ePLATE: Smart Grid Integrated Digital Licence Plate

Final Engineering Report

Team Members:

Abdul Bhutta - 100785884

Yussef Elzein - 100641407

Emran Soltani - 100618333

Kumail Syed - 100661596

Walid Ayub - 100695612

This final engineering report is submitted in partial fulfillment for the final year Capstone Project in the Faculty of Engineering and Applied Science.

Project Advisor: Dr. Tarlochan Sidhu, P.Eng.

Capstone Coordinator: Dr. Vijay K. Sood, P.Eng., ECSE

Submitted to Ontario Tech University

April 6th, 2023

Abstract

In recent years, it has become evident that traditional licence plates suffer from their many flaws such as security, durability, and lack of functionality. As large technical advancements as have been in recent years, licence plates have not kept up with the times. It is time for them to undergo a digital transformation. A smart digital licence plate that the potential to be a tremendous upgrade to vehicles on the road and disrupt the automotive industry. Current technologies such as digital displays, communications, and electric vehicles have created a possibility for smart digital licence plates that can offer many different features.

The goal of this project was to create an alternative option to traditional metal plates and take advantage of current technologies to provide our users with a number of features. ePLATE is a powerful tool that boasts features such as theft detection, renewal updates, smart grid integration, and web information access. In addition to the added functionality, our product is also visually appealing and much more durable than traditional plates.

In summary, smart digital licence plates have the potential to disrupt entire markets and mark a significant milestone in the automotive industry. Using latest technologies, we can eliminate the long-standing issues that come with the use of older metal plates. We firmly believe that our product presents a compelling alternative with various elements that improve user experience while providing better security and durability.

Dedication

We would like to dedicate this report to each of our group members' families who have continuously supported us throughout the university in both moral and material needs. Moreover, we would like to dedicate this report to all our professors, peers, and friends for their consistent encouragement and motivation.

Executive Summary

This capstone project aims to create a smart digital licence plate that will present an innovative design for displaying all the requirements needed for a traditional licence plate on a digital screen with the integration of smart grid and various other improvements. Given current technological advancements, it is highly possible to add features that allow clients to be kept updated on all current information and alerts such as theft, battery life, plate renewal, etc., all while being visually appealing. The digital licence plate will be used to display the characters needed for a legal licence plate clearly for law enforcement to read. It will also have customizable aspects that vehicle owners to take advantage of. A website is available for all the services a user may need, such as fulfilling the requirements to renew a vehicle owner's licence plate, tracking their vehicle's location, and alerting others that their vehicle is stolen using their digital plate.

This report contains a combination of reports 1, 2, and 3. Report 1 includes all the initial research conducted to acquire the possible solutions for our problem statement. The report also outlines the estimated cost breakdown of the project. Report 2 includes a concept analysis to show the required key components for our prototype and some viable options we can eliminate. A system design was also provided to clearly outline the software aspect of the project, with diagrams explaining how everything will operate and coordinate for the system to run. Furthermore, visuals for a website example, using a wireframe, showed how the actual website will look and specify how a user can navigate around the services. Lastly, report 3 includes all the final hardware and software design. This report illustrates all the electrical components and connections. Furthermore, it shows a complete diagram on how the cloud server will operate in conjunction with our product and its website. Moreover, it includes a 3D rendering of the weatherproof casing. Lastly, this document outlines the passion, dedication, and efforts made by each member throughout this schoolyear.

Table of Contents

List of Figures

List of Tables

---- BEGINNING OF PREVIOUS REPORTS ----

Smart Grid Integrated Digital Licence Plate

Capstone Project Report #1

Team Members:

Abdul Bhutta - 100785884

Yussef Elzein - 100641407

Emran Soltani - 100618333

Kumail Syed - 100661596

Walid Ayub - 100695612

Report #1 submitted in partial fulfillment for the final year Capstone Project in the Faculty of Engineering and Applied Science.

Project Advisor: Dr. Tarlochan Sidhu, P.Eng.

Capstone Coordinator: Dr. Vijay K. Sood, P.Eng., ECSE

Submitted to Ontario Tech University

October 18th 2022

Abstract

In recent years, it has become evident that traditional licence plates have many flaws such as security, durability, and functionality. Current licence plates have proven time and time again that it is time for an update. The world is quickly going digital as technological advancements are being made every day. Licence plates have not yet caught up to the times. A smart digital licence plate would be a tremendous upgrade moving into this electric and digital world. Current technologies such as displays, communications, and electric vehicles have created a possibility for new smart digital licence plates with features such as theft detection, renewal updates, smart grid integration, and web information access. As the world is transitioning to an all-electric automotive infrastructure, the need for smart grid features will soon enough become a necessity. For this reason, integrating smart grid features such as V2G, V2H, smart charging, and smart metering into EVs is becoming crucial. This report outlines our research conducted on methods of implementing our digital licence plate into the smart grid as well as research on smart features that we plan on implementing in our smart digital licence plate. We will be creating our digital licence plate prototype using components such as a Raspberry Pi, a high-definition display, an RFID card/reader, an SD card, and a rechargeable power bank. Our findings have proven that a smart grid-integrated digital licence plate is becoming increasingly advantageous in the electrification of the automotive industry. Later in this report, we also list additional helpful features that we plan on implementing into our product if time permitting. Throughout this report, our smart grid integrated licence plate will be proven to have elements that are much more functional and favorable than the current metal licence plates used today.

Dedication

We would like to dedicate this report to each of our group members' families who have continuously supported us throughout university in both moral and material needs. Moreover, we would like to dedicate this report to all our professors, peers, and friends for their consistent encouragement and motivation.

Acknowledgements

We would like to express our gratitude to our supervisor Dr. Tarlochan Sidhu who made this project possible. With his guidance we were able to get a thorough understanding of the project and how to execute our ideas. His continuous support fed our ambition to take this project above and beyond.

We would also like to acknowledge our capstone coordinator Dr. Vijay Sood. He was able to give us a strong detailed understanding of producing reports and how to have a complete presentation on our project.

Our sincere appreciation to Dr. Sheldon Williamson for offering his knowledge and guidance with this project. In our first meeting he provided us with many ideas on smart grid technology and possible recommendations on how to implement them.

Lastly, we would like to thank our friends and family for their continued support, especially Siear Lutfi for attending one of our meetings and encouraging us throughout.

We will be forever grateful for this capstone project as it has not only challenged us but helped us understand the process for designing, testing, building, and implementing a product from start to finish.

Table of Contents

List of Figures

List of Tables

List of Acronyms Used

Acronym	Meaning
ALS	Ambient Light Sensor
AMI	Advanced Metering Infrastructure
AMR	Automatic Meter Reading System
API	Application Programming Interface
ATM	Automated Teller Machine
AWS	Amazon Web Service
BMS	Battery Management System
CPU	Central Processing Unit
CSS	Cascading Style Sheet
DB	Database
EV	Electric Vehicle
FEAT	Feature
GCP	Google Cloud Platform
GPIO	General Purpose Input Output
GPS	Global Positioning System
GPU	Graphic Processing Unit
HTML	Hypertext Markup Language
I/O	Input / Output
ID	Identification
IESO	Independent Electricity System Operator
IP	Internet Protocol
LCD	Liquid-Crystal Display
LDR	Light Dependent Resistor
LED	Light-Emitting Diode
LTE	Long Term Evolution
MTO	Ministry of Transportation
OS	Operating System
RFID	Radio-Frequency Identification
SD	Secure Digital
SOC	System-on-Chip
SoC	State of Charge
SoH	State of Health
STRQ	Stakeholder Requirement
TC	Test Case
UC	Use-Case
US	United States
USD	United States Dollar
V2G	Vehicle-to-Grid
V2H	Vehicle-to-Home

1 Problem Identification

1.1 Problem Statement

Licence plates in North America have many issues when it comes to durability. The current licence plates across north America are made of aluminum, a colored reflective adhesive sheeting and paint [14]. Many advancements have been made in technology and there is no reason for vehicles today not to be equipped with smart licence plates. The current licence plates endure issues such as peeling, theft, and readability. Moreover, the province of Ontario had recently updated their plates to blue ones with a new slogan. The goal was to refresh the plates and solve the peeling issue but, instead it made matters worse as law authorities found it difficult to see the plates at night as they weren't reflective. These new plates cost the province about 1 million dollars and shortly after were discontinued [13]. Introducing a smart digital licence plate would automatically eliminate all the problems with the current licence plates. Furthermore, implementing digital licence plates not only would save the province issues like legibility at night, but also create cost-effective solutions for plate updates in the future.

