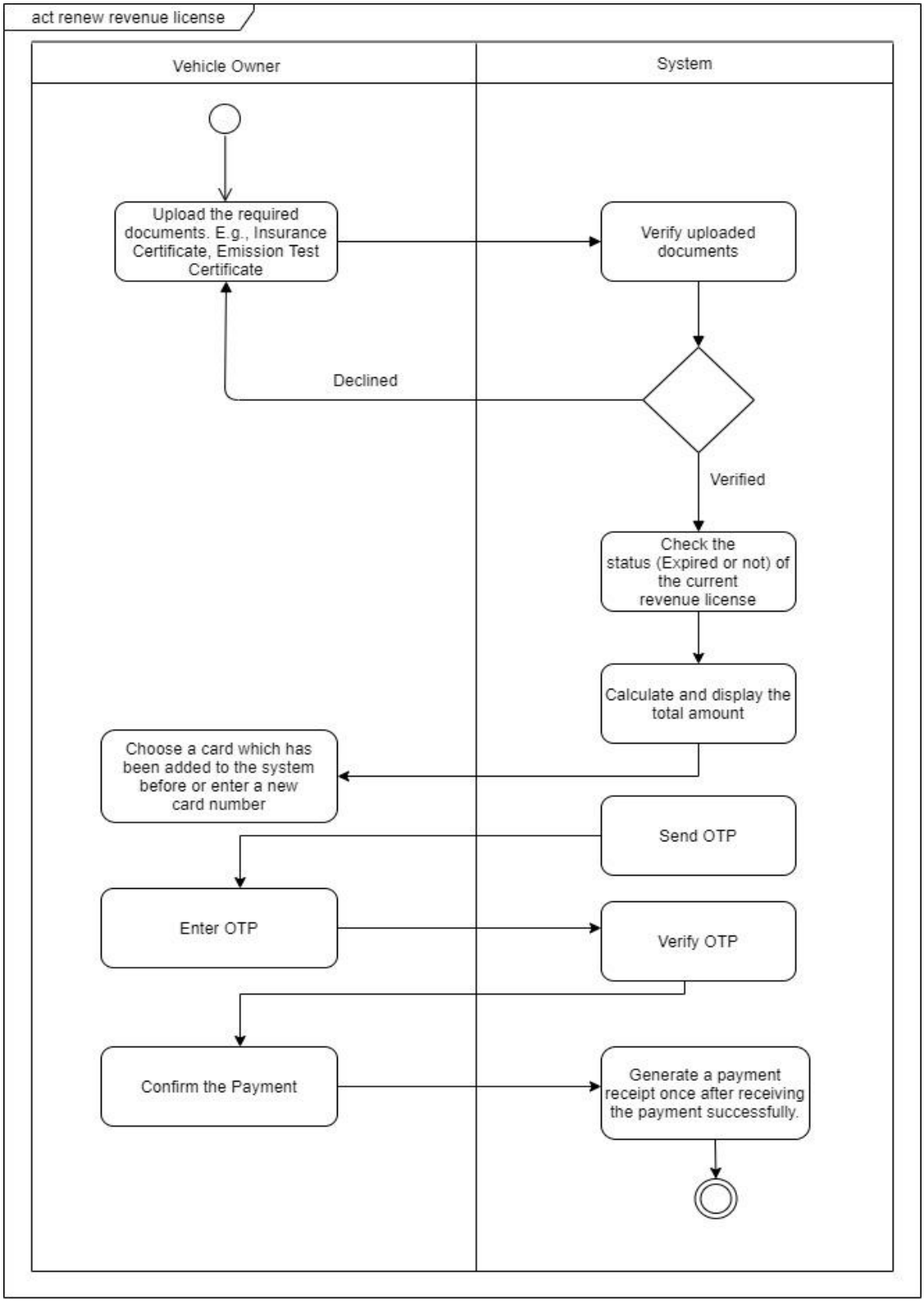

Figure 3-17: Activity diagram for renew revenue license.

3.4.2.2 Add Vehicle.

Use Case	Add vehicle	
Actor	Vehicle Owner	
Brief Description	This use case represents the interaction between the vehicle owner and proposed system when adding one or more vehicles to the system.	
Purpose	This use case allows the vehicle owner to add an existing vehicle or new vehicle.	
Pre-conditions	1.Vehicle owner must be logged in to the system providing valid credentials.	
Main Flow	**Actor Action**	**System Response**
	1. "Add vehicle".	2. Show all the vehicles which have been registered under the user's NIC.
	3. Select a vehicle to add.	4. Show basic vehicle registration details to get the confirmation.
	5. "Confirm"	6. Send the OTP.
	7. Enter the OTP.	8. Validate the OTP.
	9. …	10. Update the all-vehicle registration details of the added vehicle.
Alternative Courses	1. If user has changed the mobile number which was given to the system initially, user shall have ability to receive an OTP via email. 2. If user clicks "decline" in the confirmation stage, system shall allow to select another vehicle.	
Post-conditions	Successfully add a vehicle.	

Table 3-5: Use case diagram for Add vehicle.

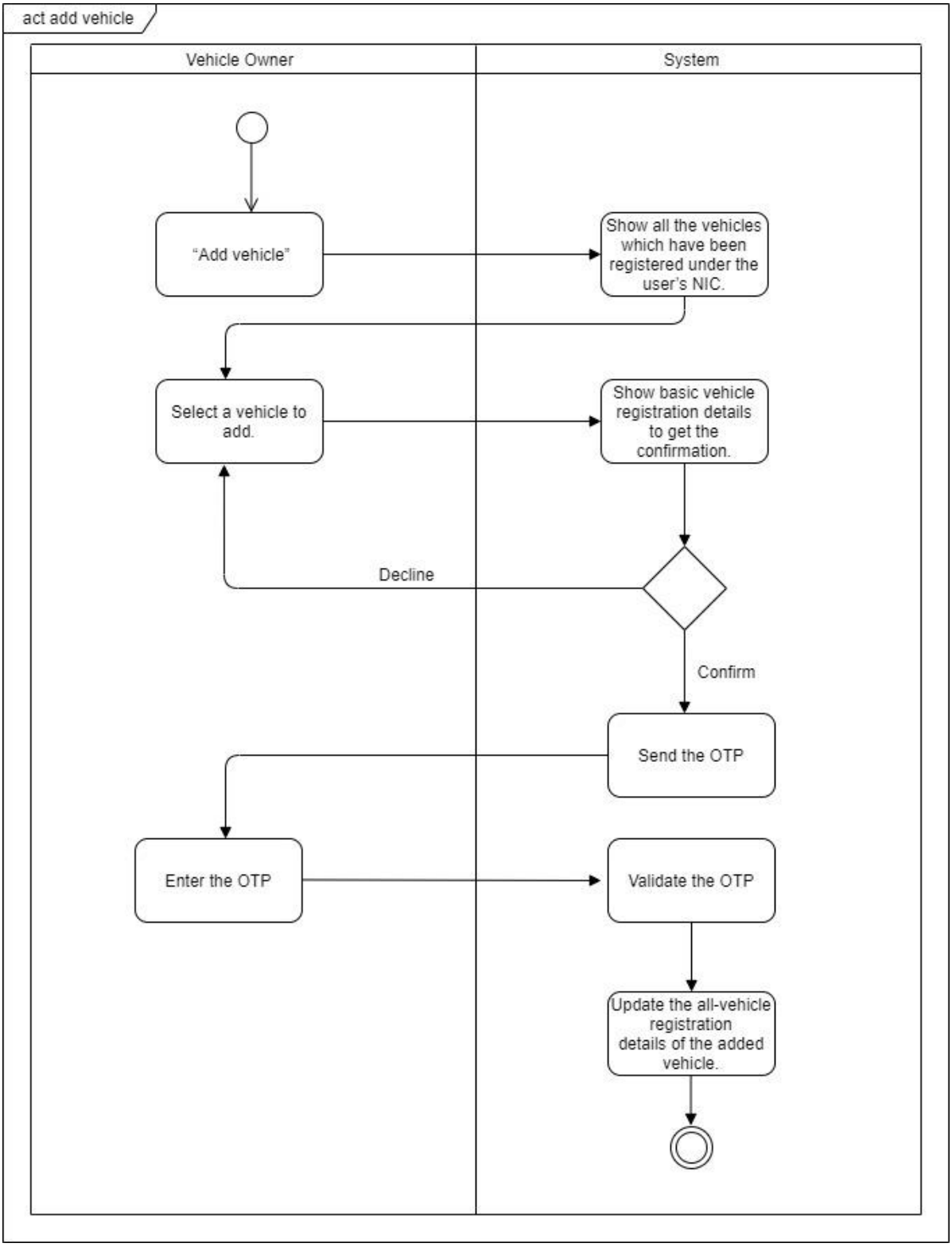

Figure 3-18: Activity diagram for Add vehicle.

3.5 List of functional Requirements

3.5.1 Functional Requirements

ID	Requirement	Priority	Use Case
FR01	Vehicle Owner/ Police Officer shall be able to register to the system by providing the correct details in the required fields.	Must Have	Register User
FR02	Vehicle Owner/ Police Officer shall be able to login to the system.	Must Have	Login User
FR03	Vehicle Owner shall be able to add multiple vehicles to the system.	Must Have	Add Vehicle
FRO4	Vehicle Owner shall be able to view the last renewal date of the revenue license.	Must Have	View Last renewal date
FR05	Vehicle Owner shall be able to view the expiry date of the revenue license.	Must Have	View expiry date
FR06	Vehicle Owner shall be able to view the amount of fine for being late to renew.	Must Have	View amount of fine
FR07	Vehicle Owner shall have the ability to add multiple credit/debit cards to the system.	Must Have	Add card
FR08	Vehicle Owner shall be able to upload Vehicle Emission Test Certificate and Insurance Certificate to the system.	Must Have	Upload documents
FR09	Vehicle Owner shall be able to pay fine along with the registration fee or separately.	Must Have	Pay fine
FR09	Vehicle Owner shall be able to pay the registration fee prior to renew the revenue license.	Must Have	Pay registration fee

FR10	Vehicle Owner shall be able to view the nearest Emission Test Centers.	Must Have	View Emission Test Centers
FR11	Police Officer shall be able to view registration details by providing the vehicle number to the system.	Should Have	View registration details
FR13	Police officer shall be able to view the number of offenders which were able to be taken into custody with their details.	Should Have	View Offender profile
FR14	Police Officer shall be able to scan the vehicle owner's QR code to view vehicle owner's comprehensive details including reg. details.	Should Have	View driver's profile
FR15	Police officer shall be able to report a violator to the system	Must Have	Report Offenders
FR16	System shall be able to notify the drivers prior to get expired their vehicle revenue license, an alert to the driver if he/she drives after the expiration but without renewing.	Must Have	Send reminder to renew
FR17	System shall be able to share the live location of a vehicle which does not have a valid revenue license with the nearest police officer.	Must Have	Share Navigation
FR18	System shall be able to notify nearest police officer when a vehicle which does not have valid revenue license moves around him.	Must Have	Notify to inspect
FR19	System shall be able to notify amendments of the law with both vehicle owners and police constables.	Shall have	Notify amendments
FR20	System shall be able to analyze the revenue gain through late renewals and on-time renewals.	Shall have	Analyze revenue

FR21	System shall be able to generate summary report of the violators.	Shall have	Generate summary report

Table 3-6: Functional Requirements

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3.5.2 Non-Functional Requirements

ID	Constraints	Requirement
NFR01	Usability	1.1 Navigation through the pages should be easy and understandable. 1.2 User Interface (UI) design of the application will be followed Shneiderman's design principles.
NFR02	Availability	2.1 Police officers and Vehicle Owners shall be able to access the application 24x7.
NFR03	Performance	3.1 Application should be able to provide the next User Interface which appears after the login form in 50 milliseconds once a user successfully providing credentials.
NFR04	Compatibility	4.1 Application should be runnable in all android devices which supports android version 4.0 (Ice Cream Sandwich) or higher any higher version.
NFR05	Security	5.1 System shall be able to temporary block a user after attempting 3 times of providing invalid credentials. 5.2 Data shall be backed up to cloud once in 24 hours. 5.3 Secure Socket Layer (SSL) will be implemented to ensure the protection of client-server communication. 5.4 No locations of a vehicle owner will be saved in the cloud servers.
NFR06	Reliability	6.1 Real time synchronizing shall be available to provide accurate data.

		6.2 The application shall not close unexpectedly.

Table 3-7: Non-Functional Requirements.

''The only method to capture revenue license violators is to stop vehicles randomly. We may stop the violators, sometimes we may not be able to stop them. The problem we do have is currently there is no way of pre-identifying the violators. We have to stop a driver to check whether he belongs a valid, non-expired revenue license or not. We could have done something to pre-identify the offenders at least if we had the details of the vehicle owners who have been late to renew their vehicle revenue license. Things would have been easier for all of us to impose.

the law against violators if we had those details. But we do not have them. Therefore, we assume that without having a proper dataset of the vehicle owners who have been late to renew their vehicle revenue license, it is hard to catch all of them. We know that this fact is well known not only by us but also by the vehicle drivers. So, what they do is, they try to avoid the places where our officers stay often." This was revealed by Janaka, Officer in charge of Galle Police, traffic branch.

3.6 Legal, Social and Ethical issues

3.6.1 Legal issues

Data protection:

Data Protection act of 1998 affirms all data a system/application gathers in regard to the end users such as names, locations and telephone numbers are needed to be kept safely and not be disclosed without agreement to any party involved (Mdiit.gov.lk, 2020). The application being created would manage an enormous number of delicate and individual data of people. Consequently, sufficient safety efforts ought to be in spot to forestall unapproved admittance to the data sets holding sensitive information. It is significant that the application developed adheres to these guidelines.

3.6.2. Social Issues

Language barriers:

The initial development of the application is in English, and as English is not the mother-tongue of the country, there could be scenarios where the application creates a gap in understanding the sole purpose of its function and usability. As a result, an alternative with the mother-tongue should be developed to put the application in place.

Lack of technological awareness:

Though it can be statistically proven how well Sri Lanka evolves with the technology around the world, the lapses in usage can cause adrift across end users, as lack of basic technological understanding can create an issue in the usage.

Attitudinal factors:

Comparing how well government offices and departments adopt to new technology, it is a proven fact, paper-based approaches are the widely accepted. Along with this and how well employees of the relevant authorities will adopt can create a lapse in the usage of the application.

3.6.3. Ethical Issues

Confidentiality:

Confidentiality of the information accessed in the application should be high, as the application gives access to highly sensitive information. Third-party use of this application can cause a vulnerability to the confidentiality and this needs to be handled well in the application.

Quality of Service:

As supported by claims by the interviewees as well, the quality of the product, its reliability and credibility play a crucial role in the application and its success. With effective usage,

the Police Department as well as the public users will be able to reap the highest benefits of the application.

3.7 Chapter Summary

This chapter presented the requirements analysis along with the modelling requirements, which included examples of use case diagrams and activity diagrams. This chapter concludes with an overview of the project's legal, social, and ethical issues. The methodologies used throughout the project will be discussed in the following chapter.

Chapter 4: Methodology

4.1 Chapter Overview

This chapter is about the methodologies that are used for development of this research project. Further, it includes different approaches taken in carrying out this project. These approaches include aspects of Project Management, Software Development, and the other general approaches. All these are rationalized and explained in detail.

4.2 Methodology

4.2.1 General Approach

There are many possible approaches that can be used for this project. Out of those, the most suitable approach selected is **Iterative and Incremental approach.** When this approach is used, there are certain key steps to be implemented. There are different components in the project to be developed, in versions. According to Iterative and Incremental approach, those components are first recognized. When all different components or modules are identified, then those can be developed one by one. That is the way Iterative and Incremental approach is used in implementation of a project (Larman and Basili, 2003). When different components are developed one by one, efficient time management is achieved. Thereby, it efficiently allocates time to increase functionalities of the project and do revisions to delivered versions of the application. This is done in iterative cycles until the whole project is completed successfully.

Selection of iterative approach allows this particular project to be developed in small, repeated cycles and versions. According to different resources available, one of the main benefits of using this approach would be to easily debug and test different small versions of the solution (Semerath et.al., 2016). Further, Iterative, and Incremental approach provides a flexibility to the project, where it allows continuous and more efficient testing of different components. When smaller components of projects can be developed iteratively, it is possible to get user feedbacks step by step, so that each step can be better

improved compared to the previous. Unlike in traditional waterfall like approaches, changes in the requirement set can be better coped with when this approach is used.

4.2.2. Software Development Approach

Software Development approach selected for this project is RUP – **Rational Unified Process.** RUP is a modern approach of Software Development that is used widely across the industry. This methodology supports and balances Project Management approaches and general approaches chosen in this particular project. According to cited resources, Rational Unified Process is a more concrete Software Development Methodology, which is supportive of Iterative and incremental approach of projects (Kruchten, 2004). Therefore, for this project, RUP is better suitable to make the development process effective and efficient. There are four key stages in RUP as, Inception, Elaboration, Construction and Transition. This approach, which is component based, supports component re-usability. Therefore, development is more time and resource effective than a traditional approach. Further, it is a much adoptive and flexible methodology. As mentioned earlier, this methodology also supports changes in user requirements half-way into the development.

4.2.3 Project Management Approach

There are two main different project Management approaches used in the Industry. Out of those **PRINCE2** is used as the approach most suitable for this project since it aligns with the project development requirements and resource management.

PRINCE2 is more of a Product-based approach than a process-based approach, thereby allowing an iterative development methodology to be properly managed. It supports the project from start to the end throughout (Bentley, 2009). Further, other methodologies were incorporated with this method. WBS – **Work Breakdown Structure,** Project **Gannt Chart** etc. are such PRINCE2 related concepts which helps in development and management of this project in a successful manner. These are included in the Appendix C of the project.

4.3 Chapter Summary

This chapter is a detailed elaboration of different methodologies that have been used in this project. It includes General Methodology used, which is Iterative and Incremental Approach. Further, Project Management Approach used, which is PRINCE2 incorporated with WBS and Gantt Charts as well. Finally, the Software Development methodology selection has been justified, which is RUP – Rational Unified Process. RUP has supported both Project management and general approaches of the project.

Chapter 5: Design

5.1 Chapter Overview

This chapter presents a high-level design of the proposed solution and a class diagram to illustrate the structure of it. The wireframes of the proposed solution have been included to provide a graphical understanding of the functionalities. All the mock interfaces added, are mapped against the requirements which were gathered and presented in chapter 3.

5.2 High-Level Design

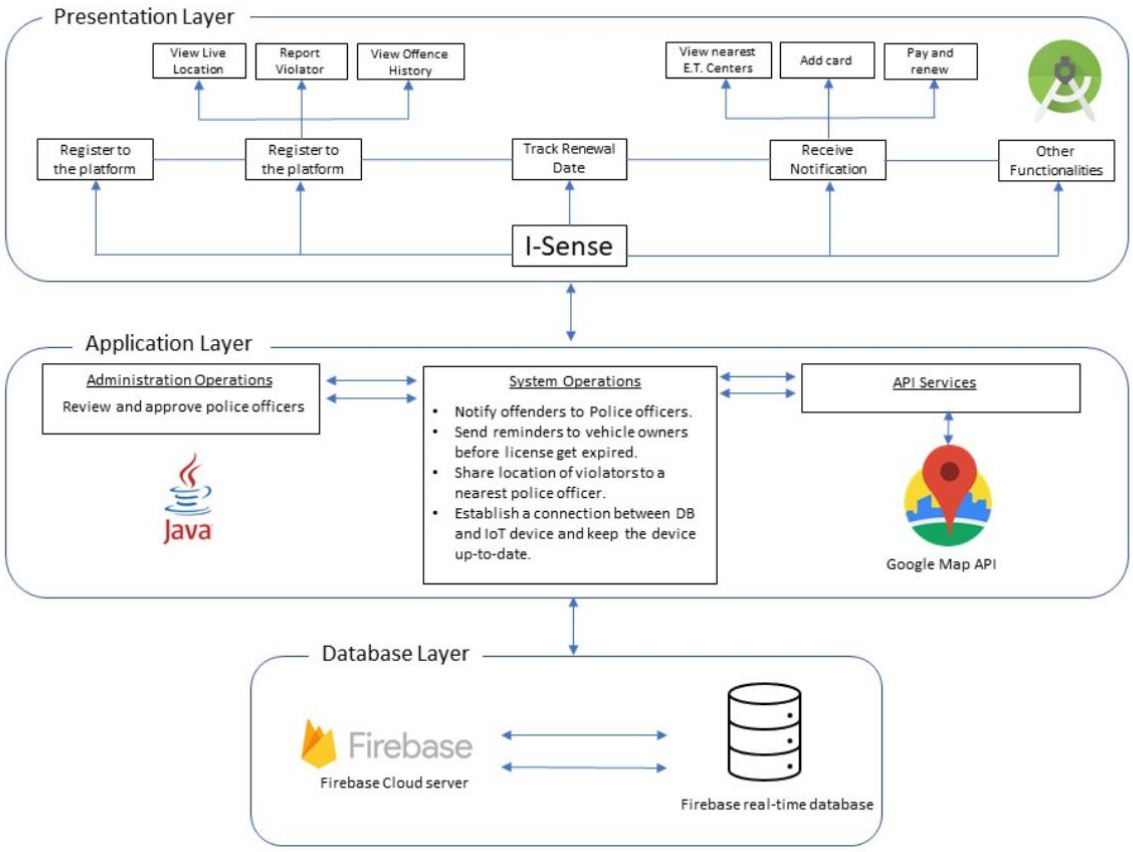


Figure 5-32: High Level Design of the proposed solution

5.3 Low-level Design

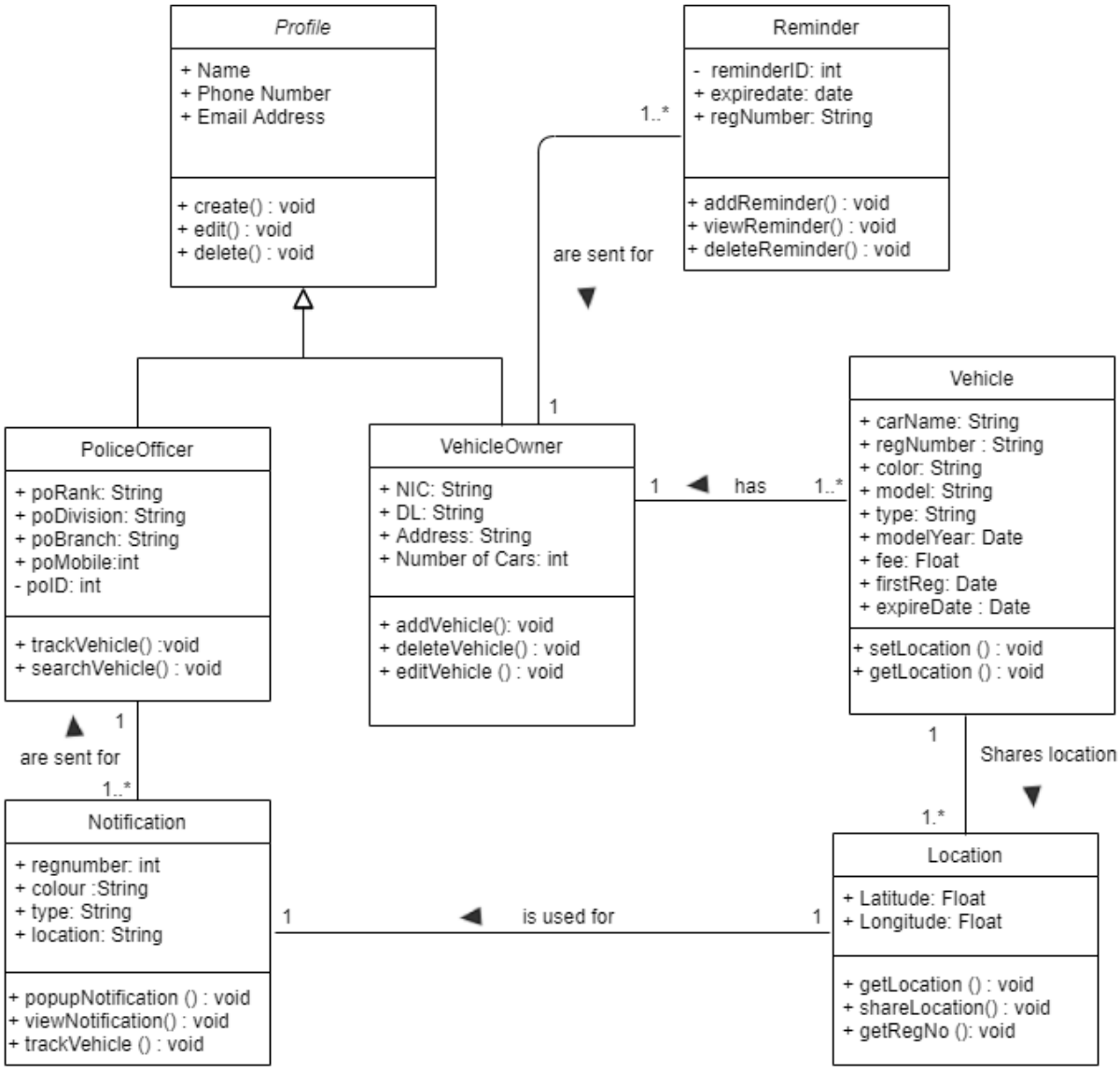


Figure 5-2: class diagram

5.4 Design and development Considerations

5.4.1 User Interfaces

As the User Interfaces for the proposed solution has to be designed for 2 key users including police officer (related to traffic branch) and vehicle owner 2 user interfaces were done according to the Schneiderman's eight golden rules of interface design (Wong, 2020). The tasks which are accessible by any police officer or a vehicle owner were presented distinctly, and the font size, font family, colors, images, white space, and standard navigation was included deliberately to increase readability and legibility for the users to obtain the optimal usage while ensuring the usability (NFR01).

5.4.2 Privacy and Security.

As Information of the vehicle owners and their vehicle's location is classified as sensitive, to view a vehicle's current location by providing any data related to the owner or vehicle is restricted. Prior to Sign-In to the mobile application, each user will have to provide a One Time Password (OTP) once filling the registration form to validate their identity (NFR05). Location of a violator will only be shared with the nearest police officer and will not be stored in a database. To protect sensitive information such as vehicle details including current location of a vehicle, offender information, ownership information of a vehicle, biometric authorization (Fingerprint) will be incorporated as another layer of security which enables verification.

5.5 Wireframes of the proposed solution

Wireframes of the proposed solution have been designed for the requirements gathered in the Chapter 3. All the wireframes were designed to depict the key components/ features and have been mapped with the identified requirements.

5.5.1 W01 – FR02 – User Login

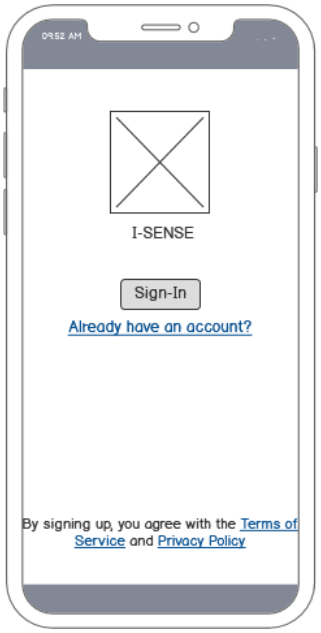


Figure 5-3: Landing

Figure 5-4: User Login.

5.5.2 W02 – FR01 – Vehicle Owner Sign Up

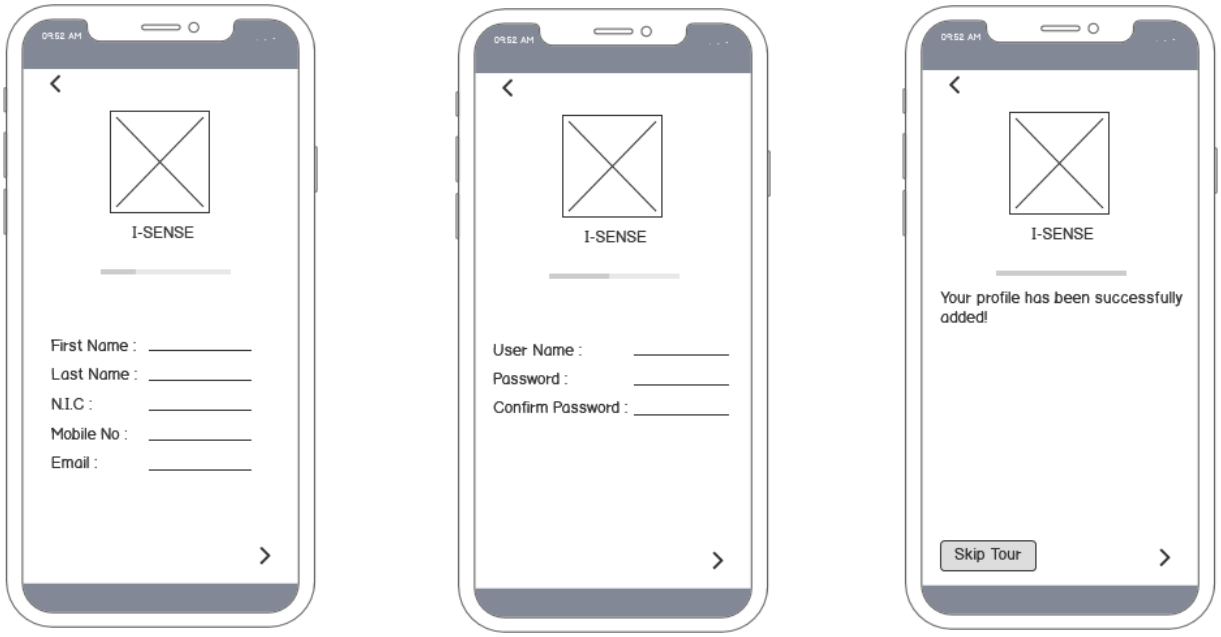


Figure 5-5: Vehicle Owner Sign Up.

5.5.3 – W03 – FR01 – Police Officer Sign Up

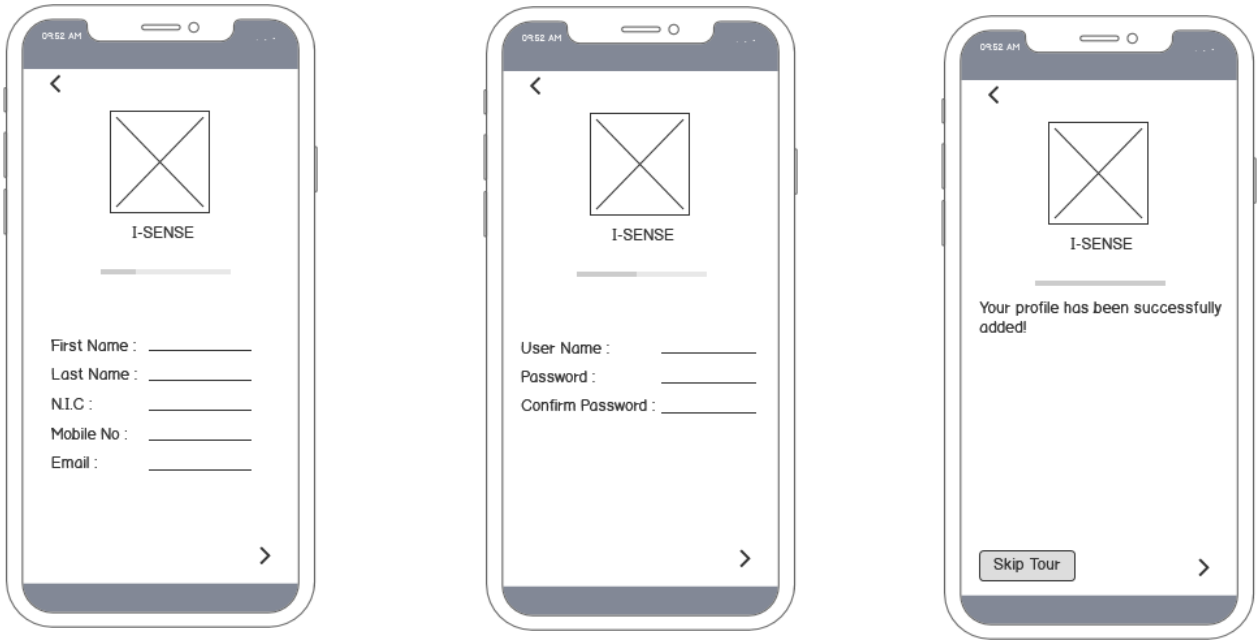


Figure 33-6: Police Officer Sign Up.

5.5.4 – W04 – FR03 – Add Vehicle

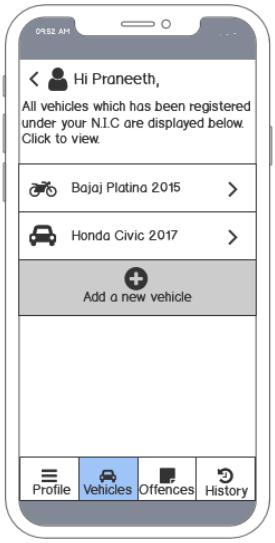


Figure 5-7: Add Vehicle.

5.5.5 – W05 – FR04/05/06 /08 – View Last Renewal Date/ Expiry Date/ Amount of Fine & Upload Documents

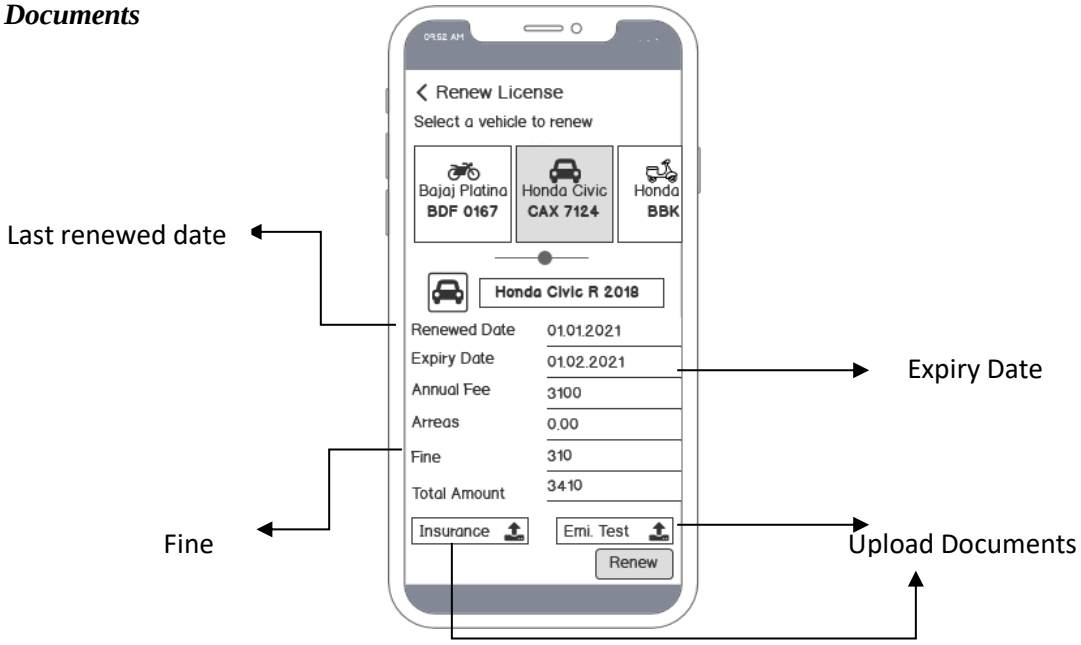


Figure 5-8 : View Last renewal date, Expiry date, Amount of fine, Upload documents.

5.5.6 – W06 – FR07/ FR10 – Add Card/ View Emission Test Centers

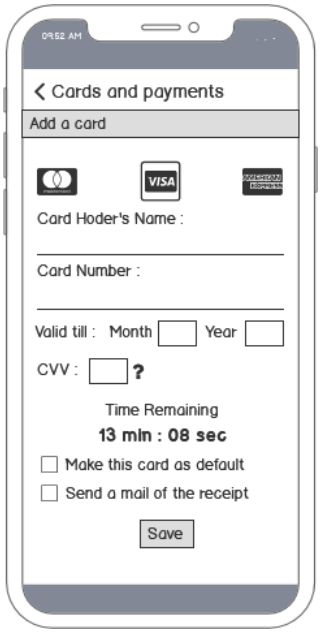


Figure 5-9: Add Card.