1.2 Project Objective

The objective of this project is to design and implement a smart grid integrated licence plate. Current licence plates are outdated and lack many features. The licence plate we plan on designing will include many smart features such as anti-theft, auto brightness, smart charging, and many more. A full list of features can be found in **Table 1** below. This futuristic and innovative smart grid integrated digital licence plate will be a steppingstone for not only automotive manufacturers but transportation ministries as well.

1.3 Project Features

After many discussions, we have decided on the important features that will be included in our project. **Table 1** below lists the features that will be implemented on the left side of the table. The right side of the table lists features that will be implemented if we have adequate time.

Table 1: Digital Licence Plate Features

Features	Time Permitting Features
High-Definition Digital Screen	*Smart Phone Application*
Online Digital Licence Renewal	*Plate Visual Personalization*
Digital Plate Sticker Renewal	*Parking Metering*
Online Website	*Toll Road Payment Integration*
Auto-Brightness	*Telematics (Vehicle Locator)*
Replaceable Battery	
Anti-Theft	
V2G/V2H Integration	

Smart Metering	
Smart Charging	
EV Battery Information	
Easy Installation	
LTE Connection	
Secure Cloud Communication	
Follows Licence Plate Standards	
Water & Dust Resistant	

1.3.1 Estimated Cost of Project

Table 2 below shows our estimated costs for each of the components needed to build the prototype. The main costs will be the display screen at $200 and the Raspberry Pi at $260. The high cost of the Raspberry Pi is due to the industry-wide shortage of Raspberry Pi products; therefore, we have planned to set aside much of the budget for this part. Each of the estimated costs below represents the high end of the cost of parts and will most likely be higher than the actual cost of the part.

Table 2: Project Estimated Cost of Parts

Part Name	Part Estimated Cost	Total Running Cost
13.4” Display Screen	$200	$200
Raspberry Pi (4GB)	$260	$460
SD Card	$35	$495
Rechargeable Power Bank	$60	$555
RFID Card/Reader	$75	$630
Video and Power Cables	$80	$710
3D Printed Casings	$140	$850
Miscellaneous Parts	$150	$1000
Estimated Total Cost:		**$1000**

1.4 Overview of the Report

In this report, we will discuss all the developments and methods which would necessitate the transition of old-fashioned metal plates into futuristic smart grid integrated digital licence plates. Throughout this project, research has been done on the smart features, hardware, and software design processes. This will demonstrate how the results of the project-related research will meet the specifications and requirements for this smart plate as well as potential future applications. The functional and marketing requirements have been listed in this report to discuss the characteristics and aspects of a digital licence plate. The website will present use cases and acceptance tests to give an idea of how each situation should be handled. The project schedule is displayed using a Gantt chart.

2 Background & Research Review

2.1 Vehicle-to-Grid (V2G)

V2G or vehicle-to-grid is a new technology that allows EV car batteries to supply power back to the grid. V2G enables car owners to push back their vehicle's electrical energy back to the power grid from their electrical vehicle's battery. The idea of V2G is to draw power from electric vehicles during peak energy production hours in order to balance the variations in energy production and consumption [1]. EV batteries would essentially be used as auxiliary storage cells for electrical grids [2]. This would help stabilize the grid during peak hours preventing grid instability. Grid stability is important as the amount of energy generated must equal the amount of energy consumed. The need for energy is often volatile during peak usage hours, which may lead to the overloading of transmission lines, voltage and frequency anomalies, and/or a supply and demand mismatch [1]. The need for drawing power from EV batteries would likely only be for a few minutes a day in small discharges at a time.

Many people's concerns regarding V2G is the negative effect on EV battery health. In practice, it can be seen the battery health is mainly affected by leaving a battery fully charged and unused for long periods of time. This is the reason that vehicle manufacturers recommend charging EV batteries to at most 80% to preserve battery life. As V2G would only require small discharges at a time to balance the volatility of the grid at peak hours, it would have a minimal effect on battery life. Studies have shown that providing energy back to the grid through V2G causes no significant loss in battery capacity when compared to typical battery use such as for driving [1].

2.1.1 Bidirectional Charging

In order to give energy back to the grid, we must employ the use of bidirectional chargers. Bidirectional chargers would normally be set to charge vehicles that are plugged in however if the demand for electricity is high at a given time, the charger would receive a signal to pull energy from the vehicle back to the power grid and ultimately supply power to the houses and buildings in the region [3]. Car owners would be credited based on the amount of charge taken from their vehicles or charged for the energy taken by their vehicle if its battery charge has increased. Many EV charging stations in place today are unidirectional however, bidirectional chargers are quickly replacing the current infrastructure.

There are methods that exist today that can allow individuals to begin contributing to the V2G infrastructure such as installing a V2G bidirectional charging unit at home. People would be able to plug in their vehicles at home and use their vehicles to help stabilize their region's power grid or even provide power to their own houses or to their neighborhoods during outages. Owners would have the ability to control their vehicle's charging by setting a minimum charge so that they may ensure that they have enough charge to use their vehicle when needed.

Currently, as of October 2022, there are only 6 vehicles on the market that support bidirectional charging: Nissan Leaf, Ford F-150 Lightning, Hyundai Ioniq 5, Kia EV6, Volkswagen ID.4, and Mitsubishi Outlander PHEV. However, there are several new vehicles releasing in the next 5 years that are slated to support bidirectional charging.

2.1.2 Advantages of V2G

V2G expands storage capacity for renewable energy sources such as wind and solar. Since wind and solar energy generating systems are volatile and inconsistent due to the unpredictability of climate, V2G would allow us to store energy when the system's storage is full. EVs would be able to relieve and store the excess energy during surges due to vigorous weather conditions such as heavy winds. This means that EVs can act as a solution to grid congestion as well as prevent the need for costly upgrades to existing infrastructure.

A transportation electrification company called Pecan Street estimates that one plug-in electric vehicle is capable of powering a single home for up to five hours or five homes for about an hour [2].

2.1.3 Vehicle-to-Home (V2H)

As discussed in the previous section, it is possible to install a V2G unit at home in order to provide energy back to the grid. There are also V2H units that allow homeowners to use their vehicle's battery to power their homes. This would normally be used to power your entire home in the case of a power outage. However, in some cases if you have many appliances turned on at once, you could use the energy stored in your EV to reduce power drawn from the grid. This would be useful if you'd like to save money by using your EV's power during peak hours and charge it at night during off-peak hours where the cost of energy is comparatively lower.

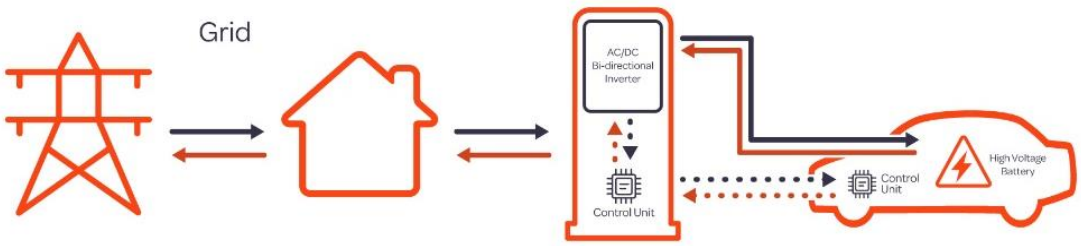


Figure 1: V2G/V2H Unit Visual [4]

While V2G technologies are rapidly progressing, there is still much progress to be made before V2G can be implemented on a large-scale level. Due to the many benefits for both EV drivers and power grid operators, there is a large push being made to accelerate the production of compatible vehicles and chargers.