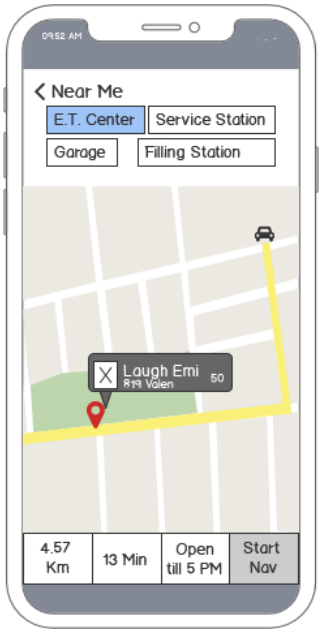


Figure 5-10: View Emission Test Centers

5.5.7 – W06 – FR11 – View Profile

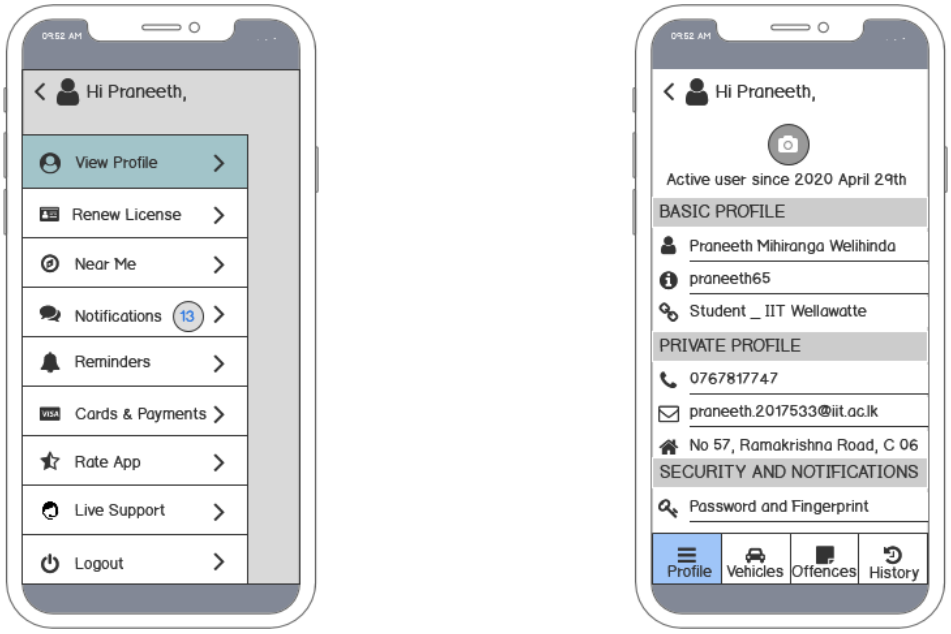


Figure 5-11: First View of Vehicle Owner's App after login

5.5.8 – W07 – FR12 –View History

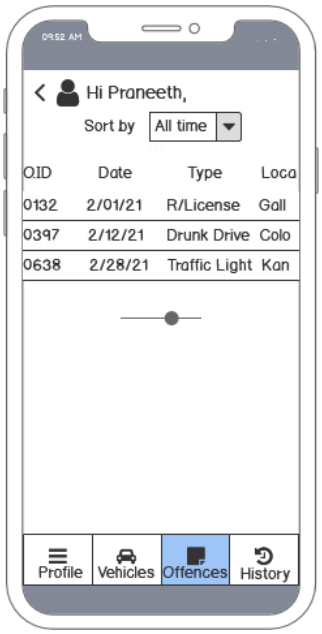


Figure5-12: View Offence History

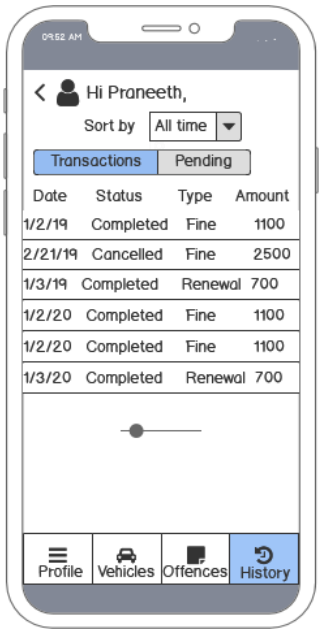


Figure 5-13: View Transaction History

5.5.9 – W08 – FR13 – View Notifications

Figure 5-14: Amendment Notifications

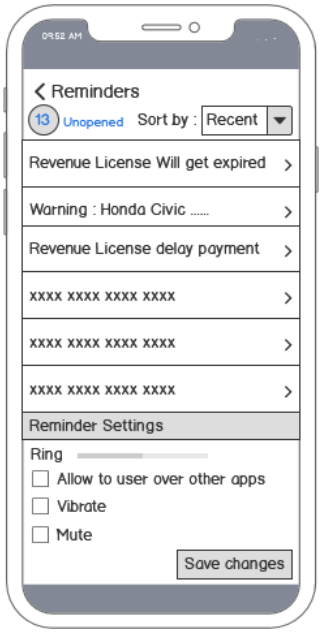


Figure 5-15: Renewal Reminders

5.5.10 – W09 – Officer Application's Landing Page after login

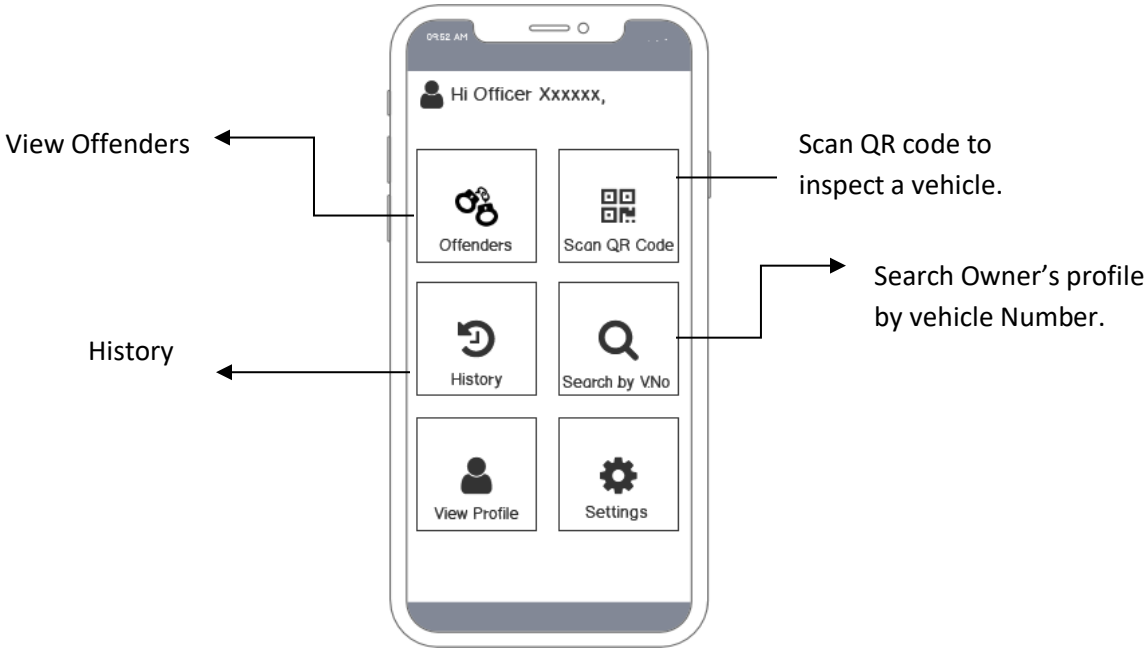


Figure 5-16: Officer Application's Landing Page

5.5.11 – W10 – FR15 – View Offenders

Figure 5-17: Map View of Offenders.

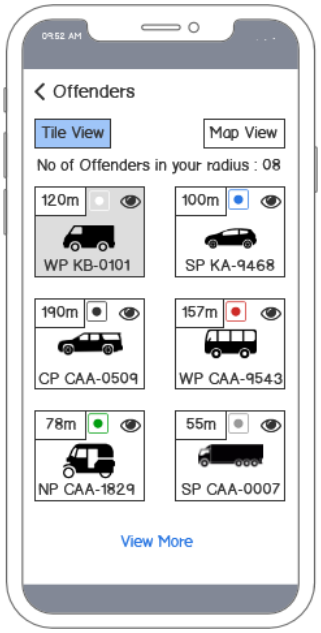
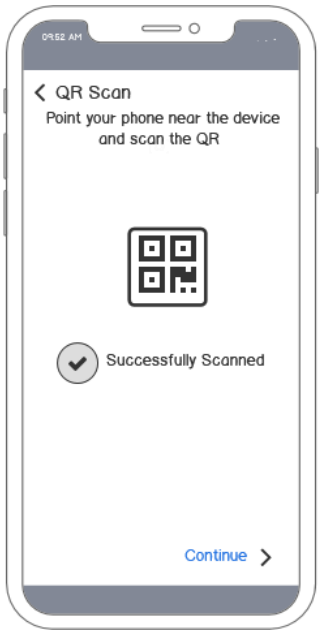


Figure 34-18: Tile View of Offenders.

5.5.12 – W11 – FR16 – View Registration Details



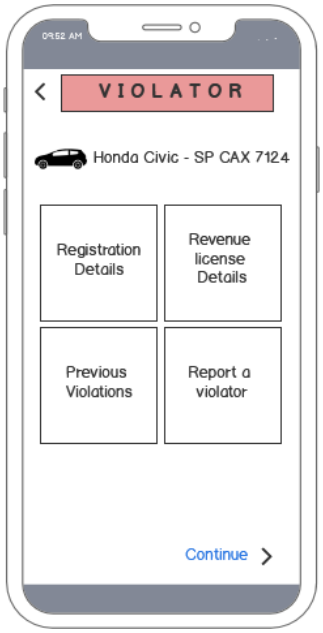


Figure 5-19: Scan QR code to view Reg. Details.

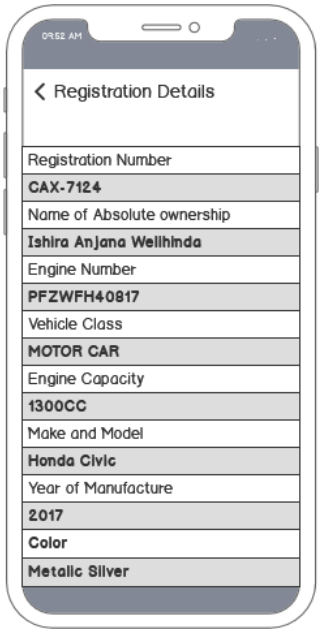


Figure 5-20: View Registration Details.

5.5.13 – W12 – FR18/FR19 -View Driver's Profile/ Report Violator

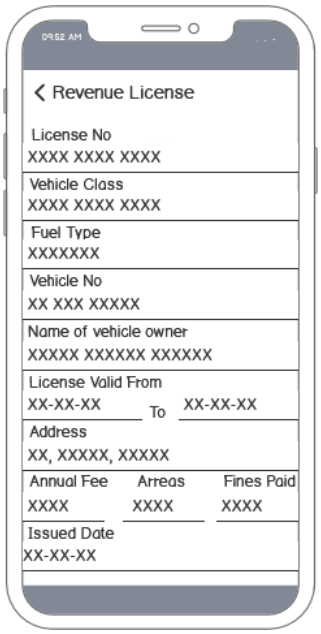


Figure 5-21: View Revenue License.

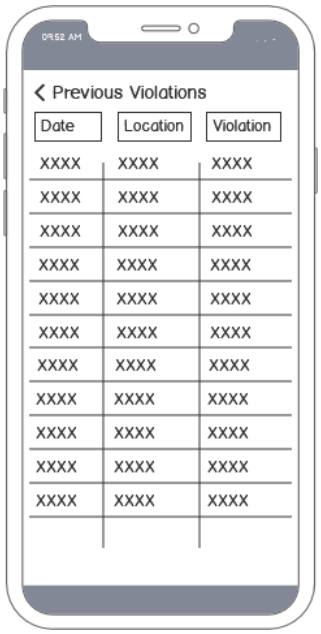


Figure 5-22: Previous Violations.

Figure 5-23: Report a Violator.

5.7 Chapter Summary

This chapter illustrates all the design and development concerns of the proposed solution according to the identified requirements and considerations in chapter 3. The following chapter will focus on how the proposed solution has been implemented according to the above illustrated design methodologies and requirements gathered in chapter 3.

Chapter 6: Tools and Implementation

6.1 Chapter Overview

This chapter further describes and justifies the tools and technologies mentioned in *section 2.5.4* which were utilized to develop the prototype of the proposed solution. Furthermore, after considering all of the design considerations addressed in chapter 5, specifics if the implementation of the prototype's core functionalities are defined.

6.2 Tools and Technologies.

Purpose	Tool(s)	Justification
Development Environment	Android Studio	It was decided to design and develop 2 android mobile applications for the proposed solution. As Android Studio is eligible of providing a unified environment for its' users to build applications, it was chosen to utilize android studio for android development (Android-Studio, 2021). Allow to have Structured code modules by Android Studio, make its users much more comfortable with building the application independently as well as testing and debugging. This reason was critically considered when choosing the correct platform to implement the proposed solution. Furthermore, features enabled by Android Studio such as easy analysis, intelligent code editors as well as accuracy and efficiency (compared to eclipse and visual studio) were reasons to stick with Android Studio.
Programming/ scripting Languages	Java, Python, JSON	**Java** is considered as an object-oriented language which is most commonly used in android development. Available significant number of libraries and tools as well as the provided open-source support were few major reasons to decide java to script the application through the above chosen platform. Further, the users are allowed to create sandbox applications in order to improve the security of the application using java.

		Python was chosen when implementing the IoT device of the proposed solution. This programming language was chosen considering its powerfulness and easiness to both read and write the script (Raspberry-Pi-Foundation, 2021). **JSON (JavaScript Object Notation)** is considered as a subset of programming language which is used to storing and exchanging data (w3schools, 2021). This was chosen over XML (Extensible Markup Language) as it is more readable, and it can be parsed and ready-to-use via a JavaScript Function (json, 2021). Motive of utilizing JSON in the proposed solution is to retrieve data from the webserver.
Provide an interface to connect components.	Raspberry Pi 3 Model B	When choosing the **Raspberry Pi 3** board over Arduino, the ease of connecting other components which have been used in the final device was critically considered. For an instance Raspberry Pi 3 provides interfaces such as ethernet, HDMI which are not available in Arduino. Main reason of choosing Raspberry Pi 3 is that the proposed solution is involved with networking and the overall solution consist of two mobile applications. Further, the clock speed,
Provide an Internet Connectivity	4G Sim Module	A 4G sim module was used to give provide an internet connectivity to the developed IoT device and get GPS positioning data (this device comes along with a GPS antenna). This was chosen due to its compatibility with the Raspberry Pi board, less power consumption and mainly, the capability of providing high speed 4G connection (150Mbps downlink and 50Mbps uplink) which helps to increase accuracy and efficiency.
Display QR code and revenue license details.	5” LCD Display	5” inches LCD display was plugged in to the Raspberry Pi 3 board via a HDMI cable in order to depict the QR code and the revenue license details of the respective vehicle.

Database	Firebase	Firebase was chosen over other substitutions considering its easiness to integrate with the chosen platform of implementing, android studio. Further features provided by firebase such as real time database feature and authentication feature was critically considered when choosing the database (Firebase, 2021).
Plugin	ZXing	ZXing barcode scanner was used in the dedicated mobile application which was build for Police Officers in order to allow them to scan a vehicle revenue license and retrieve details such as registration, renewal details etc.
	Android Mad	This plugin was used to generate a static and unique QR code which contains the revenue license details.

Table 6-1: Tools and Technologies.

6.3 Implementation.

The proposed solution has been implemented as an IoT device along with two native mobile applications based on the problem identified in *chapter 1* and the core functionalities identified and discussed in *chapter 3*.

6.3.1 Identify revenue license violators.

An IoT device was implemented to retrieve the current location of an offender's vehicle prior to share it with a police officer. Since it was decided to indicate only the violators in police officer's mobile application, the IoT device will connect to a firebase real-time database and check the revenue license details of a particular vehicle in order to provide accurate information. However, as it was decided to indicate the offenders to a nearest police officer, radius was defined as 500 meters. Hence the offenders who are within the radius of 500 meters will only be shown in police officers' mobile application.

Figure 6-35: Set radius to identify violators.

Sending a notification to a police officer in order to identify a revenue license violator is a key feature described in the *section 3.5.1*, functional requirements. As the IoT device is programmed to connect (real-time) with the firebase database, it checks the status of the revenue license and notify a nearest police officer if an offender moves within the given radius. Even if the notification is missed at some point, the relevant police officer has been given the ability to check it by entering the offenders tab in the application. Code related to above mentioned functionalities and few of their user interfaces are depicted in below figures.

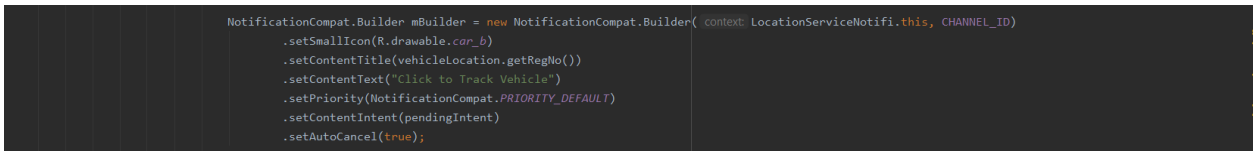


Figure 6-36: Notify the offenders.

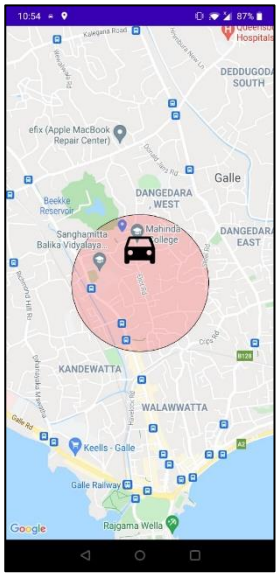


Figure 6-5: Show Offenders in Map.

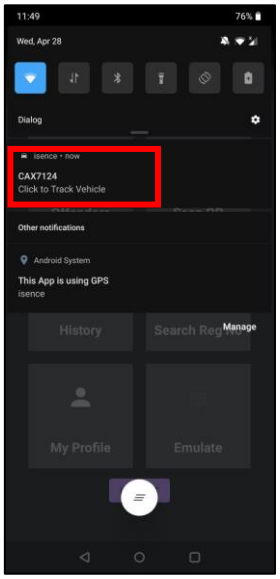


Figure 6-4:Notify to Inspect.

6.3.2 Scan QR code to report.

As described in *section 3.5.1* any authorized traffic police individual is capable of scanning the QR code displayed in the front surface of the implemented IoT device in order to retrieve the registration details of a particular vehicle or report an offender if he/she has violated a motor traffic law. A user must grant permissions to access camera prior to scan the QR code. To enable this feature *ZxingScanner plugin* was utilized. The script which was written by the author addressing this feature is depicted below along with respective user interfaces. Once a violator was reported, necessary information regarding the violation will be directed in to "History" tab of the mobile application. Though it was decided to keep a record of the type of the violation, vehicle registration details of the violator's vehicle, driving license details of the offender, location the offender was captured etc. it only indicates the N.I.C and the vehicle registration details of the offender along with the date that he/she was reported.

```
public void handleResult(Result result) {
    Toast.makeText( context: this, result.getText().toString(),Toast.LENGTH_LONG).show();
    Intent intent=new Intent( packageContext: this, Vehicle.class);
    intent.putExtra( name: "Vehicle", result.getText());
    startActivity(intent);
    finish();
}
```

Figure 6-5: Retrieve scanned vehicle's registration details.

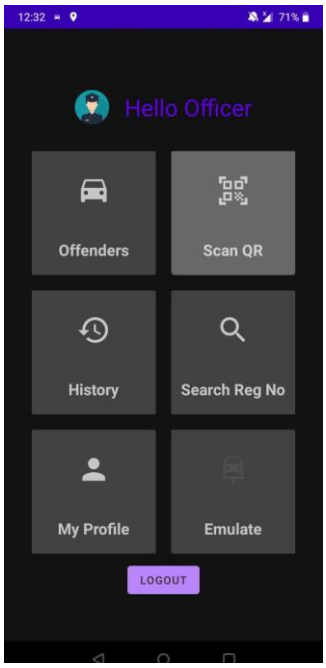


Figure 6-6: Scan QR Code.

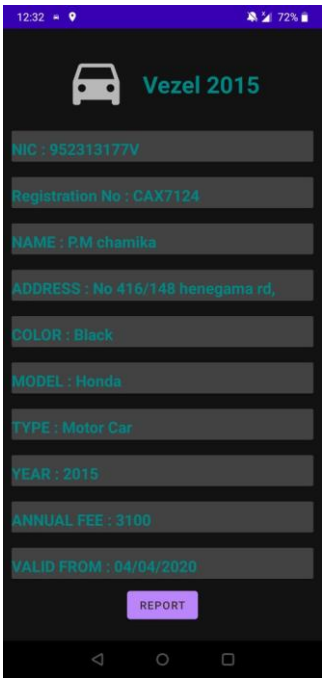


Figure 6-7: Report an offender after scanning the QR.

6.3.3 Search vehicle registration details by providing Vehicle Registration Number.

A feature called “Search by registration number” was added as it was decided to let the police officers to find registration details of a particular vehicle by providing VRN to the application. By utilizing this functionality, an authorized traffic police officer shall be able to view expiry date any particular vehicle’s revenue license. Though the developed application indicates less number of details, it was planned to present details such as previous violations.

6.3.4 Functionalities available in the vehicle owner’s mobile application.

It was decided to implement a separate mobile application for the vehicle owners to utilize functionalities such as set reminders prior to get their revenue license get expired, notify

them once the revenue license is expired, make payments in order to renew license etc. A user shall have the ability to log in to this system by providing their N.I.C (National Identity Card) number to view and manage all the vehicles which have been registered under the provided N.I.C. Hence, it is a mandatory to provide the same National Identity Card Number which has been given when registering the respective vehicle in order to logging in to this mobile application. When a user provides a N.I.C, respective vehicle details will be retrieved from the firebase database and will be shown in the "Vehicle" section.

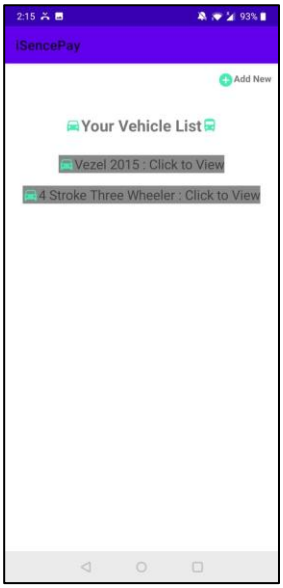


Figure 6-9: Available Vehicle List

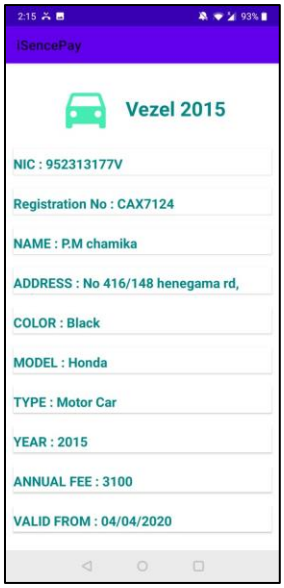


Figure 6-10: View Vehicle Details

Enabling the users to set reminders is considered as the core functionality of this application. A user who has successfully logged in to the application shall have the ability to select a (could be more than one) vehicle and set a reminder (before 1,2,3 etc. months) prior to expire the vehicle revenue license.

```
DocumentReference docRef = db.collection( collectionPath: "Reminders").document(id);
docRef.get().addOnCompleteListener(new OnCompleteListener<DocumentSnapshot>() {
    @Override
    public void onComplete(@NonNull Task<DocumentSnapshot> task) {
        if (task.isSuccessful()) {
            DocumentSnapshot document = task.getResult();
            if (document.exists()) {
                Log.d(TAG, msg: "DocumentSnapshot data: " + document.getData());
                regNo=document.get("Vehicle").toString();
                monthsData=document.get("Months").toString();

                regnoView.setText(regNo);
                monthView.setText("Alert "+monthsData+" months before licence expired");
            } else {
```

Figure 6-11: Script to add a reminder.

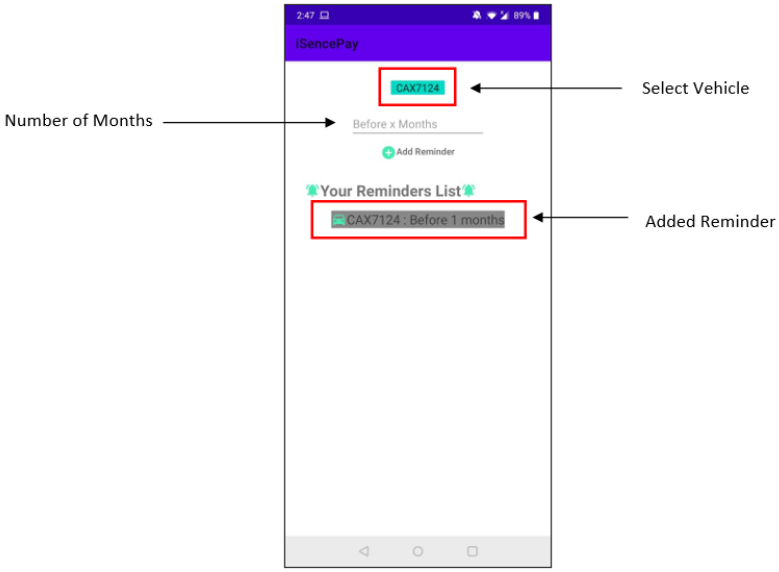


Figure 6-12: Add a reminder.

6.4 Implementation of the IoT device.

Below *figure 6-11* depicts the python script which was written to retrieve vehicle license information from firebase database and check the status of particular vehicle's revenue license. Further, once an expired revenue license is captured, current location of the respective vehicle will be directed to the firebase database.

```
doc_ref = fdb.collection(u'license').document(u''+Uid)

doc = doc_ref.get()
if doc.exists:
    documentData=doc.to_dict()
    expireDate=documentData.get('From')
    if expireDate > expireDates:
        while True:
            port="/dev/ttyAMA0"
            ser=serial.Serial(port, baudrate=9600, timeout=0.5)
            dataout = pynmea2.NMEAStreamReader()
            newdata=ser.readline()

            if newdata[0:6] == "$GPRMC":
                newmsg=pynmea2.parse(newdata)
                lat=newmsg.latitude
                lng=newmsg.longitude
                mydict={'regNo':Uid,'latitude':lat,'longitude':lng}
                ref2 = db.reference('Location/'+ Uid)
                ref2.update(mydict)
                gps = "Latitude=" + str(lat) + "and Longitude=" + str(lng)
```

Figure 6-13: Python Script to check status and send location to firebase database.

Following is an 3D model of the implemented IoT device which consist of the components described in the above tabular. Few of the actual images of implemented device have been included in appendix D.

Figure 6-14: 3D Model of proposed solution.

6.5 Chapter Summary

Tools used to implement the proposed solution (IoT device along with two mobile applications) were listed and justified. Further, screenshots of the core functionalities of the implemented prototype were added with respective code snippet. Following chapter will present the testing of the prototype along with the evaluation done by experts and non-expert individuals.

Chapter 7: Testing

7.1 Chapter Overview.

Based on implementation discussed in above *chapter*, this chapter presents two main testing methodologies which have been used to evaluate the proposed solution: functional testing and user testing. Functional Testing has been carried out using both white-box and black-box testing techniques, while user testing has been carried out via providing certain inputs gathered through industry experts and non-experts in the domain.

7.2 Functional Testing.

7.2.1 White-box testing.

Test Case ID	Code	Sample Input	Expected Output	Actual Output	Test Case Status

TCID01	Date today = new Date();
	if(today == expireDate){
	NotificationCompat.Builder builder = new NotificationCompat.Builder(Home.this, CHANNEL_ID)
	.setSmallIcon(R.drawable.*car*)
	.setContentTitle(car)
	.setContentText("Today is the finale day to renew your licence")
	
	.setPriority(NotificationCompat.*PRIORITY_DEFAULT*);
	}
		1.1 Expire Date=04.10.2021 && Today=04.10.2021	"Today is the finale day to renew your licence"	"Today is the finale day to renew your licence"	Pass

		1.2 Expire Date=05.10.2021 && Today=05.10.2021	"Today is the finale day to renew your licence".	"Today is the finale day to renew your licence".	Pass

	if (Build.VERSION.*SDK_INT* >= Build.VERSION_CODES.*O*) {
	CharSequence name = "MyNotifi";
	String description = "MyNotifi";
	int importance = NotificationManager.*IMPORTANCE_DEFAULT*;
	NotificationChannel channel = new NotificationChannel(CHANNEL_ID, name, importance);
	channel.setDescription(description);
	NotificationManager notificationManager = getSystemService(NotificationManager.class);
	
	notificationManager.createNotificationChannel(channel);
	}
		1.3 Expire Date=05.10.2021 && Today=05.10.2021	"Today is the finale day to renew your licence"	"Today is the finale day to renew your licence"	Pass

TCID02	reg=customReg.getText().toString();
	reg.toUpperCase();
	Log.*d*(TAG, "reg: " + reg);
	DocumentReference docRef = db.collection("license").document(reg);
	docRef.get().addOnCompleteListener(new OnCompleteListener<DocumentSnapshot>() {
	@Override
	public void onComplete(@NonNull
		2.1 Reg=CAX7124	Model= " Vezel2015" Till= 04/04/2020	Model= " Vezel2015" Till= 04/04/2020	Pass

	Task<DocumentSnapshot> task) {
	if (task.isSuccessful()) {
	DocumentSnapshot document = task.getResult();
	if (document.exists()) {
	Log.*d*(TAG, "DocumentSnapshot data: " + document.getData());
	LinearLayout.LayoutParams lparams = new LinearLayout.LayoutParams(
	
	LinearLayout.LayoutParams.*WRAP_CONTENT*, LinearLayout.LayoutParams.*WRAP_CONTENT*);
	TextView tv = new TextView(Search.this);
	lparams.gravity = Gravity.*CENTER*;
	lparams.setMargins(10, 60, 10, 10);
	
	tv.setCompoundDrawablesWithIntrinsicBounds(R.drawable.*car_b*, 0, 0, 0);
	tv.setTextSize(25);
	tv.setLayoutParams(lparams);
	tv.setBackgroundColor(Color.*GRAY*);
	Timestamp timestamp=(Timestamp)document.get("From");
	Date date = timestamp.toDate();
	SimpleDateFormat formatter = new SimpleDateFormat("dd/MM/yyyy");
	year = formatter.format(date);				

		2.2 Reg=AGS2349	Model=”4 Stroke Three-Wheeler” Till= 02/08/2020	Model=”4 Stroke Three-Wheeler” Till= 02/08/2020	Pass
		2.3 Reg=DMV1432	Model=” Civic 2018 Sedan” Till= 22/10/2020	Model=” Civic 2018 Sedan” Till= 22/10/2020	Pass

	DocumentReference docRef = db.collection("Register").document(reg); docRef.get().addOnCompleteListener(new OnCompleteListener<DocumentSnapshot>() }				

TCID03	public void addVehicle(String reg){
	
	Map<String, String> user = new HashMap<>();
	user.put("NIC", nic);
	user.put("Vehicle", reg);
	db.collection("MyList")
	.add(user)
	.addOnSuccessListener(new OnSuccessListener<DocumentReference>() {
	@Override
	public void onSuccess(DocumentReference documentReference) {
	Log.*d*(TAG, "DocumentSnapshot added with ID: " + documentReference.getId());
	Toast.*makeText*(NewVehicle.this, "Successfully Added", Toast.*LENGTH_SHORT*).show();
	finish();
	startActivity(getIntent());
	}
		3.1 N.I.C= 952313177v	Model= "Vezel 2015"
			Model= "4 Stroke Three-Wheeler"
				Model= "Vezel 2015"
				Model= "4 Stroke Three-Wheeler"
					Pass

		3.2 N.I.C= 93200128v	Model= "Civic 2018 Sedan"	Model= "Civic 2018 Sedan"	Pass

	}) .addOnFailureListener(new OnFailureListener() { @Override public void onFailure(@NonNull Exception e) { Log.*w*(TAG, "Error adding document", e); Toast.*makeText*(NewVehicle.this, "Something Wrong", Toast.*LENGTH_SHORT*).show(); } }); }				
		3.3 N.I.C= 695268341v	Model= "Vanette-200"	Model= "Vanette-200"	Pass
TCID04	DocumentReference docRef = db.collection("Reminders").document(id); docRef.get().addOnCompleteListener(new OnCompleteListener<DocumentSnapshot>() { @Override public void onComplete(@NonNull Task<DocumentSnapshot> task) { if (task.isSuccessful()) { DocumentSnapshot document = task.getResult(); if (document.exists()) {	4.1 Months=2	Alert 2 months before license get expired.	Alert 2 months before license get expired.	Pass
		4.2 Months=3	Alert 3 months before license get expired.	Alert 3 months before license get expired.	Pass

	Log.*d*(TAG, "DocumentSnapshot data: " + document.getData());
	regNo=document.get("Vehicle").toString();
	monthsData=document.get("Months").toString();
	regnoView.setText(regNo);
	monthView.setText("Alert "+monthsData+" months before licence expired");
	} else {
	Log.*d*(TAG, "No such document");
	}
		4.3 Months=4	Alert 4 months before license get expired.	Alert 3 months before license get expired.	Pass

TCID05	db.collection("Reminders")
	.whereEqualTo("NIC", nic)
	. get()
	.addOnCompleteListener(new OnCompleteListener<QuerySnapshot>() {
	@Override
	public void onComplete(@NonNull Task<QuerySnapshot> task) {
	
	if (task.isSuccessful()) {
	for (QueryDocumentSnapshot document : task.getResult()) {
	Log.*d*(TAG, document.getId() + " => " + document.getData());
	LinearLayout.LayoutParams lparams = new LinearLayout.LayoutParams(
		5.1 N.I.C= 952313177v && Months=”2”	Reminder List = CAX7124: Before 2 months	Reminder List = CAX7124: Before 2 months	Pass

		5.2 N.I.C= 932001282v && Months=”3”	Reminder List= DMV1432: Before 3 months	Reminder List= DMV1432: Before 3 months	Pass

	LinearLayout.LayoutParams.*WRAP_CONTENT*, LinearLayout.LayoutParams.*WRAP_CONTENT*);
	TextView tv = new TextView(Reminders.this);
	lparams.gravity = Gravity.*CENTER*;
	lparams.setMargins(10, 40, 10, 10);
	tv. setCompoundDrawablesWithIntrinsicBounds(R.drawable.*vehicle*, 0, 0, 0);
	tv.setTextSize(20);
	tv.setLayoutParams(lparams);
	tv.setBackgroundColor(Color.*GRAY*);
	Log.*d*(TAG, "DocumentSnapshot data: " + document.getData());
	
	tv.setText(document.get("Vehicle").toString() + " : Before "+document.get("Months").toString()+" months");
	LL.addView(tv);
	}				

		5.3 N.I.C= 695268341v && Months=”2”	Reminder List= GIE4382: Before 2 months	Reminder List= GIE4382: Before 2 months	Pass

Table 7-1: White box Testing.