2.2 Raspberry Pi

The Raspberry Pi is a microcontroller and essentially a system-on-chip (SOC) that behaves as a computer. Raspberry Pi has a CPU, memory, GPU, storage device, I/O, and network capability, all enclosed on one device. It can be used to create an embedded system to perform a specific task, such as a Smart Licence Plate. The device is preconfigured with an OS version named Raspbian, which allows the integration of numerous languages such as C, C++, Java, and Python. Python is one of the most used in the industry and is regarded as the future of programming language, which is why our application will be created using Python. The front end of our application will predominantly be HTML, CSS, and JavaScript. The Raspberry PI allows numerous devices to communicate and is not limited to linking external devices through the GPIO pins. GPIO, or general-purpose input-output, will integrate the outside world into the raspberry pi through the physical pins on the board. GPIO can read data (input) from various devices or output a digital signal to a device. Some devices integrated using GPIO pins are sensors, LEDs, buttons, switches, lights, GPS, and motors.

2.2.1 Location Services

The raspberry PI allows us to connect an external GPS and additional sensors to the board through the GPIO pins. However, since the raspberry pi will be connected to a network 24/7, we can use the built-in function to locate the device, which uses the IP address. The IP address will be sent to a google map geolocation API to locate the device, and the API will return coordinates (longitude/latitude) [6]. It must be taken into consideration that the results from the IP address will vary and may not be as accurate as an external GPS device. During the testing phase, it must be determined whether the location service provides data that can be used in a real-life environment or whether a GPS module will be the better option. The coordinates returned from the API can be used to display the exact location of the licence plate using Google Maps.

2.3 Security

One of the significant reasons why a digital licence plate is required in the future is due to the increase in licence plate thefts. Criminals usually take the licence plate from a similar car to what they are driving, allowing them to move freely without any consequences. There are many reasons why criminals steal plates, such as insurance fraud, a suspended licence, driving a stolen car, or planning on committing a crime. There are few countermeasures to stop criminals from such activities, whether the licence plate is digital or metal. Although a considerable benefit of a smart licence plate is that it helps level the playing field as it can detect whether the plate has been stolen or not, which can be sent to the local authority. Integrating theft prevention within smart licence plates will assist in limiting licence plate theft. The theft prevention system will allow the user to remove the licence plate while notifying the user that the plate has been detached from the car. If the user removed the licence plate for personal reasons, the device would not enter “theft mode." If the user did not remove the licence plate, they could report it stolen on the application while allowing the plate to enter a new state known as “Stolen Mode.” In this mode, if the criminal decides to attach the plate to another vehicle, it will display stolen on the plate while sending a signal allowing the electric vehicle to shut down. The prototype will demonstrate the licence plate to change its state to “stolen mode” while allowing the user to have the option to disable the vehicle if they desire. The module that disables the vehicle is a highly complex embedded system and is out of this

project's scope. Therefore, a simulation of a transmitted signal will be presented, and the result from the signal will be indicated on the application.

2.3.1 Radio Frequency Identification (RFID) Reader

RFID reader, or radio frequency identification, is an integral part of security in many systems developed today. The RFID reader requires a unique identification number which grants authorization to the required environment. The RFID contains two key components: the reader/writer and the RFID tag. The RFID tag is an integrated circuit that stores a unique identification number. The RFID tag reader/writer will read the identification number when the card is placed near the reader through the card's magnetic field, which will power the card's circuit, allowing it to transmit the unique identification number stored on the card [5]. The unique identification number can be read from the raspberry pi, which can be used for authentication. In our system, the RFID tag will be attached to the LCD, while the RFID reader will be connected to the microcontroller. Each RFID tag will store the serial number of the LCD as a unique ID which will be linked to a microcontroller. As a security measure, each LCD can only be linked to the microcontroller that has authorization within the database.

2.4 Cloud Computing

We live in an era where downtime of service for the customer can be disastrous, as we witnessed one of the most significant outages in Ontario, where more than 12 million Rogers customers were left without service throughout Canada, including calls to 911 or access to ATMs. Rogers' infrastructure had issues that were not addressed, leading many displeased customers to migrate to a competitor company. This leads us to address the issue of availability, failure, and performance. Initially, in our design process, a centralized system was considered to store our application and data on a local server, but the system had a few known limitations associated with it, such as,

1. It is highly dependent on network connectivity,
2. If one component in the system fails, the whole system goes down.

a. All data is stored on the central server; if any updates are required, the server must be shut down for maintenance.

One of the significant innovations in our generation is cloud computing which helps us distribute various computing services such as servers, storage, databases, and software over the internet. Cloud computing helps with availability, failure, reducing cost, scalability, data security and much more [7]. Integration of cloud service within our application will help with the incoming requests from customers, and during various times the network traffic will fluctuate. Cloud computing can implement autoscaling to use the allocated resources required for a task to reduce cost and enhance performance.

There are a few great choices for cloud services, such as Google Cloud Platform (GCP), Amazon Web Service (AWS), and Microsoft Azure. As we are cost-constrained for our application, one of the ideal solutions is using the Microsoft Azure service, which provides a $200 credit and allows us to use the MySQL database for 12 months without additional cost. The MySQL database will be required to produce three independent databases, MTO DB, PowerGrid DB, and Smart Licence DB. The MTO DB and PowerGrid DB are vital to simulate a real environment as we assume the licence plates are registered with the provincial ministry of the government.

When a user signs up for our application, they must enter their licence plate number and personal information. Before a digital licence plate is issued to the user, the application will authenticate the information before storing the data within the database (Smart Licence Plate Database). An identical authentication will take place to retrieve the data from the power grid database, such as energy consumed, and energy transferred to the grid. The user can opt to pay on the website or signup for a recurring monthly payment.

2.5 Measurement of Battery Health & State

2.5.1 Battery State

Measuring a battery's state of charge (SoC) is no simple task. Currently there is no direct method available to obtain a battery's SoC. In order achieve this we must estimate the SoC indirectly using one of the following methods: measuring voltage, coulomb counting, or Kalman filter method. The first method as stated is the voltage method. When a new battery is fully charged it will read the voltage according to what the manufacturer has specified. As the battery is being discharged the voltage drops and eventually the battery becomes depleted. In order to determine the SoC for the battery as a percentage, the voltage must be compared to a battery discharge curve [15]. Take this typical 4.5V Lithium-ion battery discharge curve as an example (figure 2.5.1). The voltage curve on the graph is kept flat relatively between the approximate SoC percentages 80% - 20%. When the discharge cycle reaches approximately 10% the voltage declines rapidly resulting in a reading of when the battery will be fully depleted [18].

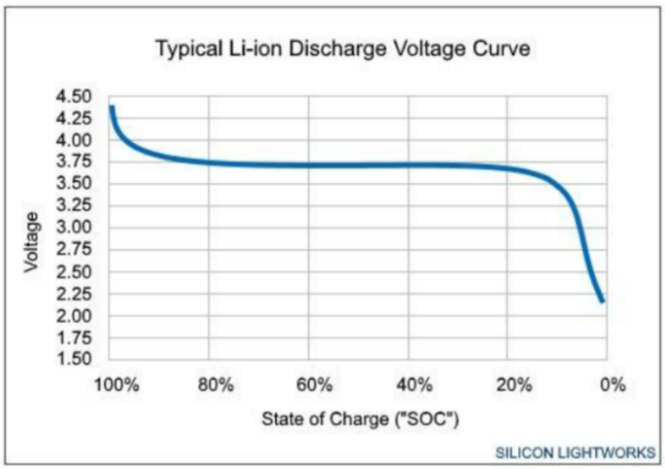


Figure 2: Graph of Typical Li-ion Discharge Voltage [19]

The second method as noted is the coulomb counting method also known as ampere counting method. To approach this method, we first need to obtain the current of the battery. This can be done using a voltmeter or any other device that can obtain the current. Once the current is obtained it must be integrated using the following formula:

$$SoC(t) = \frac{1}{C}\int_0^t I(p)\,dp$$

Figure 3: Battery State of Charge Equation [21]

Where C is denoted as the total capacity of the battery, and I is the current measured. This is a relatively quick and cheap method in estimating the SoC of a battery. The downside of this method is any errors found will accumulate over time when integrating causing it to become inaccurate [15].

The final method in estimating SoC is with the use of observers, also known as a Kalman filter. The Kalman filter uses an algorithm that constantly predicts the future SoC and corrects it by measuring the current, voltage, and temperature. For the Kalman filter to operate as accurately as possible, it must have precise dependencies when operating and accurate environmental conditions [16]. Due to the filter requiring more resources to estimate the SoC it makes it a rather complicated method compared to the voltage and coulomb counting method. Figure 2.5.3 below shows a simple diagram of a Kalman filter system.