7.2.2 Black-box testing.

Test Case ID	Description	Sample Input	Expected Output	Actual Output	Test Case Status
TCID01	Confirm a violation prior to report.	Scan QR code depicted in the device	If Today=>Expire date, enable "report" button to report the identified offender. The reported details should be automatically transferred to "history".	If Today=>Expire date, enable "report" button to report the identified offender. The reported details should be automatically transferred to "history".	pass
TCID02	Search nearby offenders withing the given 500m radius.	Click on the offenders' tab in the I-sense application.	Depict the vehicle type and vehicle color via an icon in the Google map and the current location of the offender's vehicle.	Depict the vehicle type and vehicle color via an icon in the Google map and the current location of the offender's vehicle.	Pass
TCID03	Track an offender's vehicle.	Tap the vehicle depicted as a bitmap icon	Display the vehicle registration number of the offender's vehicle along with the distance between the current location of vehicle and police officer.	Display the vehicle registration number of the offender's vehicle along with the distance between the current location of vehicle and police officer.	Pass

TCID04	View vehicles which are belongs to a particular owner.	Login to the I-Sense Pay app by providing N.I.C number	Display all the vehicles which is registered under the provided N.I.C prior to login.	Display all the vehicles which is registered under the provided N.I.C prior to login.	Pass
TCID05	Receive a reminder prior to get the revenue license expired.	Click add reminder, select the vehicle registration number, and provide a whole integer in the month field.	Receive a notification on the same date which was given when setting up a reminder.	Receive a notification on the same date which was given when setting up a reminder.	Pass
TCID06	Search random vehicle revenue license details.	Click on "Search by Reg No" and provide the vehicle registration number with letters(case sensitive) in the given field.	Display the Expiry date of the vehicle revenue license.	Display the Expiry date of the vehicle revenue license.	Pass
TCID07	Add a new vehicle	Click "Vehicles" tab and tap on "Add Vehicle."	Display all the vehicle models which has been registered under the provided N.I.C used to log in to the application.	Display all the vehicle models which has been registered under the provided N.I.C used to log in to the application.	Pass

Table 7-2: Black box Testing.

7.3 User Testing.

Both applications were further evaluated by industry expert and non-expert individuals in order to verify concept and design & development of the implemented prototype. Further, details of the evaluators, have been disclosed in the below tabular. Questions which were shared with the evaluators have also been presented in Appendix D.

Evaluator's Name	**Designation**
Mr. Janaka	Officer in Charge, Galle Police Station
Mr.Chanuka Wattegama	Head of policy, Information & Communication Technology Agency
Mr. Amal Gunathilake	Robotics Research Engineer. (Former Senior Software Engineer WSO2)

Table 7-3: Evaluator's Details

7.3.1 Evaluation based on the concept of the prototype.

This evaluation was mainly based on the perspectives of experts in the respective domain. Following statements were retrieved from the answers to the questions posed to the domain experts depicted in above tabular.

Mr. Jagath stated,

"*This project really makes our lives easy; I know how much of my co-workers struggle to complete their targets by inspecting hundreds of vehicles each day. The problem we had till the time I make this statement is, not having any method of pre identifying the revenue license violators. During a traffic jam, in a heavy raining day, inspecting the documents by randomly stopping a vehicle is impossible I would say. Notifying us whenever an offender passing us, is something we never expected. Even the reporting system will definitely be efficient and accurate as it automatically fills a particular police officer's details in the fine sheet."*

Mr. Chanuka Wattegama stated,

"*This overall project will make every traffic police officer's life easier rather than it was before. Random check to identify the vehicle revenue license violators is not a productive approach I would say. It takes time but still you cannot identify the revenue license violators who passes you by. Reminding the vehicle owners to renew their revenue license before it gets expired is a quite good functionality. This may be a compelling reason for vehicle owners to turn to the proposed new revenue license.* "

Mr. Jagath rationalized,

"*The solution fulfills the major problems addressed during the problem statement. Having a display instead of the paper would give a sign that the device has been plugged properly to the car. However, it is a must to keep a track of the vehicle owners who drives a vehicle and who have purposely unplugged the device to not to be caught. Color of the device's display should remain white even it is violated."*

Mr. Chanuka Wattegama added,

"*Nowhere it is mentioned that a traffic police officer has no right to know the live location of an offender who has violated a motor traffic low. It will not be a problem as long as the project can ensure that the live location of a violator is share only with a traffic police officer, but no one else. Overall, the features which exist in both applications are quite interesting and it fulfills most of the identified problem.*"

Mr. Jagath further supported the statement made by Mr. Chanuka as excerpted below.

"*As police officers nowhere says that we do not have rights to know a live location of a particular offender who has violated a motor traffic rule. But all the vehicle owners who would really bother of their privacy; may not be willing to attach an IoT device which has the capability of track their vehicles as long as the device and both applications are well secured and make sure that no one else can track a violator or any other vehicle owner other than a traffic police officer.*"

Furthermore, Mr. Chanuka Wattegama, Head of Policy, ICTA (Information & Communication Technology Agency) noticed and revealed another advantage which can be gained through publishing this solution.

"*Due to the Covid-19 virus that is prevalent throughout the country, police officers including the general public, have to follow health guidelines and safety measures as instructed by the health ministry of Sri Lanka. So, I see a problem in handing over one's revenue license to a police officer; to investigate, at a time when such a situation has arisen in the country. However, with the proposed solution, it is possible for a police officer to scan the device and obtain the relevant data, which will provide an opportunity to avoid that situation.*"

The above statement was proven by Mr. Janaka's explanation and it is as follows,

"*Due to the pandemic situation, the on-duty police officers are reluctant to obtain the revenue license or any other document on the possession of the driver, even for the purpose of inspection, as it may spread the existing virus. According to what I believe, the drivers are also reluctant to prove even they have valid revenue license, as they do consider the same reason. I hope that this proposed solution will help to get rid of this issue. However, issuing a fine sheet to an offender is still there. So, I suggest adding online fine sheet issuing functionality to the proposed solution; as an improvement, while allowing the vehicle owners to pay the fine through their mobile application.* "

When questioned about the ease of use, both Mr. Jagath and Mr. Chanuka were agreed that both implemented applications are user-friendly. Further, both of them revealed that none of them had to go through any special learning process on identifying how both applications are functioning. According to both feedbacks obtained by above mentioned evaluators it was decided to not to make any changes on downgrading the design standards of both mobile applications.

7.3.2 Evaluation based on the design and development of the application.

The proposed solution was demonstrated to Mr. Amal via Google Meet call. The chosen evaluator provided the feedback during the demonstrated period. Initially the feedback was given on the chosen tools and techniques utilized to develop the proposed solution.

"Choosing the tools and technologies to implement the proposed solution has been done properly, I would say. It is proven by integrating Google Maps API to develop the offender indicating functionality. Navigation of both applications are very simple and makes easy to use and I believe no technical knowledge will be required as both applications are implemented by using attractive colors, images and simple layout".

He further stated,

"Coming back to the device which has been built, it is a must to use a 4G sim module instead of the Wi-Fi module. I consider the display as a classy feature that this project contains, but the same thing can be done by pasting a static QR code in the front surface of the IoT device. According to my opinion this will definitely help to reduce the total cost of the device hence it will be something affordable to the relevant parties."

A major aspect of the prototype was raised by Mr. Amal Gunathilake and that was to increase the security of both applications along with the IoT device since they handle/ carry confidential and sensitive information.

Mr. Gunatilake stated,

"*No changes of the User Interfaces to be made as they are already done perfectly. But quality of the overall code should be improved, and better coding practices have to be followed. Having google authentication when logging in to an application is good but whenever a particular user requests to make a change or do something special, such as report a violator; add vehicle; re-authenticate prior to allow making changes by sending via an OTP (One Time Password)."*

According to the feedback obtained during the discussions had with all above mentioned evaluators, it was analyzed that the key components of the proposed solution has been

addressed the problem statement, and the chosen tools and techniques to develop the application and device are acceptable. Suggestions raised by the evaluators regarding design of the application will be incorporated in the prototype.

7.4 Chapter Summary.

This chapter described all of the techniques which were utilized to evaluate the prototype of the proposed solution. To test the application, functional testing techniques such as white-box testing, and black-box testing were utilized. Furthermore, the user testing was based on inputs obtained from both experts and non-experts in the respective domain. The conclusion, reflection along with the strengths, weaknesses and limitations of the proposed solution will we have discussed in the following chapter.

Chapter 8: Conclusion

8.1 Chapter Overview

This chapter is an overview of how the project aims and objects were achieved. Further, identified strengths and weaknesses of the project and limitations which were analyzed throughout the course have been discussed below. The developed prototype has been critically evaluated in order to conclude the future enhancements to be followed and new skills to be acquired.

8.2 Evaluation of the process.

8.2.1 Achievement of the Aim

The issues faced by local authorities in pre-identifying revenue license violators were discussed with regards to the *section 1.2,* which were further elaborated through literature review and interviews and questionnaires conducted. Data retrieved from the circulated questionnaire, research and findings of existing solutions and interviews conducted with domain experts were considered prior to initialize the design and development of the proposed solution. Following all above activities were considered as the reason to successfully achieve the aim of the project.

8.2.2 Achievement of the Objective

ID	Status of Achievement	Evaluation
PO1	100%	Initial background research was conducted to identify the existing problems related with vehicle revenue license. The project Initiation Document (PID) which consist of a problem statement, aims and objectives of the project, required tools and skills, initial list of requirements and a project plan was submitted before the given deadline.
PO2	100%	In order to justify the problem statement, a thorough research was carried out on how revenue license violators are

		identified in other countries all around the world. This was composed and submitted as chapter 2 (Literature Review). Motive of conducting a research was to identify and analyze existing similar solutions, evaluate tools and technologies which will be most suitable when implementing the proposed solution.
PO3	100%	A research was carried out and interviews were conducted with industry expertise in order to identify the legal issues, ethical issues and social issues of the proposed solution.
PO4	100%	Due to the considered factors considered such as adaptability and the capability to be tailored, PRINCE 2 was chosen as the most appropriate project management model.
PO5	100%	A questionnaire was sent out to retrieve inputs from the main stakeholder of the project (distributed among vehicle owners and the police officers who are enrolled to traffic division). This was conducted in order to enhance the research from findings based on LR (Literature Review). Furthermore, interviews were conducted with respective expertise in the domain to have a better understanding on how the existing system flows.
PO6	100%	Findings and analysis conducted for both literature review (LR -Chapter 2) and System Requirement Specification (SRS) were used to identify and derive the requirements as non-functional requirements and functional requirements. All the identified requirements have been provided in a tabular format in chapter 3. These set of requirements are prioritized and elaborated comparatively to the requirements identified in Project Initiation Document (PID).

PO7	100%	High level design along with the class diagram of the proposed solution is depicted in the chapter 5. Furthermore, included wireframes depicted in chapter 5 were illustrated based on the requirements identified in chapter 4. A research was conducted on design considerations in order to increase the user experience of stakeholders.
P08	100%	Performed black-box testing and white-box testing which were performed was helpful to minimize the errors of the developed prototype and ensure the accuracy of all the functionalities proposed in chapter 3. Test cases and their respective results which were retrieved while executing, have been shown in chapter 7 in a tabular format.
P09	100%	The implemented prototype was evaluated with the help of selected expertise in the domain (police officers, respective employees in Department of Motor Traffic, ICTA agents) and vehicle owners. All user experience and perspectives gathered were summarized and included in chapter 08.
P10	100%	The finalized project report along with the completed code of the proposed solution were submitted on time as per the depicted project plan in appendix.

Table 8-1: Project Objective achievement

8.3 Evaluation of the Solution.

8.3.1 Uniqueness of the solution.

Main objective of I-Sense solution is to identify the revenue license offenders, keep track of them and enforce the law against them in an effective manner. An IoT device was implemented along with 2 android mobile applications to achieve the above-described objective. The proposed solution was critically compared with both existing solutions and

published studies. Further the comparison has been properly documented in a tabular format in *section 2.4.*

1. At present, Using ANPR and ALPR cameras to identify motor traffic violators are being used in several countries, but non-of those applications are unable to notify police officers to inspect a vehicle immediately when a revenue license violation happens.
2. The proposed solution is capable of sharing real-time location of a violator's vehicle along with vehicle registration details, with a nearest police officer which does not exist in any current application.
3. All the existing solutions which are currently implemented, allow only the police officers/ respective authorities to login and monitor motor traffic violations. Therefore, the proposed solution was designed and developed including a separate mobile application for the vehicle owners to sign up for the application where they can become beneficiaries of this solution (Set reminders to receive a notification prior to expire the vehicle revenue license). Hence, this application becomes the first application that allows vehicle owners to receive reminders and alerts.
4. The proposed application will only allow the traffic police officers to register. The head of Administration (O.I.C) will only be able to have an overview (location and respective registration details) of the offenders.
5. Vehicle owners are capable of managing, viewing vehicle registration information (set reminders, payment renewals etc.) from one mobile application.

8.3.2 Limitations of the Application.

Due to the time constraints and lack of expertise the developed solution only concentrates the major problems which were identified during the first three chapters. The functionalities which were not implemented due to above reason have been clearly outlined below.

1. Currently the police officers will not receive notification when an offender moves around the given radius. Hence, the police officers will have to keep the application opened and refresh the offender's interface in order to keep a track of violators.

2. Two factor authentications were not implemented in both applications. However, the police officer's mobile application authenticates with google and the credentials are stored in firestore.
3. A tile view of offenders was implemented as it is hard to monitor/ identify a particular offender when there are too many offenders in a less radius.
4. Vehicle owners will not be able to make renewals of their vehicle revenue license as a payment gateway has not linked yet with the application due to the lack of time that the author had.
5. Accuracy of the distance between an offender's vehicle and a police officer may get vary due to the connectivity and accuracy of "Geolocation API".
6. As majority of the imports have been limited due to the pandemic situation it was not quite possible to find all the appropriate tech components. Hence a Wi-Fi module was built instead of the 4G (GSM) sim module due to the unavailability.
7. Currently the vehicle owners will not be able to receive a notification before/ after expiration of their revenue license. Hence, they will have to search their vehicle registration details manually by providing a vehicle registration number.

8.4 Skills and knowledge acquired.

Throughout the project, all the new skills and knowledge acquired by author are described as follows.

1. Project management and time management skills in managing the final year project along with the enrolled other modules.
2. Fact finding skills, research skills, data gathering skills and analytical skills to find research on existing solutions, evaluate requirements and prioritize requirements.
3. Modelling skills were revised and acquired to convey a visual representation of the identified problem.
4. Communication skills were improved as the author had to interview few expertise in the domain in order to understand the problem, gather requirements and decide the appropriate functionalities of the proposed system.

5. Documentation and writing skills of the author have been clearly and precisely improved comparatively to the beginning.
6. Designing skills of the author has been significantly developed by illustrating simple, attractive, and user-friendly mobile user interfaces for suggestion solution.
7. Knowledge on programming languages, tools and technologies along with knowledge on IoT technologies/ components were gained by author during the implementation stage and developed an IoT device along with two mobile applications.
8. Acquired domain knowledge on current process of issuing revenue license, law enforcement, motor traffic act and its policies were helpful for the author to define the scope of the project and prioritize the functionalities of the proposed solution.

8.5 Recommendations and Future Work.

1. Monitor the IoT devices which have been disconnected from the vehicle along with vehicle registration details to take necessary actions against if there is any offence.
2. Introduce demerit point system where a particular number of points will get deducted from overall points when a vehicle driver violates a law.
3. Introduce a merit point system to police officers where they can achieve targets (Report a significant number of offenders in a given time period) by reporting offenders to the system once after inspecting.
4. Enable various payment methods such as FriMi, PayHere, Genie etc.
5. Enhance the current design considerations in order to increase user engagement.
6. Integrate biometric authentication to both mobile applications as they carry sensitive data.
7. Integrate OTP (One Time Password) with both mobile applications as a two-factor verification method in order to secure both applications.
8. Allow the police officers to customize criteria such as radius, time period (according to their availability), division wise location etc.
9. Utilize the IoT device in obtaining other government charges such as expressway(highway) toll fee, parking fee etc.

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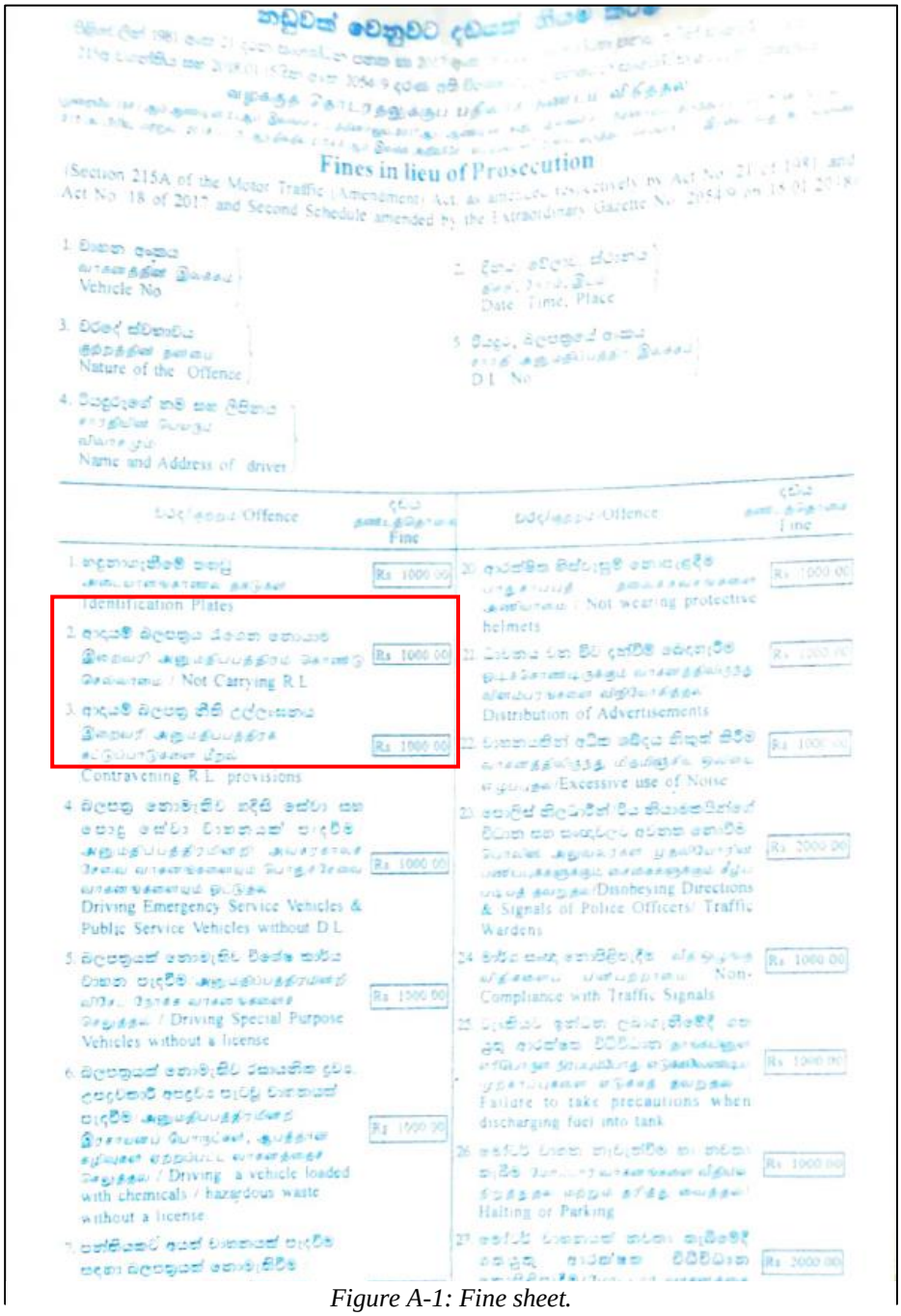
Appendix

Appendix A – Law Enforcement

Appendix A1 - Revenue license law with its respective amount of fine mentioned in fine sheet.



Fines in lieu of Prosecution

(Section 215A of the Motor Traffic (Amendment) Act, as amended by Act No. 21 of 2017 and Second Schedule amended by the Extraordinary Gazette No. 2054/10 of 15.01.2018)

Vehicle No

Date, Time, Place

Nature of the Offence

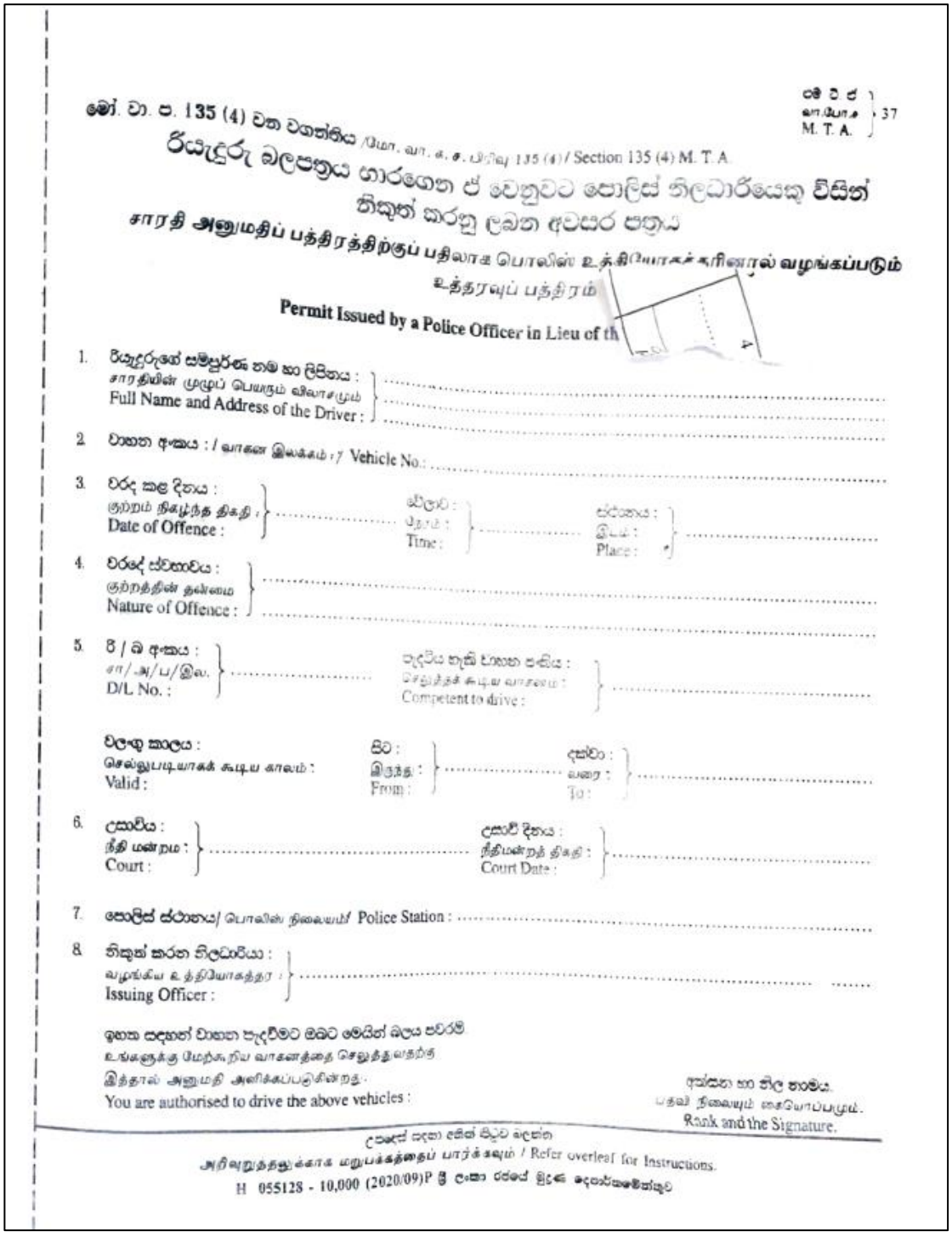
D.L. No

Name and Address of driver

Offence	Fine	Offence	Fine
1. Identification Plates	Rs. 1000.00	20. Not wearing protective helmets	Rs. 1000.00
2. Not Carrying R.L	Rs. 1000.00	21. Distribution of Advertisements	Rs. 1000.00
3. Contravening R.L provisions	Rs. 1000.00	22. Excessive use of Noise	Rs. 1000.00
4. Driving Emergency Service Vehicles & Public Service Vehicles without D.L	Rs. 1000.00	23. Disobeying Directions & Signals of Police Officers/ Traffic Wardens	Rs. 2000.00
5. Driving Special Purpose Vehicles without a license	Rs. 1500.00	24. Non-Compliance with Traffic Signals	Rs. 1000.00
6. Driving a vehicle loaded with chemicals / hazardous waste without a license	Rs. 1500.00	25. Failure to take precautions when discharging fuel into tank	Rs. 1000.00
7.		26. Halting or Parking	Rs. 1000.00
		27.	Rs. 2000.00

Figure A-1: Fine sheet.

Appendix A2 – Permit issued by a police officer.



මෝ. වා. ප. 135 (4) වන වගන්තිය /மோ. வா. ச. ச. பிரிவு 135 (4) / Section 135 (4) M. T. A.

රියැදුරු බලපත්‍රය භාරගෙන ඒ වෙනුවට පොලිස් නිලධාරියෙකු විසින් නිකුත් කරනු ලබන අවසර පත්‍රය

சாரதி அனுமதிப் பத்திரத்திற்குப் பதிலாக பொலிஸ் உத்தியோகத்தரினால் வழங்கப்படும் உத்தரவுப் பத்திரம்

Permit Issued by a Police Officer in Lieu of th

1. රියැදුරුගේ සම්පූර්ණ නම හා ලිපිනය : / சாரதியின் முழுப் பெயரும் விலாசமும் / Full Name and Address of the Driver :
2. වාහන අංකය : / வாகன இலக்கம் : / Vehicle No. :
3. වරද කළ දිනය : / குற்றம் நிகழ்ந்த திகதி : / Date of Offence : වේලාව : / நேரம் : / Time : ස්ථානය : / இடம் : / Place :
4. වරදේ ස්වභාවය : / குற்றத்தின் தன்மை / Nature of Offence :
5. ර / බ අංකය : / ச / அ / ப / இல. / D/L No. : පැදවිය හැකි වාහන පංතිය : / செலுத்தக் கூடிய வாகனம் : / Competent to drive :

   වලංගු කාලය : / செல்லுபடியாகக் கூடிய காலம் : / Valid : සිට : / இருந்து : / From : දක්වා : / வரை : / To :
6. උසාවිය : / நீதி மன்றம் : / Court : උසාවි දිනය : / நீதிமன்றத் திகதி : / Court Date :
7. පොලිස් ස්ථානය / பொலிஸ் நிலையம் / Police Station :
8. නිකුත් කරන නිලධාරියා : / வழங்கிய உத்தியோகத்தர் : / Issuing Officer :

ඉහත සඳහන් වාහන පැදවීමට ඔබට මෙයින් බලය පවරමි
உங்களுக்கு மேற்கூறிய வாகனத்தை செலுத்துவதற்கு
இத்தால் அனுமதி அளிக்கப்படுகின்றது.
You are authorised to drive the above vehicles :

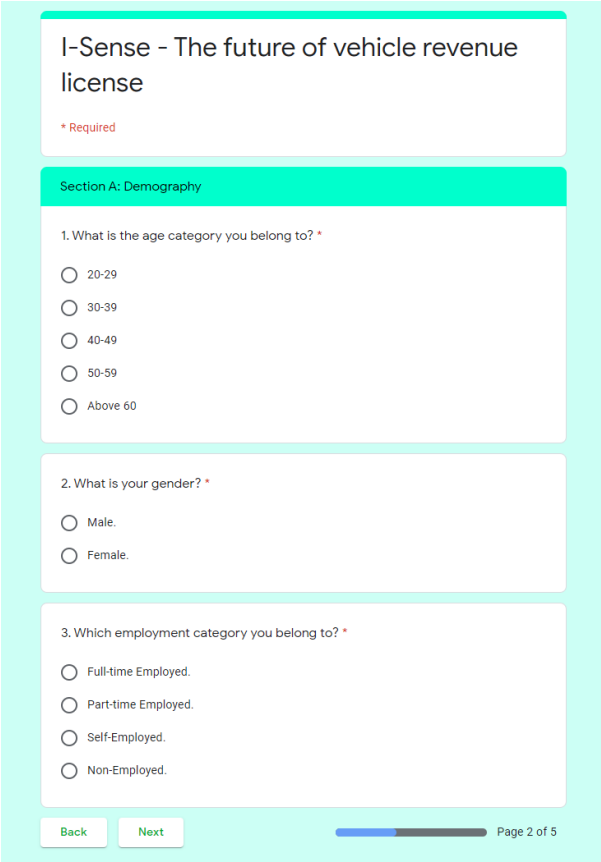
අත්සන හා නිල නාමය.
பதவி நிலையும் கையொப்பமும்.
Rank and the Signature.

උපදෙස් සඳහා අතින් හිටුව බලන්න
அறிவுறுத்தலுக்காக மறுபக்கத்தைப் பார்க்கவும் / Refer overleaf for Instructions.
H 055128 - 10,000 (2020/09)P ශ්‍රී ලංකා රජයේ මුද්‍රණ දෙපාර්තමේන්තුව

Figure A-2: Permit Issued by a police officer.

Appendix B – Requirements.

Appendix B1 – Questionnaire.



I-Sense - The future of vehicle revenue license

* Required

Section A: Demography

1. What is the age category you belong to? *

- 20-29
- 30-39
- 40-49
- 50-59
- Above 60

2. What is your gender? *

- Male.
- Female.

3. Which employment category you belong to? *

- Full-time Employed.
- Part-time Employed.
- Self-Employed.
- Non-Employed.

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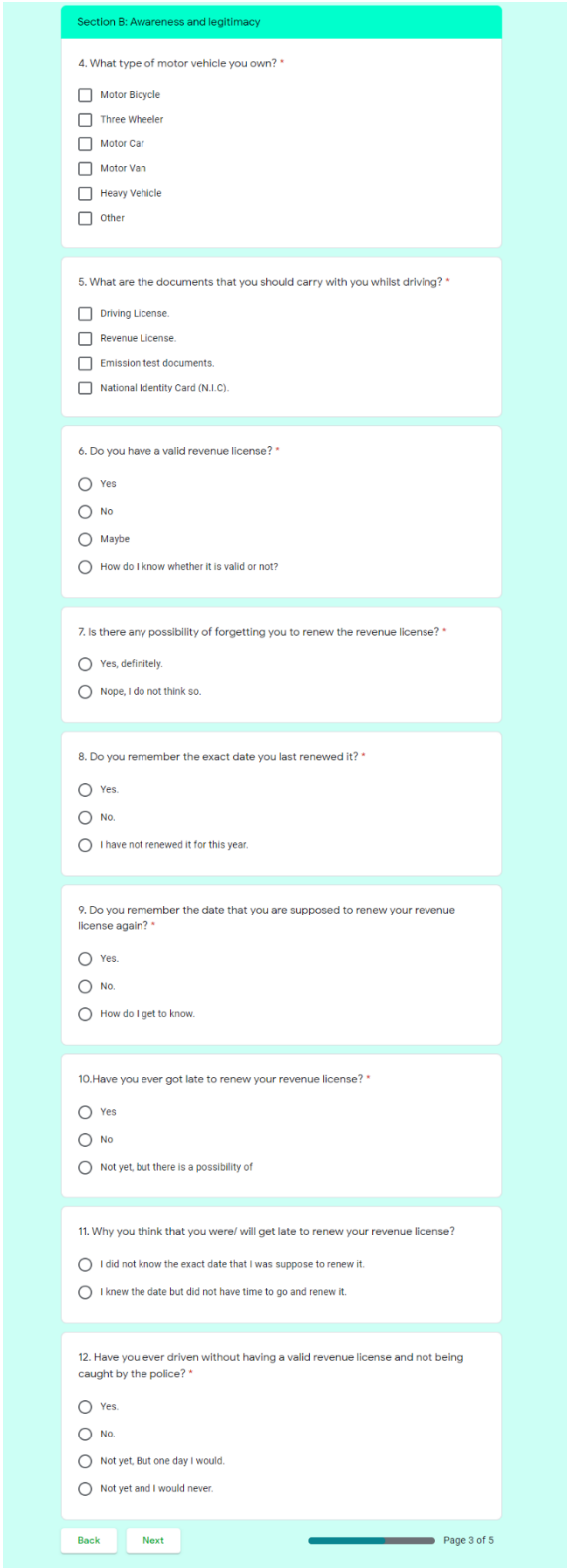

Section B: Awareness and legitimacy

4. What type of motor vehicle you own? *

- Motor Bicycle
- Three Wheeler
- Motor Car
- Motor Van
- Heavy Vehicle
- Other

5. What are the documents that you should carry with you whilst driving? *

- Driving License.
- Revenue License.
- Emission test documents.
- National Identity Card (N.I.C).

6. Do you have a valid revenue license? *

- Yes
- No
- Maybe
- How do I know whether it is valid or not?

7. Is there any possibility of forgetting you to renew the revenue license? *

- Yes, definitely.
- Nope, I do not think so.

8. Do you remember the exact date you last renewed it? *

- Yes.
- No.
- I have not renewed it for this year.

9. Do you remember the date that you are supposed to renew your revenue license again? *

- Yes.
- No.
- How do I get to know.

10.Have you ever got late to renew your revenue license? *

- Yes
- No
- Not yet, but there is a possibility of

11. Why you think that you were/ will get late to renew your revenue license?

- I did not know the exact date that I was suppose to renew it.
- I knew the date but did not have time to go and renew it.

12. Have you ever driven without having a valid revenue license and not being caught by the police? *

- Yes.
- No.
- Not yet, But one day I would.
- Not yet and I would never.

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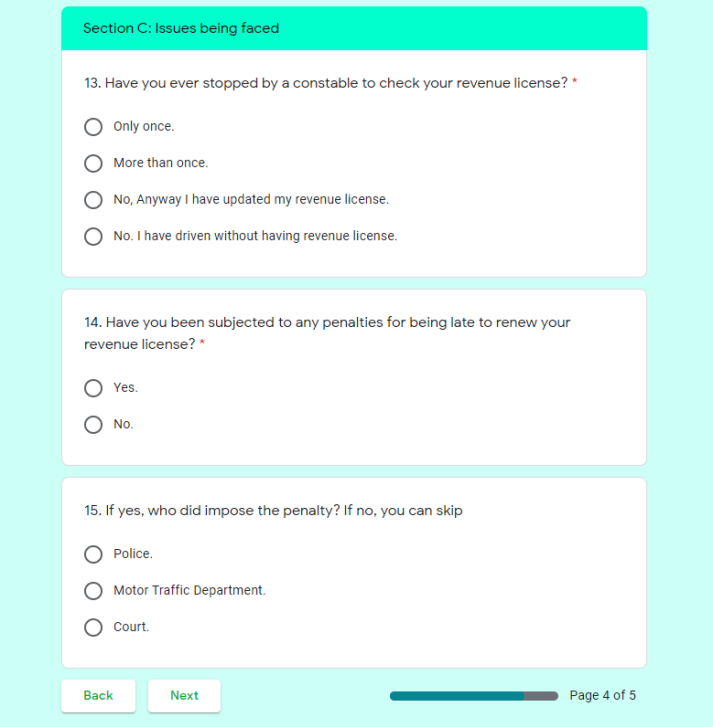


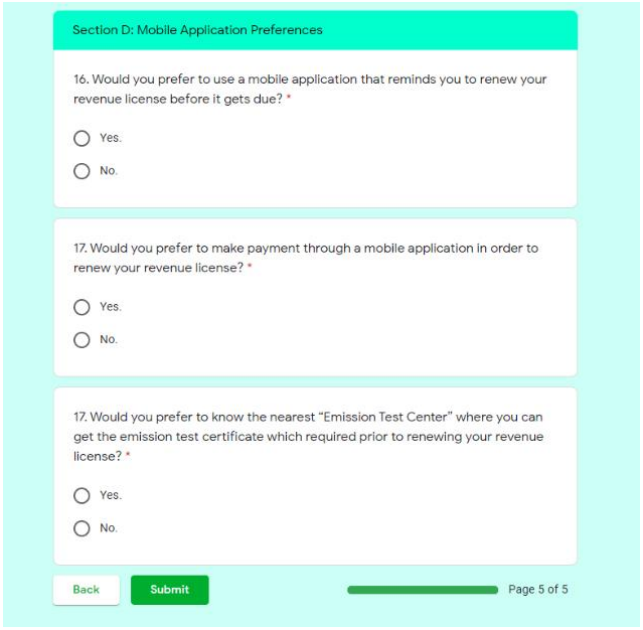


Figure B1: Questionnaire.

Appendix B2 – Questionnaire circulated among vehicle owners.

1. What is the age category you belong to?
    a. 20-29
    b. 30-39
    c. 40-49
    d. 50-59
    e. Above 60

2. What is your gender?
    a. Male
    b. Female

3. Which employment category you belong to?
    a. Full-time Employed
    b. Part-time Employed
    c. Self-Employed
    d. Non-Employed

4. What type of a motor vehicle you own?
    a. Motor Car.
    b. Motor Van.
    c. Motor Bicycle.
    d. Heavy Vehicle.
    e. Other

5. What are the documents that you should carry with you whilst driving? (Check Box)
    a. Driving License.
    b. Revenue License.
    c. Emission test documents.
    d. National Identity Card (N.I.C).