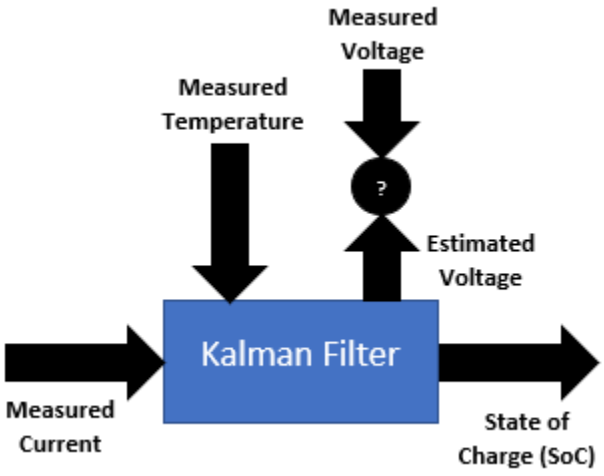


Figure 4: Kalman Filter System Diagram

2.5.1 Battery Health

Measuring the state of health of a battery is an arbitrary process that uses one simple formula. It is the current maximum capacity divided by the capacity of a new battery multiplied by 100%. The current and new capacity of a battery can be measured in Ampere Hours [17]. A simple and quick way for us to obtain battery health would be by using a Battery Management System (BMS). Electric Vehicles (EVs) all come standard with a BMS. Using the onboard BMS we will be able to obtain the battery health but instead of calculating by Ah we will be calculating it by the maximum range at full charge divided by the maximum manufacturers rating. For example: If the EV at full charge is 643km and it is rated for 700 km that would mean the battery health is at 91.8%.

$$SoH = \frac{\text{Current Maximum Range}}{\text{Manufacturer Rated Range}} * 100\%$$

Figure 5: Battery State of Health Equation

2.6 Smart Metering & Smart Charging

2.6.1 Smart Metering

Smart Meter is an electronic device that processes and records energy consumption data which is connected to the local utility. It allows the user to track their power consumption and electricity expenses. One of the benefits of having a smart meter is its capability to measure energy consumption bidirectionally between the users and power suppliers [8]. This meter will be connected to the grid and integrated in the app to allow user to always view the energy consumption data and other readings.

Furthermore, the V2G process will permit EVs to feed the power back to the grid during peak hours to avoid grid instability which will be displayed on the smart meter. This adaptable power system offers users the chance to manage their energy consumption and perhaps drastically lower their monthly expenditures [9].

2.6.1.1 Types of Smart Meters

1. AMI – Advanced Metering Infrastructure

An AMI smart meter provides users with comprehensive data on power consumption from them. This lets users better regulate their power usage to lower greenhouse gas emissions and electricity expenses. It permits two-way communication between the meter and the provider. Utilities may identify system problems more rapidly by using real-time data from smart meters [8].

2. AMR – Automatic Meter Reading System

An AMR meter acts in a similar fashion to an AMI meter but the only difference is that it communicates information one-way with the energy provider on behalf of the user. The supplier will receive data from the customer's energy consumption which ensures proper invoicing and enables the consumer to see their statistics on energy use [8].

2.6.1.2 Application of Smart Meters

Electric meters currently provide a little measuring role in the operation of charging stations for electric vehicles. The management of electric car charging stations can use smart meters to fulfill the following functions through their optimization [8].

1. Remote Control

Relays and valves included in smart meters can accept remote instructions sent by the power grid firms when they want to perform switching operations. As a result, real-time remote control is possible with smart meters [8].

2. Real-time Power Measurement

Real-time measurements are possible with smart meters. The timely completion of grid line failure analysis, equipment condition monitoring, and energy bill settlement is made possible by the real-time gathering of charging data and automated analysis. Electricity suppliers may use this data to better understand power usage and consumption, as well as enhance and improve the quality of the power supply [8].

3. Communication and Network Function

The network communication function will undoubtedly be impacted by some charging facilities' subterranean or distant locations. A useful smart meter feature is that when the signal is weak, a smart meter may use power lines to convey data through power line communication and even act as a Wi-Fi hotspot to enable intelligent network connections for electric vehicles and charging stations [8].

4. Demand Response

With the owner's permission, a smart meter may receive remote instructions and modify the amount of time an electric car needs to charge based on grid load and power costs. It is beneficial to charge electric vehicles at times of low grid load or cheap electricity costs in order to lower the maximum difference of the grid load and enhance the effectiveness of power grid operation [8].

2.6.1.3 Independent Electricity System Operator (IESO)

The Independent Electricity System Operator (IESO) is responsible for running Ontario's energy system. The IESO provides essential services for the whole electrical industry, such as real-time power system management, planning for the province's future energy requirements, promoting energy efficiency, and developing a more effective electricity market to assist sector development [10].

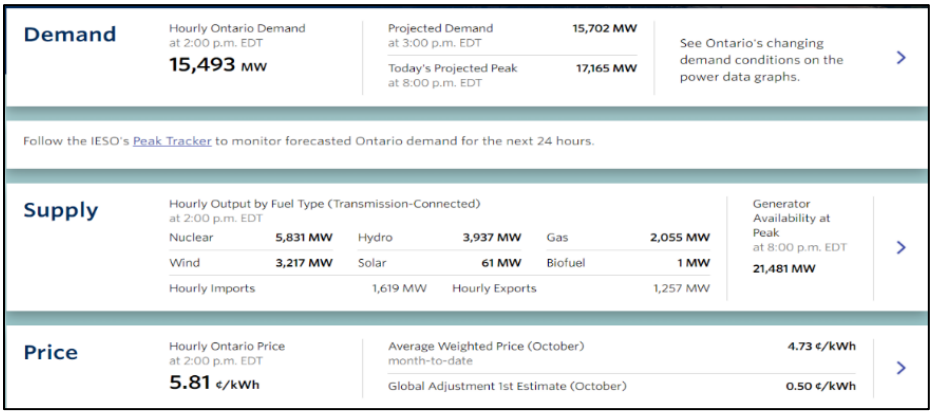


Figure 6: Real-time IESO Data [10]

The IESO would be linked to the website and all the energy consumption data would be fetched from the grid to allow the user to better keep track of the real-time peak-hours, power supply, demand, and energy rates. This would be highly beneficial for the users as they can monitor their electricity usage and save on energy bills.

2.6.2 Smart Charging

Smart Charging is one of the key elements in persevering battery health. This would allow the user's vehicle to charge the battery to an optimal 80%. Thus, making it beneficial for a battery's efficiency and long-term performance. According to the price of electricity, its accessibility, and the demands of the driver, electric vehicle (EV) charging employs intelligence to control when and how an electric car linked into a smart charger will get power for charging [9]. It needs a data link between the EV, the charger, the grid, and the cloud-based charging management platform of the charge station operator.

2.6.2.1 Smart Energy Management

In addition to smart charging for EVs, smart energy management has additional benefits. It enables the user to manage and modify energy usage depending on the grid constraints, electricity rates, and energy storage. Smart energy management makes the most of the power that is available to charge EVs while properly distributing the load among energy sources to avoid interfering with the demands of homes, businesses, or other power users.

A communication session is created between the charger and the automobile when the charging wire is plugged into an electric vehicle employing smart charging. The charger develops a communications channel with the grid at the charging infrastructure. This single, cloud-based software platform controls the chargers themselves, the charging process, and the energy sources employed [11].

2.6.2.2 Energy Optimization

It is certain that site-level constraints would affect charge station operators due to the rapid increase of EVs and their power needs for charging. When the grid is under stress, demand side response lowers electricity demand. While simultaneously reducing the charging capacity of individual charge points, the smart energy management system may use on-site renewable energy sources like solar panels or onsite batteries to supply the necessary power to charge the vehicles, extending the time to charge plugged-in cars while reducing grid stress [11].

With the aid of smart energy management, the charge station operator may keep an eye on, control, and modify energy usage in accordance with operational needs and driver- or operator-set priorities. According to the needs and restrictions of the EV and the location, the level of power delivered to chargers and energy usage may be clearly shown and adjusted. This can also prevent the utility from being fined for overstressing the system and forcing the company to buy expensive electricity from the general capacity market [11].

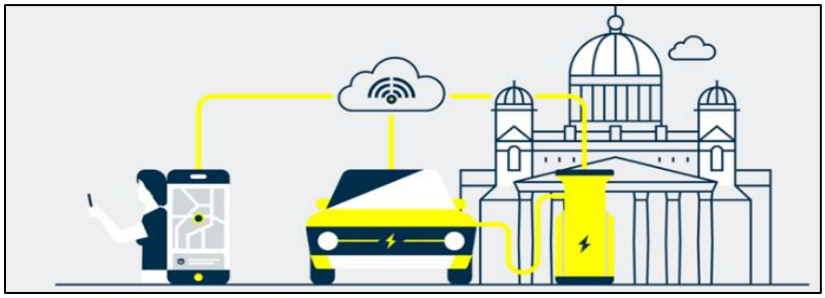


Figure 7: Smart Charging Infrastructure [12]

2.7 Auto-Brightness

Auto brightness and dimming can be achieved through an Ambient Light Sensor or ALS for short. Ambient light sensors are utilized in smart phones, tablets, LCD televisions, and automotive displays. There are currently three types of ambient light sensors: photodiodes, photonic integrated circuits, and phototransistor which is a combination of a photodetector and amplifier [18]. **Figure 8** below is an example of an ambient light circuit. This circuit includes a light dependent resistor which can change the resistance depending on its lighting environment. If the LDR senses darkness the resistance drops dramatically from millions of ohms. Thus, dimming the device in question. The same principle applies when the LDR is in a bright environment. The brightness of the device will then increase allowing a more user-friendly experience [20]. The sensors work in all types of light whether it's natural lighting or lighting from florescent or incandescent bulbs [18].

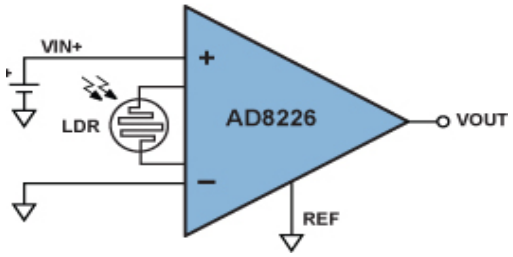


Figure 8: Ambient Light Dimming Circuit Example [20]

2.8 Ontario Licence Plate Legalities & Design Aspects

2.8.1 Legal Requirements

A metal plate is attached to a vehicle to identify official information about the owner and the vehicle. These plates are handed out when a driver purchases a car and brings it in for registration after paying a fee. Ontario uses these registered plates to determine and confirm ownership of the vehicles along with providing data to federal officers about when there is criminal activity. This is important when tracking or assessing taxes too. The terms licence and registration are important and must be given on the command to law enforcement while you are driving in any designated lane. The penalties for not having 2 licence plates, which is the requirement, or none could lead to up to $85 in fines including other issues such as not keeping it clean, improperly displayed, and other forms of placement that make it hard to identify the characters on the plate [22].

Legal actions can be taken against any driver not having their motor vehicle registered with plates that are not expired. During any stop with law enforcement or an accident that has occurred with yourself and another driver, all official documents should be presented. If in the scenario where you do not have it or refuse to show it could lead to considerable penalties like a fine anywhere between $60 to $1000 under the Highway Traffic Act [23]. This all could still be avoided because it is completely free to renew a licence plate in Ontario and the requirement is just once every three years. This is all just for confirmation of various information stored under the owner's profile that is stored in their database. Information such

as whether the car is insured or not, any extra fees that may have been added on, or with regards to the fee that comes with toll routes along with any fines given [23].

The registration process requires a vehicle owner to go to any Service Ontario location where several items will be handed out after providing all necessary information about the vehicle and designated drivers. This process is put in place to identify if the vehicle was stolen or involved in a crime. Proof of purchase also must be shown, as the owner's own personal information including documents of proof of identity and an Ontario driver's licence. Once the necessary steps have been completed, the Service Ontario associate will hand out the vehicle permit, and finally receive their licence plate along with a plate sticker [24]. Although Ontario has ceased the sticker renewal system and has terminated the whole idea of having valid stickers on the plate, the actual licence plate still needs to be renewed after a certain period.

2.8.2 Design Aspects

Before Ontario started issuing licence plates to all drivers, they were able to utilize a licence plate that they brought in. This period was between 1903 when the province first asked all residents living in Ontario to register their vehicles, to 1911 when the province started giving out plates through the Ministry of Transportation also known as MTO [25]. Every major country in North America concluded issuing their licence plates of the exact same size for all three countries, which Ontario quickly abided by. The standardized size agreed upon was 12 inches by 6 inches or 30 cm by 15 cm, which can be mounted on every vehicle [25].

The plates are made from raw materials such as aluminum by metal manufacturers and then created by plate makers and inmates at correctional facilities. Afterwards, they proceed to add sheeting, coating, colors, and paint which makes it easily visible for law enforcement. The reflective coating on the paint makes it easy for authorities to see the plate when it's dark [26]. The production process includes the sheet being applied on a black metal canvas to add colors. This makes it reflective with the coating that is applied to the sheet. A stamp is then used to dig in the plate to create characters which are later colored in using the paint [26].

In recent years, many licence plates have begun to deteriorate quicker than originally expected. Many drivers can see for themselves of their own or other vehicles they have spotted where the characters start to fade, the sheeting starting to wear off not making it visible to identify. The issue for this should be that it is legitimately old but for multiple reasons, it is happening to newly manufactured plates. Those that are going through this scenario, and not trying to do it for the sake of avoiding a toll, can have it replaced free of charge. The plates should absolutely be replaced as well because it can result in a fine.

2.8.3 Design Features

Every licence plate has its own unique features such as symbols, colours, and font. The Ontario licence plate has the symbol of a crown which represents the “Crown of Canada” which majority can presume as the country is under the constitutional monarchy of Queen Elizabeth as head of state. This symbol commemorates the coronation of the Queen along with King George VI from the year 1937 [27].

The crown separated the characters between the 4 letters on the left and the 3 numbers on the right, for example, ABCD – 123 [27]. Above the identification text is written the province name “Ontario” while below it is written “YOURS TO DISCOVER” which can also be found written in French as this is a bilingual country.

The font used for the Ontario licence plate is also like many provinces in Canada and various states in the U.S and Mexico which makes sense since the size requirement is the same for all three countries. The font used is Driver Gothic which has up to 750 characters available throughout many languages [28]. There is no specific reason as to why the font color is blue, but licence plates can come in different text colors for distinct reasons which could be because of what the car is, for example electric cars will have the characters on their plates in green symbolizing that it is not polluting the Earth with its gas emissions. Other designs and colors could be because of the status of the driver.

As of 2020 there has been a new series of designs on the Ontario licence plate that was scrapped half a year into its release with a unique design coordinated with colors in the background such as different shades of dark blue that made it hard for law enforcement to see. This was expected as the whole purpose of the original design with its unique materials is for the sole purpose of it being easy to identify and read. This licence plate had its own key features including a new slogan at the bottom stating “A PLACE TO GROW”. The font colors are white and a two-toned dark blue color. The background is meant to represent a new government of “progress, growth, and prosperity” [29].

[the remainder of this page has been intentionally left blank]

2.9 Competitor Product Comparison

2.9.1 Feature Comparison to Reviver RPlate®

Table 3: Product Comparison to Reviver RPlate® Products

	Product Comparison		
Features	**Our Product**	**Reviver RPlate (Battery)**	**Reviver RPlate (Wired)**
High-Definition Digital Screen	✓	✓	✓
Online Digital Licence Renewal	✓	✓	✓
Digital Plate Sticker Renewal	✓	✓	✓
Online Website	✓	✓	✓
Smart Phone Application	✓ (Time Permitting)	✓	✓
Trip & Mileage Tracking			✓
Park & Valet Mode			✓
Auto-Brightness	✓		
Replaceable Battery	✓	✓	
Anti-Theft	✓	✓	✓
Telematics (Vehicle Locator)	✓ (Time Permitting)		✓
V2G/V2H Integration	✓		
Smart Metering	✓		
Smart Charging	✓		
EV Battery Information	✓		
Easy Installation	✓	✓	
LTE Connection		✓	✓
Bluetooth		✓	
Secure Cloud Communication	✓	✓	✓
Follows Licence Plate Standards	✓	✓	✓
Water & Dust Resistant	✓	✓	✓
Plate Visual Personalization	✓ (Time Permitting)	✓	✓
Parking Metering	✓ (Time Permitting)		
Toll Road Payment Integration	✓ (Time Permitting)		

2.9.2 Reviver RPlate® Cost

The graphs in the figures below show the current costs for Reviver's digital licence plates. The prices are listed in US dollars (USD) as the plates are only available in the United States.