6. Do you have a valid revenue license? (Radio Button)

a. Yes.
b. No.
c. I do not know.
d. How do I know whether it is valid or not?

7. Is there any possibility of forgetting you to renew the revenue license? (Radio Button)
    a. Yes, definitely.
    b. Nope, I do not think so.

8. Do you remember the exact date you last renewed it? (Radio Button)
    a. Yes.
    b. No. I forgot to renew it.
    c. Very recently. But do not remember the exact date.
    d. Not recently. But Do not remember the exact date.

9. Do you remember the date that you are supposed to renew your revenue license again?
    a. Yes
    b. No
    c. How do I get to know?

10. Have you ever got late to renew revenue license? (Radio Button)
    a. Yes.
    b. No.
    c. Not yet but there is a possibility of being late.

11. Why you think that you were late to renew revenue license? (checkbox)
    a. I did not know the exact date that I was supposed to renew.
    b. I knew the date but did not have time to go and renew it.

12. Have you ever driven without having a valid revenue license? (Radio Button)
    a. Yes.
    b. No.
    c. Not yet. But one day I would.
    d. Not yet and I would never.

13. Have you ever stopped by a constable to check your revenue license? (Radio Button)
    a. Only once.
    b. More than once.
    c. No. Anyway I have updated my revenue license.
    d. No. I have driven without having license.

14. Have you been subjected to any penalties for being late to renew your revenue license?
    a. Yes
    b. No

15. If yes, who impose the penalty? If no, you can skip. (Radio Button)
    a. Police
    b. Motor Traffic Department
    c. Court

16. Would you prefer to use a mobile application which reminds you to renew your revenue license before it gets due? (Radio Button)
    a. Yes
    b. No

17. Would you prefer to know the nearest “Emission Test Center” where you can get the emission test certificate which required prior to renew your revenue license? (Radio Button)
    a. Yes

b. No

18. Would you prefer to make payment through a mobile application in order to renew your revenue license? (Radio Button)
    a. Yes
    b. No

Appendix B3 – Questionnaire circulated among police officers.

19. Are you an officer working with the traffic branch of a police? (Radio Button)
    a. Yes.
    b. No.

20. What is the current rank you hold? (Radio Button)
    e. Police Constable.
    f. Police Sergeant.
    g. Sub Inspector.
    h. Inspector.
    i. Officer in Charge

21. How many vehicles you stop to inspect in a day? (Radio Button)
    e. 0-24.
    f. 25-49.
    g. 50-74.
    h. 75-99.

22. Which documents do you inspect of such a stopped vehicle? (Check Box)
    c. Driving License.
    d. Revenue License.
    e. Emission Test Certificate.
    f. National Identity Card.

23. Are drivers caught driving without having a valid revenue license? (Radio Button)
    e. Yes.
    f. No.

24. Do you think that you have let a revenue license violator go, due to not stopping him? (Radio Button)
    d. Yes.
    e. No.
    f. Sometimes.

25. Do you think that people drive vehicles being uncaught without having a revenue license? (Radio Button)
    e. Yes.
    f. No.

26. What would be the reason, if "Yes" is the answer for above question? (Check Box)
    a. Difficulty in pre-identifying offenders.
    b. Difficulty to stop and check every vehicle.

27. Are you a smart phone user?
    a. Yes
    b. No

28. If yes, how is your knowledge of using a smart phone? (Radio Button)
    a. Poor
    b. Average
    c. Good
    d. Excellent

29. Would you prefer to use a mobile application which has the capability of sharing the location of a vehicle which moves without having a valid revenue license? (Radio Button)
    a. Yes, that would make our lives easy.
    b. No, Satisfied with the current process.

30. What are the suggestions to improve current process of identifying revenue license offenders? (Text Box)

As the interviews were semi structured, above questions were distributed but further questions were also added according to the conversation.

Appendix C – Methodologies.

Appendix C1 – Project Plan

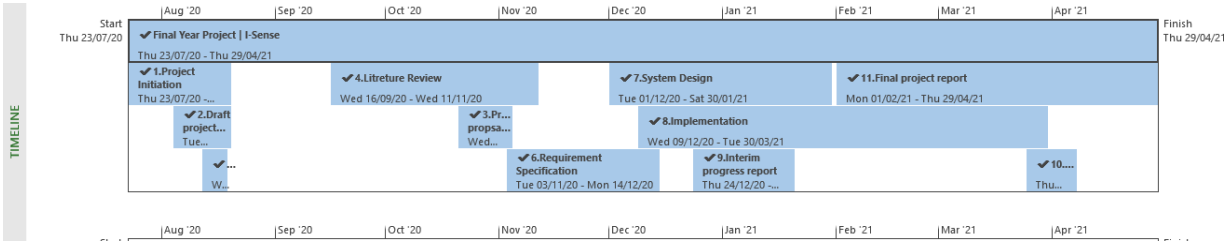
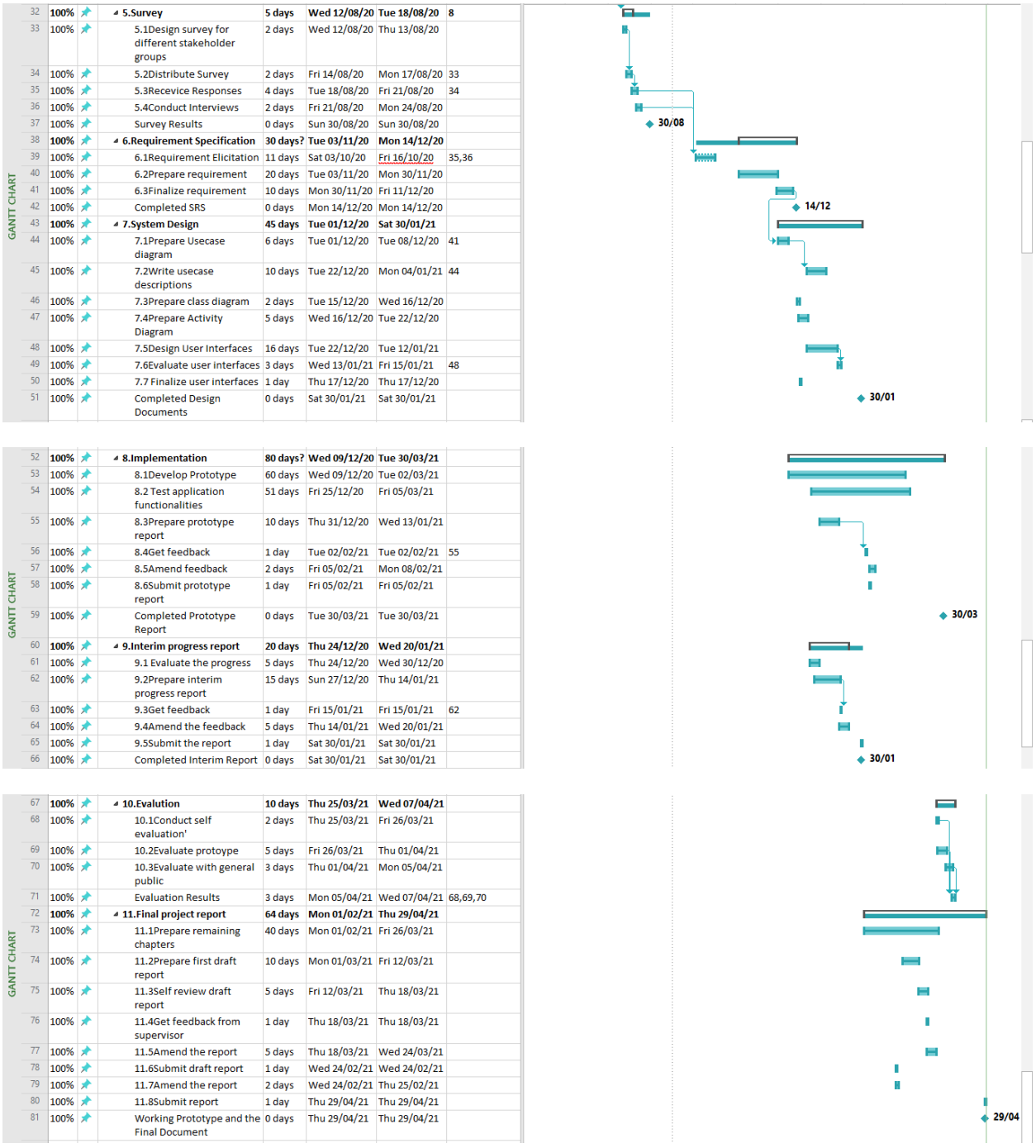


Figure C-1.1: Original Timeline

GANTT CHART

	% Co	Task Name	Durati	Start	Finish	Predecessors
1	100	**Final Year Project | I-Sense**	**201 days**	**Thu 23/07/20**	**Thu 29/04/21**	
2	100%	**1.Project Initiation**	**20 days**	**Thu 23/07/20**	**Wed 19/08/20**	
3	100%	1.1 Identify the problem	5 days	Thu 23/07/20	Wed 29/07/20	
4	100%	1.2Research on the problem	12 days	Wed 29/07/20	Thu 13/08/20	
5	100%	1.3 Get the problem validated by the supervisor	3 days	Sat 15/08/20	Tue 18/08/20	
6	100%	Finalized Project Idea	0 days	Thu 23/07/20	Thu 23/07/20	
7	100%	**2.Draft project Proposal document**	**12 days**	**Tue 04/08/20**	**Wed 19/08/20**	
8	100%	2.1Research and document the problem background	4 days	Tue 04/08/20	Fri 07/08/20	
9	100%	2.2Define aims and objectives	2 days	Mon 10/08/20	Tue 11/08/20	
10	100%	2.3List initial requirements of the proposed solution	1 day	Wed 12/08/20	Wed 12/08/20	
11	100%	2.4Identify Challenges	1 day	Wed 12/08/20	Wed 12/08/20	
12	100%	2.5prepare gantt chart	1 day	Fri 14/08/20	Fri 14/08/20	
13	100%	2.6List the litreture read requried for PP	4 days	Wed 12/08/20	Mon 17/08/20	
14	100%	2.7Prepare darft PP	3 days	Mon 17/08/20	Wed 19/08/20	
15	100%	2.8 Get feedback from supervisor	1 day	Wed 19/08/20	Wed 19/08/20	
16	100%	Draft PP	0 days	Sun 30/08/20	Sun 30/08/20	
17	**100%**	**3.Project propsal Document(PP)**	**11 days**	**Wed 21/10/20**	**Wed 04/11/20**	**7**
18	100%	3.1Adjust draft PP based on the feedback	3 days	Wed 21/10/20	Fri 23/10/20	15
19	100%	3.2Prepare final PP	3 days	Fri 23/10/20	Tue 27/10/20	16
20	100%	3.3Get the feedback from supervisor	1 day	Tue 27/10/20	Tue 27/10/20	
21	100%	3.4Update accordinly and submit	3 days	Wed 28/10/20	Fri 30/10/20	20
22	100%	Completed Project Proposal Document	0 days	Wed 04/11/20	Wed 04/11/20	
23	**100%**	**4.Litreture Review**	**41 days?**	**Wed 16/09/20**	**Wed 11/11/20**	
24	100%	4.1Prepare draft plan for LR	4 days	Wed 23/09/20	Mon 28/09/20	
25	100%	4.2 Read exsisting Litreture	18 days	Mon 10/08/20	Wed 02/09/20	8
26	100%	4.3Critically review litreture	19 days	Mon 28/09/20	Thu 22/10/20	25
27	100%	4.4Prepare Draft LR	7 days	Fri 16/10/20	Mon 26/10/20	24,26
28	100%	4.5Submit draft LR	1 day	Mon 26/10/20	Mon 26/10/20	
29	100%	4.6Amend LR accrodinly	3 days	Tue 27/10/20	Thu 29/10/20	
30	100%	4.7Finalize the LR	4 days	Tue 03/11/20	Fri 06/11/20	
31	100%	Competed LR document	0 days	Wed 11/11/20	Wed 11/11/20	



32	100%		**5.Survey**	**5 days**	**Wed 12/08/20**	**Tue 18/08/20**	**8**
33	100%		5.1Design survey for different stakeholder groups	2 days	Wed 12/08/20	Thu 13/08/20	
34	100%		5.2Distribute Survey	2 days	Fri 14/08/20	Mon 17/08/20	33
35	100%		5.3Recevice Responses	4 days	Tue 18/08/20	Fri 21/08/20	34
36	100%		5.4Conduct Interviews	2 days	Fri 21/08/20	Mon 24/08/20	
37	100%		Survey Results	0 days	Sun 30/08/20	Sun 30/08/20	
38	**100%**		**6.Requirement Specification**	**30 days?**	**Tue 03/11/20**	**Mon 14/12/20**	
39	100%		6.1Requirement Elicitation	11 days	Sat 03/10/20	Fri 16/10/20	35,36
40	100%		6.2Prepare requirement	20 days	Tue 03/11/20	Mon 30/11/20	
41	100%		6.3Finalize requirement	10 days	Mon 30/11/20	Fri 11/12/20	
42	100%		Completed SRS	0 days	Mon 14/12/20	Mon 14/12/20	
43	**100%**		**7.System Design**	**45 days**	**Tue 01/12/20**	**Sat 30/01/21**	
44	100%		7.1Prepare Usecase diagram	6 days	Tue 01/12/20	Tue 08/12/20	41
45	100%		7.2Write usecase descriptions	10 days	Tue 22/12/20	Mon 04/01/21	44
46	100%		7.3Prepare class diagram	2 days	Tue 15/12/20	Wed 16/12/20	
47	100%		7.4Prepare Activity Diagram	5 days	Wed 16/12/20	Tue 22/12/20	
48	100%		7.5Design User Interfaces	16 days	Tue 22/12/20	Tue 12/01/21	
49	100%		7.6Evaluate user interfaces	3 days	Wed 13/01/21	Fri 15/01/21	48
50	100%		7.7 Finalize user interfaces	1 day	Thu 17/12/20	Thu 17/12/20	
51	100%		Completed Design Documents	0 days	Sat 30/01/21	Sat 30/01/21	
52	**100%**		**8.Implementation**	**80 days?**	**Wed 09/12/20**	**Tue 30/03/21**	
53	100%		8.1Develop Prototype	60 days	Wed 09/12/20	Tue 02/03/21	
54	100%		8.2 Test application functionalities	51 days	Fri 25/12/20	Fri 05/03/21	
55	100%		8.3Prepare prototype report	10 days	Thu 31/12/20	Wed 13/01/21	
56	100%		8.4Get feedback	1 day	Tue 02/02/21	Tue 02/02/21	55
57	100%		8.5Amend feedback	2 days	Fri 05/02/21	Mon 08/02/21	
58	100%		8.6Submit prototype report	1 day	Fri 05/02/21	Fri 05/02/21	
59	100%		Completed Prototype Report	0 days	Tue 30/03/21	Tue 30/03/21	
60	**100%**		**9.Interim progress report**	**20 days**	**Thu 24/12/20**	**Wed 20/01/21**	
61	100%		9.1 Evaluate the progress	5 days	Thu 24/12/20	Wed 30/12/20	
62	100%		9.2Prepare interim progress report	15 days	Sun 27/12/20	Thu 14/01/21	
63	100%		9.3Get feedback	1 day	Fri 15/01/21	Fri 15/01/21	62
64	100%		9.4Amend the feedback	5 days	Thu 14/01/21	Wed 20/01/21	
65	100%		9.5Submit the report	1 day	Sat 30/01/21	Sat 30/01/21	
66	100%		Completed Interim Report	0 days	Sat 30/01/21	Sat 30/01/21	
67	**100%**		**10.Evalution**	**10 days**	**Thu 25/03/21**	**Wed 07/04/21**	
68	100%		10.1Conduct self evaluation'	2 days	Thu 25/03/21	Fri 26/03/21	
69	100%		10.2Evaluate protoype	5 days	Fri 26/03/21	Thu 01/04/21	
70	100%		10.3Evaluate with general public	3 days	Thu 01/04/21	Mon 05/04/21	
71	100%		Evaluation Results	3 days	Mon 05/04/21	Wed 07/04/21	68,69,70
72	**100%**		**11.Final project report**	**64 days**	**Mon 01/02/21**	**Thu 29/04/21**	
73	100%		11.1Prepare remaining chapters	40 days	Mon 01/02/21	Fri 26/03/21	
74	100%		11.2Prepare first draft report	10 days	Mon 01/03/21	Fri 12/03/21	
75	100%		11.3Self review draft report	5 days	Fri 12/03/21	Thu 18/03/21	
76	100%		11.4Get feedback from supervisor	1 day	Thu 18/03/21	Thu 18/03/21	
77	100%		11.5Amend the report	5 days	Thu 18/03/21	Wed 24/03/21	
78	100%		11.6Submit draft report	1 day	Wed 24/02/21	Wed 24/02/21	
79	100%		11.7Amend the report	2 days	Wed 24/02/21	Thu 25/02/21	
80	100%		11.8Submit report	1 day	Thu 29/04/21	Thu 29/04/21	
81	100%		Working Prototype and the Final Document	0 days	Thu 29/04/21	Thu 29/04/21	

Figure C-1.2: Original Project Plan

Appendix C2 – Revised Project Plan.