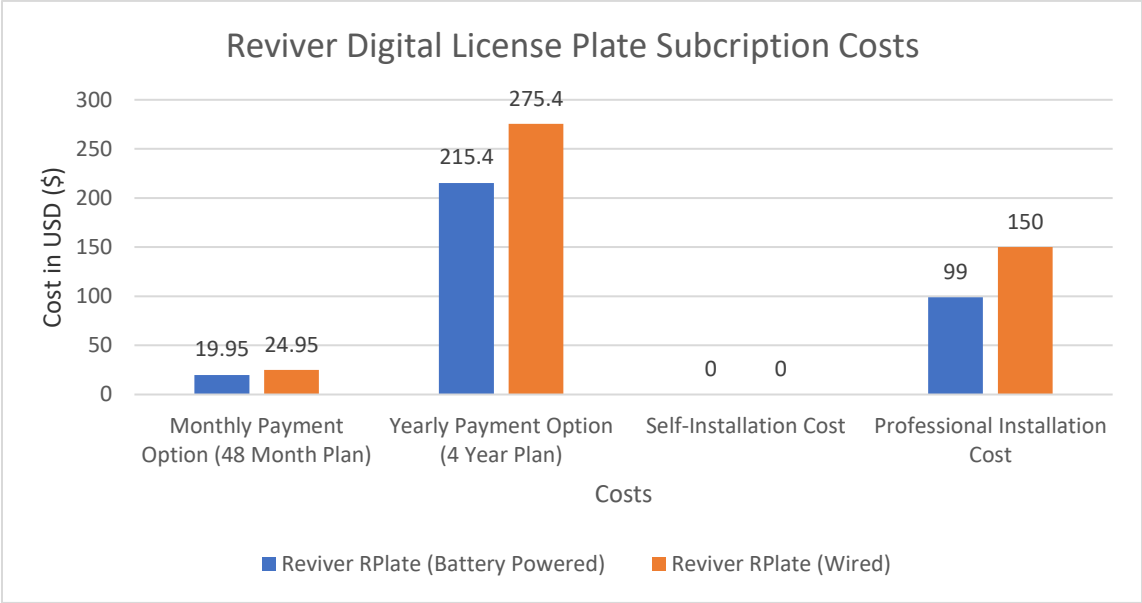


Figure 9: Reviver RPlate® Subscription & Installation Costs

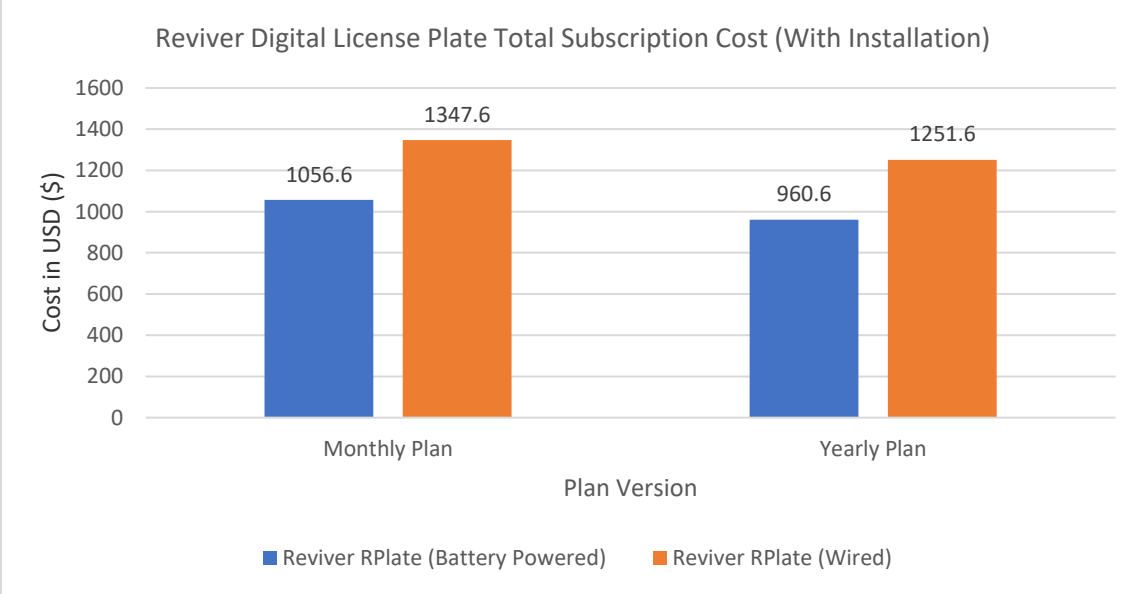


Figure 10: Reviver RPlate® Total Cost Per Subscription Plan

3 Design Process

3.1 Overall Design Process

The overall design process for the entire course can be seen in the **Figure 11** below.

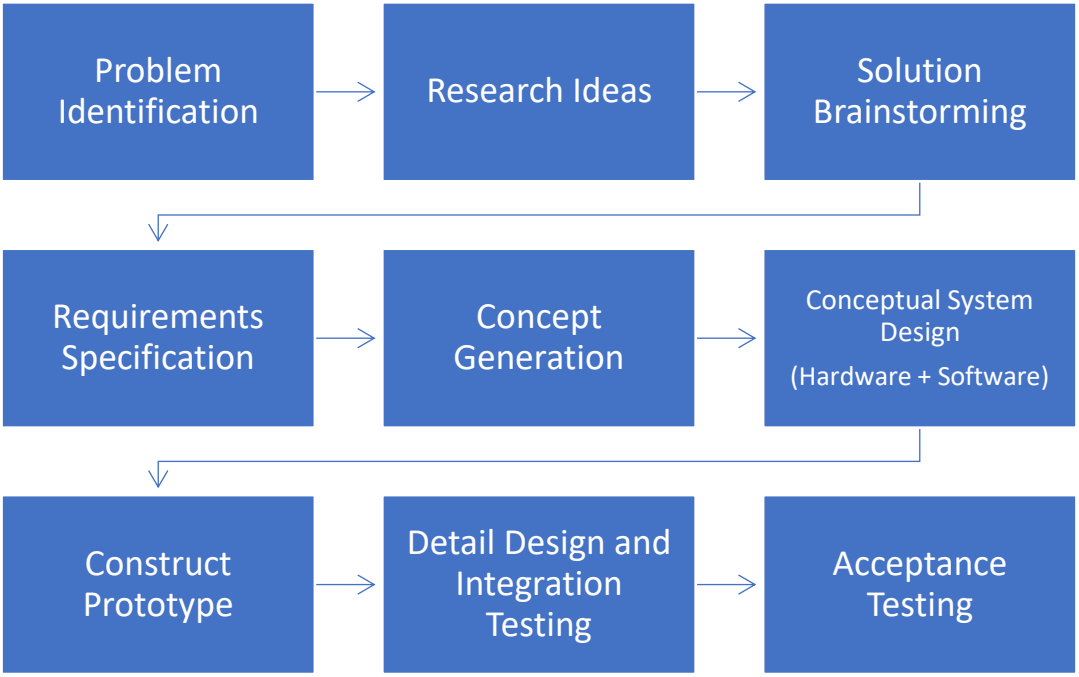


Figure 11: Overall Project Design Process

[the remainder of this page has been intentionally left blank]

3.2 Software Design Process

Figure 12 below represents the software design process that will be followed when designing applications such as the website. This process would also be followed if we determine that time allows us to create a mobile phone application.