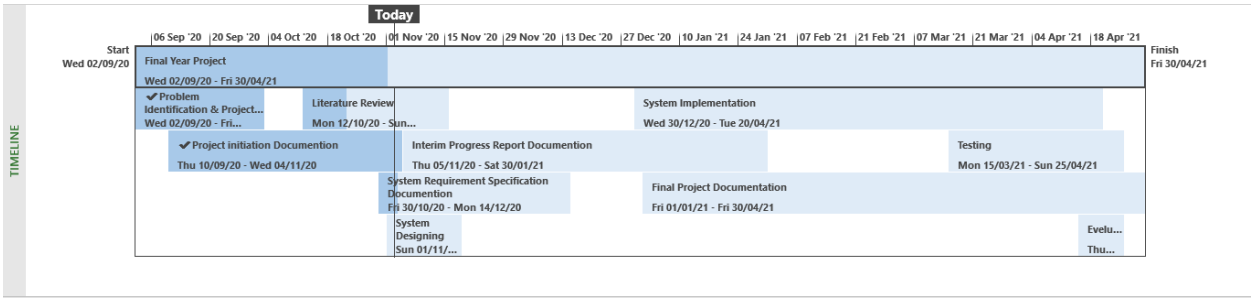


Figure C-2.1: Revised Timeline

% Co	Task Mode	Task Name	Duration	Start	Finish
25%		Final Year Project	173 days?	Wed 02/09/20	Fri 30/04/21
100%		1 Problem Identification & Project Initiation	23 days?	Wed 02/09/20	Fri 02/10/20
100%		2 Project initiation Documention	40 days	Thu 10/09/20	Wed 04/11/20
30%		3 Literature Review	26 days	Mon 12/10/20	Sun 15/11/20
10%		4 System Requirement Specification Documention	32 days	Fri 30/10/20	Mon 14/12/20
1%		5 System Designing	14 days	Sun 01/11/20	Wed 18/11/20
0%		6 Interim Progress Report Documention	63 days	Thu 05/11/20	Sat 30/01/21
0%		7 System Implementation	80 days	Wed 30/12/20	Tue 20/04/21
0%		8 Testing	31 days?	Mon 15/03/21	Sun 25/04/21
0%		8.1 Unit Testing	24 days?	Mon 15/03/21	Thu 15/04/21
0%		8.2 UAT Testing	5 days?	Tue 20/04/21	Sun 25/04/21
0%		9 Eveluation	8 days?	Thu 15/04/21	Sun 25/04/21
0%		9.1 Self Eveluation	4 days?	Thu 15/04/21	Tue 20/04/21
0%		9.2 Industry Eveluation	5 days?	Tue 20/04/21	Sun 25/04/21
0%		10 Final Project Documentation	86 days?	Fri 01/01/21	Fri 30/04/21

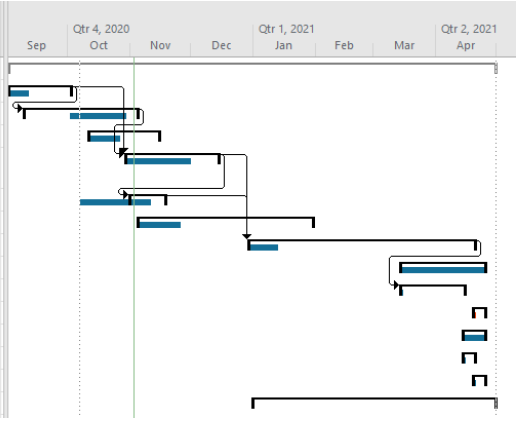


Figure C-2.2: Revised Project Plan

Appendix C3 – Work Breakdown Structure (WBS)

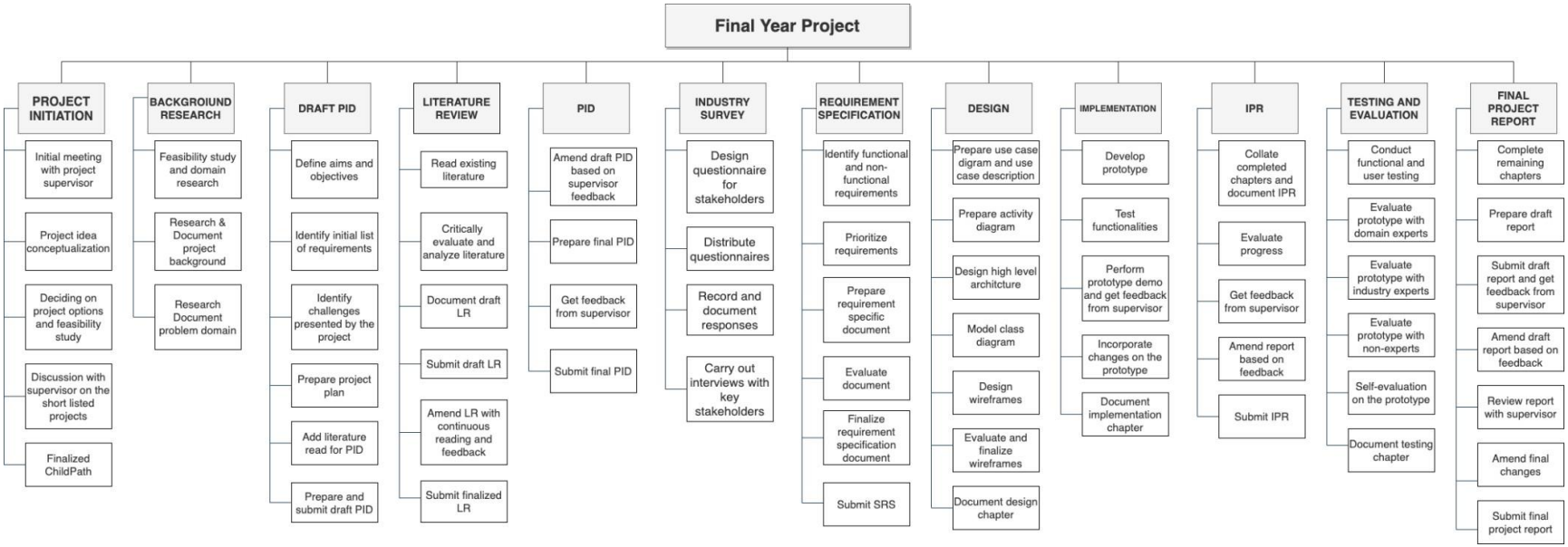


Figure C-3: Work Breakdown Structure

Appendix C4 – Meeting Logs

Name of the Supervisee		**Praneeth Mihiranga Welihinda**							
Student ID		**2017533**							
Project Title		**I-Sense: The Future of vehicle revenue license.**							
Meeting #	**Date**	**Time**	**Discussion/Guidance given**	**Tasks to complete before next meeting**	**Next Meeting Date**	**Next Meeting Time**	**Comments on previously assigned work**	**Comments on progress as per plan**	**Supervisors sign off**
1	02.09.2020	1.00PM-2.30PM	Find a business problem and solution for it.	Do research to check whether the solution exists or not.	02.09.2020	1.00PM	Do research to check whether the solution exists or not.	As planned	Janice Abeykoon
2	09.09.2020	1.00PM-2.30PM	Had to change the idea as it already exists.	Find a business problem which doesn't exist and do a proper research.	09.09.2020	8.45AM	Guidance was given how to research on a problem.	As planned	Janice Abeykoon
3	16.09.2020	8.45AM-9.45AM	Finalized the business problem and write problem statement.	Do research / write problem statement.	16.09.2020	8.00AM	Write the problem domain and work on the pilot study.	As planned	Janice Abeykoon
4	09.10.2020	8.00AM-9.00AM	How to write the problem statement/ work on PID.	Submit the revised problem statement/ pilot study.	09.10.2020	2.00PM	Feedback was given on the problem domain. Submit the	As planned	Janice Abeykoon

							pilot study questions.		
5	15.10.2020	2.00PM-2.30 PM	Start working on PID.	Do research to do the gap analysis, make a questionnaire.	15.10.2020	2.00PM	Feedback given on questionnaire	As planned	Janice Abeykoon
6	22.10.2020	2.00PM-2.30PM	Complete the PID and send in order to get feedback.	Send a draft PID and circulate the questionnaire.	6/11/2020	2.00PM	Feedback given.	As planned	Janice Abeykoon
7	6/11/2020	2.00PM-2.30PM	Feedback was given in chapter 1, was asked to start chapter 2.	Sent subtopics of chapter 2.	13/11/2020	2.00PM	feedback given on LR topic.	As planned	Janice Abeykoon
8	13/11/2020	2.00PM-2.30PM	Feedback on chapter 2 subtopics.	Interview industry expertise to gather requirements.	20/11/2020	2.00PM	guidance given on gathering requirements.	As planned	Janice Abeykoon
9	20/11/2020	2.00PM-2.30PM	Instructions were given on how to continue the next stages of chapter 2.	send completed 2 sub chapters of LR.	27/11/2020	2.00PM	feedback on topics.	slightly delayed	Janice Abeykoon

10	27/11/2020	2.00PM-2.30PM	Feedback was given on chapter 2 and was guided to start working chapter 3.	Send the first (draft) version of chapter 2. (Chapter 2 V-1.0)	15/01/2021	10.00AM	feedback given.	Delayed	Janice Abeykoon
11	15/01/2021	10.00AM-10.30AM	Instructions were given on chapter 4 along with chapter 5.	Send revised chapter 2.	25/01/2021	10.00AM	Feedback given.	Delayed	Janice Abeykoon
12	25/01/2021	10.00AM-10.30AM	Identify the stakeholders of proposed system and draw the onion diagram and finalize the list of requirements.	Send onion diagram and use case diagram.	08/02/2021	10.00AM	Feedback given on diagrams.	Delayed	Janice Abeykoon
13	08/02/2021	10.00AM-10.30AM	Instructions were given to start implementation.	Send 2 activity diagrams along with 2 use case descriptions.	22/02/2021	10.00AM	Feedback given on diagrams.	Delayed	Janice Abeykoon
14	22/02/2021	10.00AM-10.30AM	Feedback was given on diagrams. (onion, use case, activity)	Send draft SRS.	16/03/2021	10.00AM	feedback given on SRS.	Delayed	Janice Abeykoon

15	16/03/2021	10.00AM-10.30AM	Instructions were given on chapter 6.	Send chapter 5.	22/03/2021	10.00AM	feedback given on design chapter.	Delayed	Janice Abeykoon
16	22/03/2021	10.00AM-10.30AM	Instructions were given on chapter 8.	Demonstrated the protoype and send the draft SRS.	05/04/2021	10.00AM	Feedback given.	As planned	Janice Abeykoon
17	05/04/2021	10.00AM-10.30AM	Instructions were given and set deadlines to complete the rest of work before they get due.	Complete chapter 6 and 8.	19/04/2021	10.00AM	complet chapters and send for review.	slightly delayed	Janice Abeykoon
18	19/04/2021	10.00AM-10.30AM	Instuctions were given to finalize the thesis, complete the code & do the video demonstration successfully.	Send Draft thesis .			Send draft ASAP.	Delayed	Janice Abeykoon
Note									
	To be filled by the supervisee								
	To be filled by the supervisor								

Appendix D - Evaluation

All the experts and non-experts in the respective domain who contributed to evaluate the prototype were questioned via arranging physical meetings with them. Posed questions were based on the concept and the design of the developed prototype.

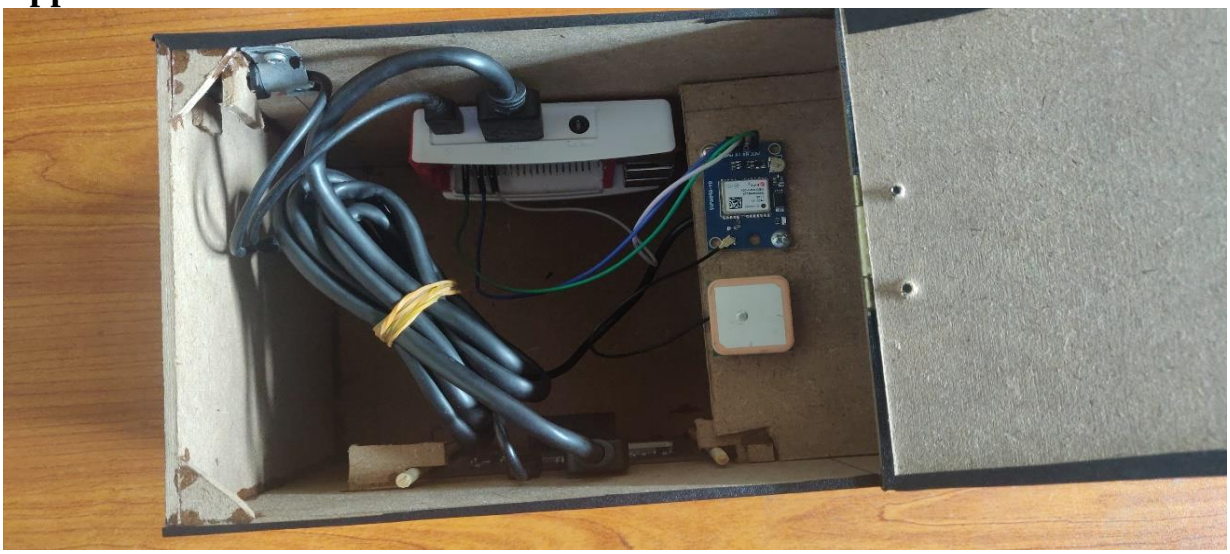
Appendix D1 - Questions based on the concept of the prototype.

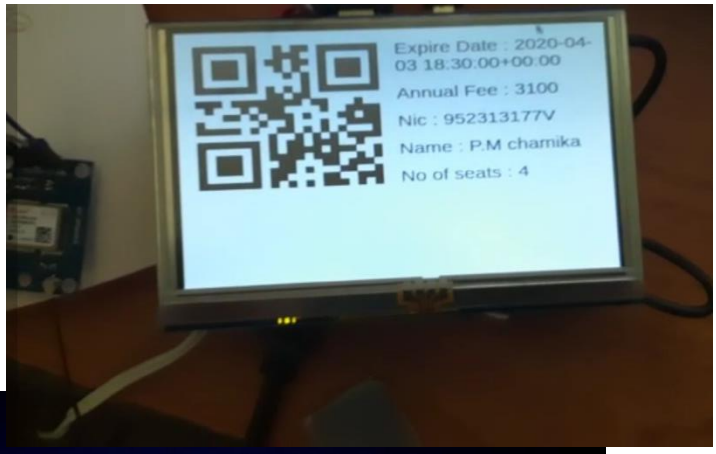
I. According to your perspective, do you think that the existence of this application is really required?
II. Do you think that the solution has addressed the problem statement identified?
III. Do you think that this application requires any significant enhancements in terms of identifying revenue license violators?
IV. Do you think that this application is easy to utilize?
V. Please state the overall impression of the project and your suggestions to be done for further improvements?

Appendix D2 - Questions based on design and development of the prototype.

I. According to your perspective, do you think that this prototype is eligible to fulfill all the problems addressed?
II. Do you have any suggestions on key features and functionalities to be made?
III. Please state your feedback on the design considerations utilized in both applications.
IV. Please state your feedback on the technologies utilized in both applications.
V. Please state your comments or suggestions to be done for further improvements of this project.

Appendix E – IoT Device





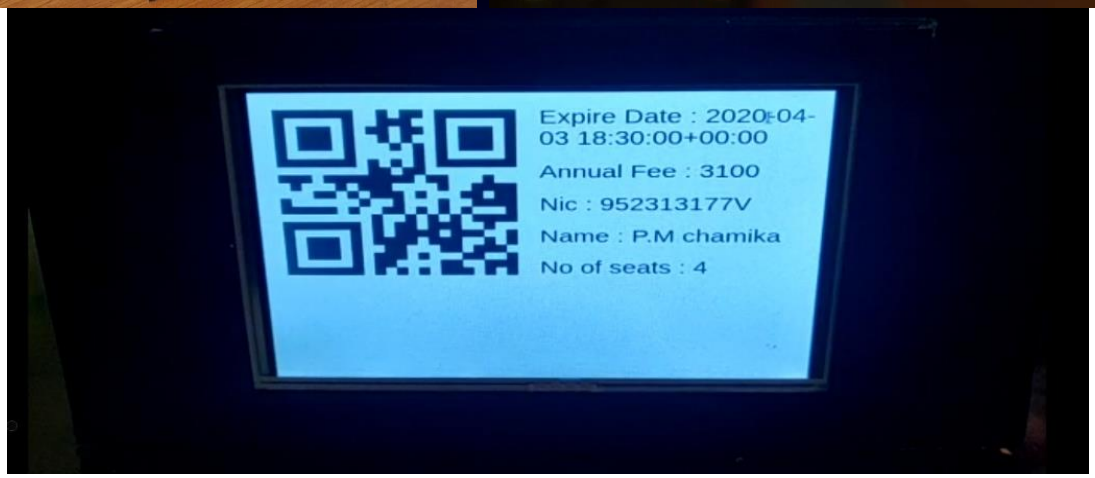


Figure E: IoT Device of I-sense

Appendix F -Plagiarism Report

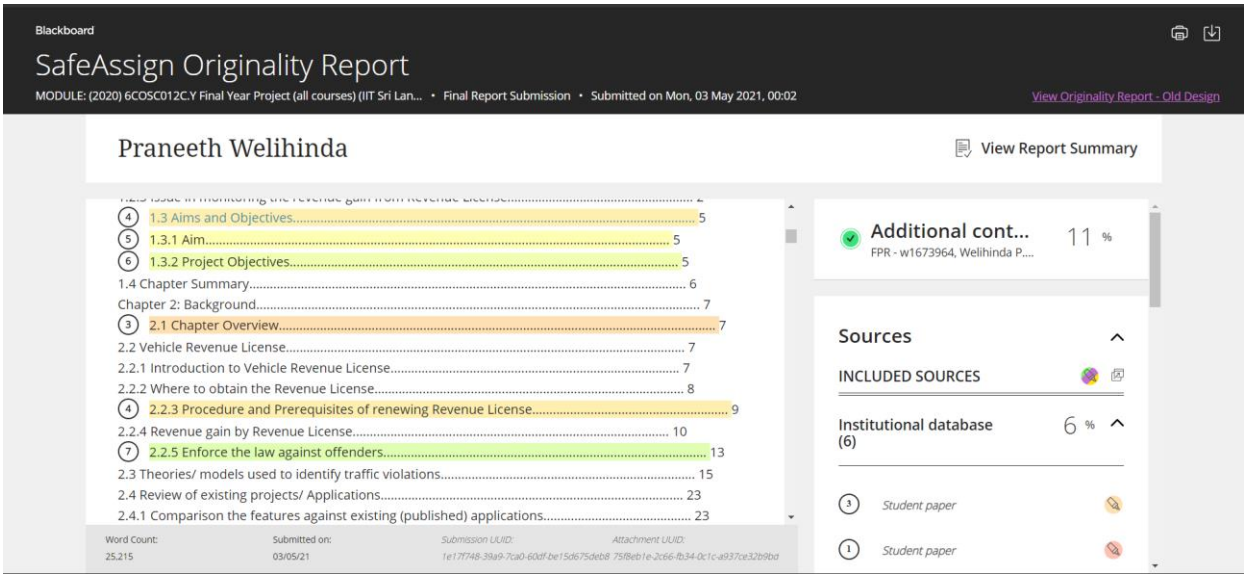


Figure F: Plagiarism Report