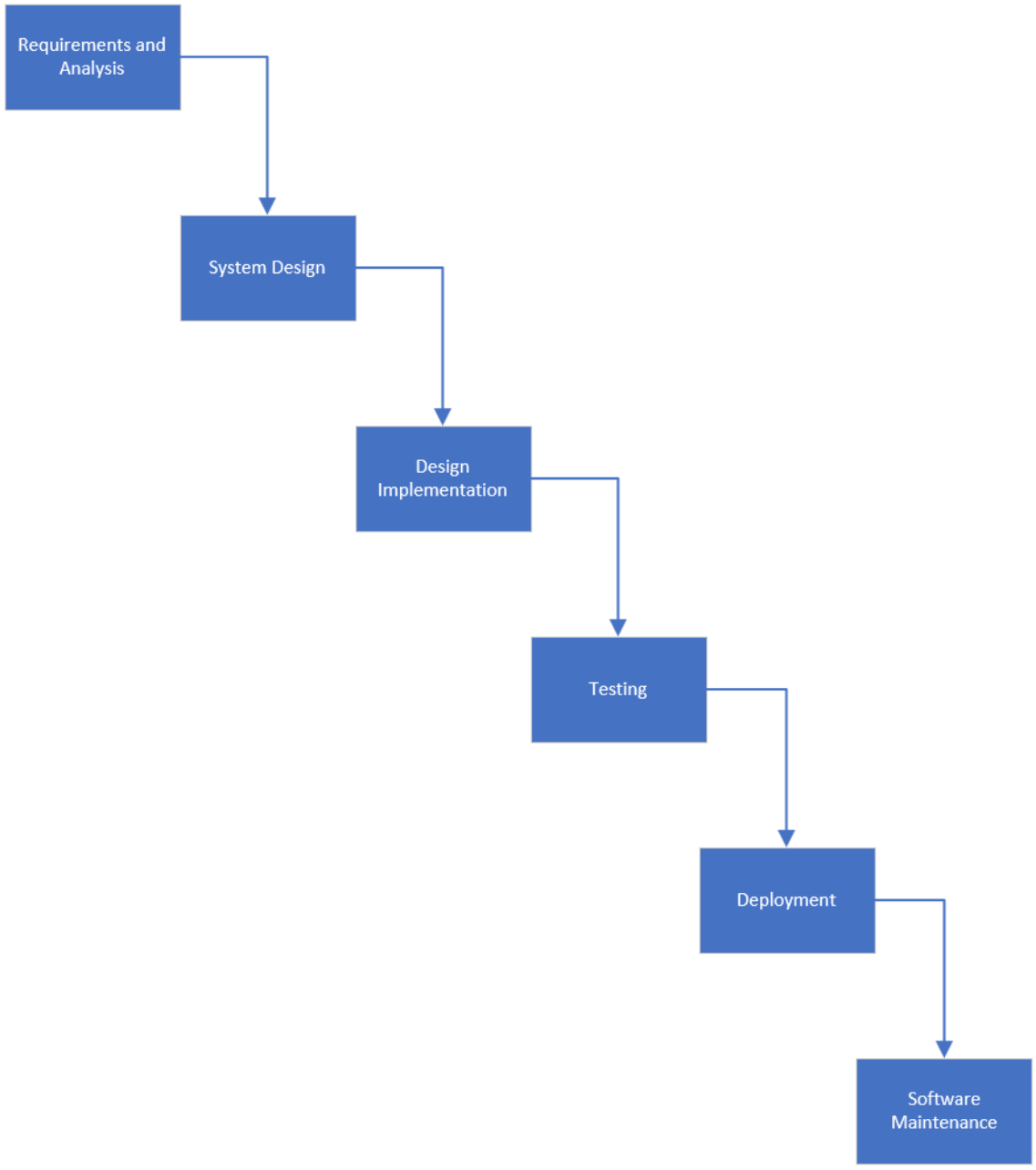


Figure 12: Software Design Process

3.3 Electrical Design Process

Figure 13 below represents the electrical design process to be followed when designing electrical circuits such as the circuits for battery health and state measurements.

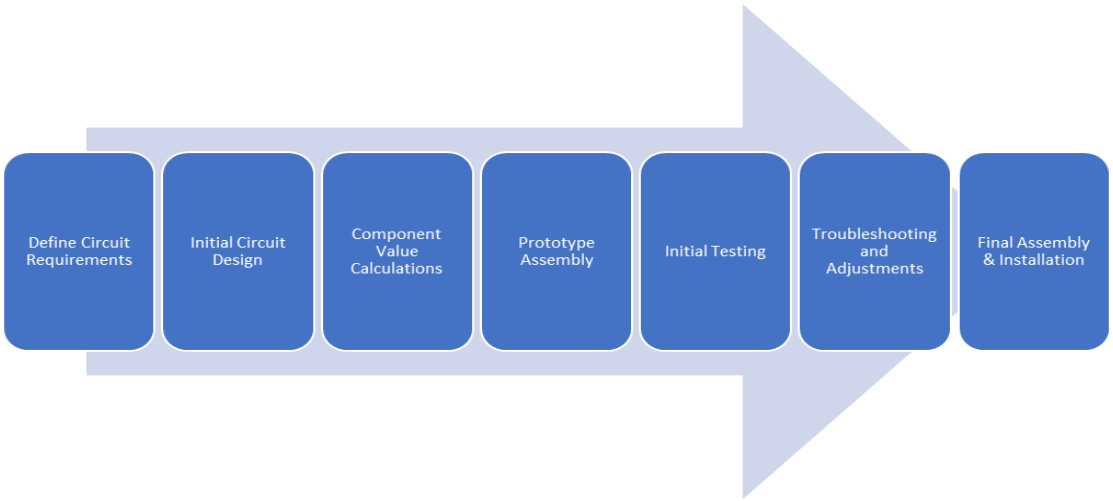


Figure 13: Electrical Design Process

3.4 Sequence Diagrams

3.4.1 Sequence Diagram for Plate Renewal

The sequence diagram in **Figure 14** demonstrates how our system will interact when plate renewal occurs.

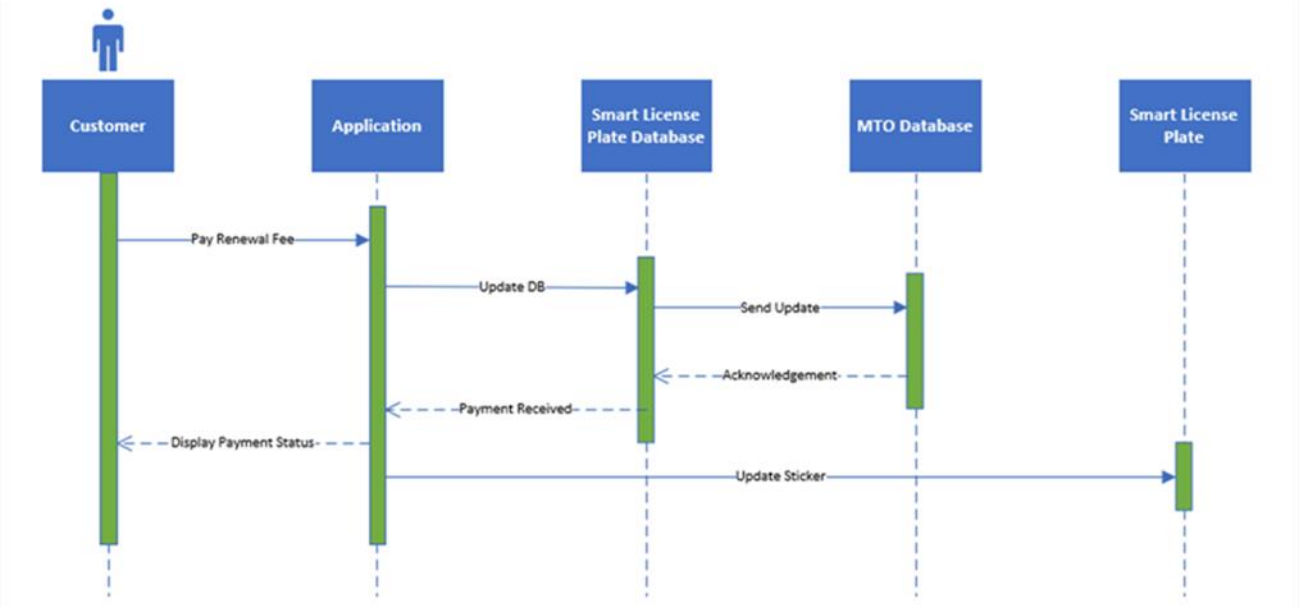


Figure 14: Sequence Diagram for Plate Renewal

3.4.2 Sequence Diagram for Stolen Plate Mode

The sequence diagram in **Figure 15** demonstrates how our system will interact when our licence plate is removed from a vehicle, and stolen plate mode is activated.

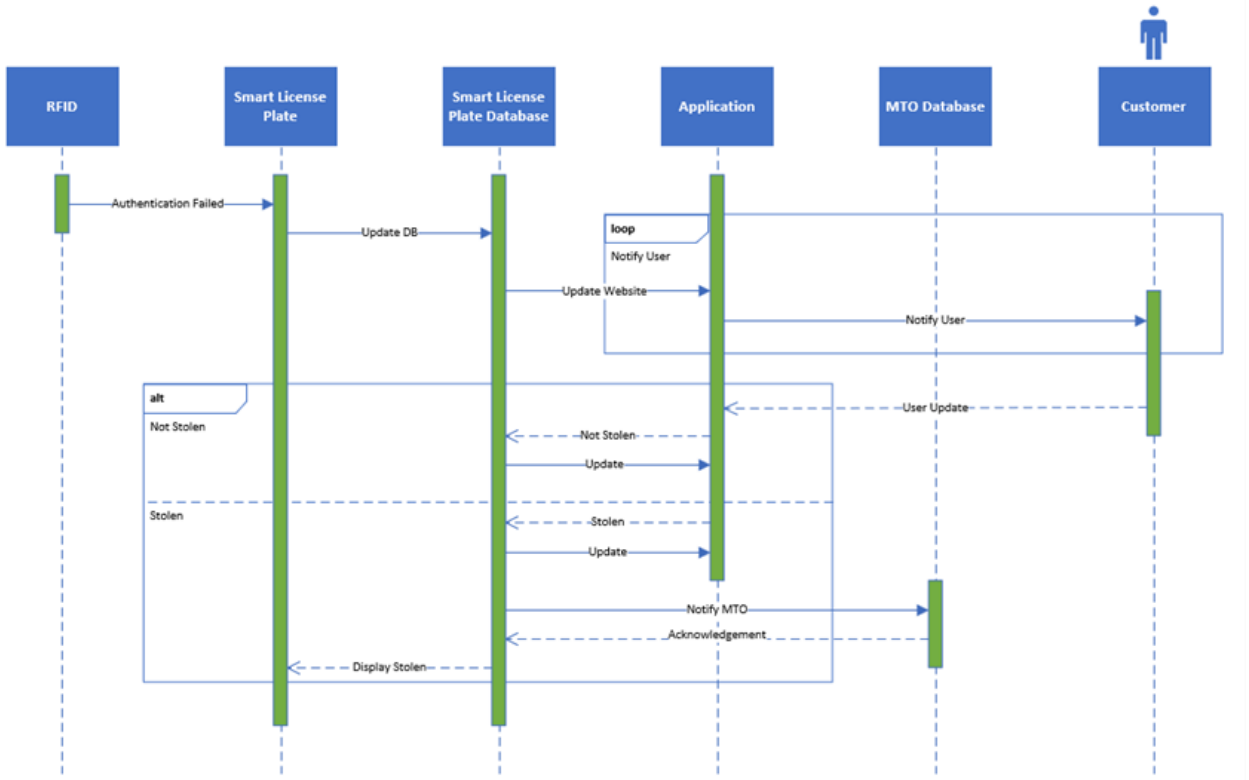


Figure 15: Sequence Diagram for Stolen Plate Mode

[the remainder of this page has been intentionally left blank]

4 Scenarios & Use Cases

4.1 Use-Case Diagram

Figure 16 below shows the use-case diagram for the integrated smart licence plate application.

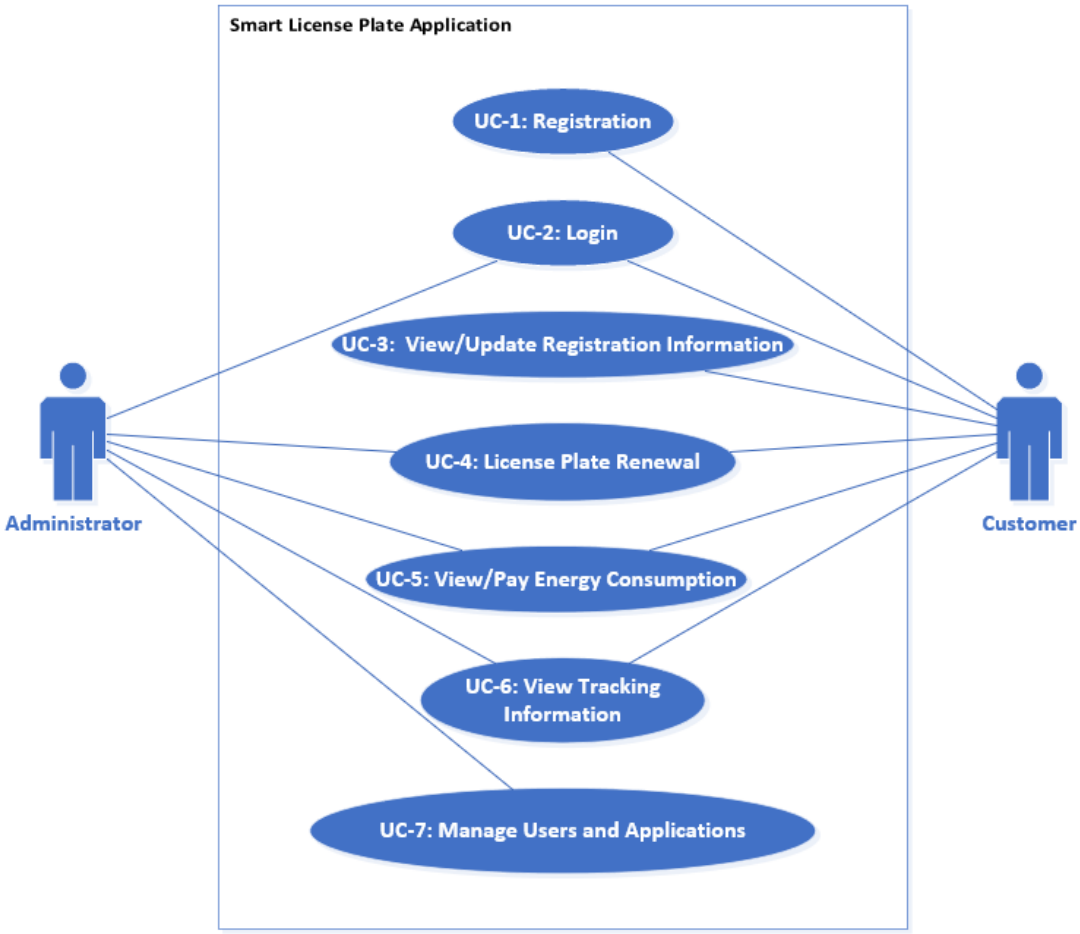


Figure 16: Use-Case Diagram for Smart Licence Plate Application

[the remainder of this page has been intentionally left blank]

4.2 Use-Cases

4.2.1 Use-Case List

Below, **Table 4.0** lists the use-cases that will be described.

Table 4.0: List of Use-Cases with ID Numbers

Use Case ID	Use Case Name
UC-1	Registration
UC-2	Log in
UC-3	View/Update Information
UC-4	Licence Plate Renewal
UC-5	View Energy Consumption
UC-6	View Tracking Information
UC-7	Manage Users and Applications

[the remainder of this page has been intentionally left blank]

4.2.2 Use-Case Descriptions

The tables below describe the use-cases depicted in **Table 4.0**.

Table 4.1: Use-Case 1

Use Case ID	**UC-1**
Use Case Name	Registration
Actors	Customer
Description	The user will have access to a page where they can register with their personal information.
Normal Flow	1. User will access the registration page 2. System will request required fields 3. User will enter the required fields 4. System validates the information and logs into system.
Pre-Condition	None
Post Condition	If successful, the actor will be logged into the system.

Table 4.2: Use-Case 2

Use Case ID	**UC-2**
Use Case Name	Log in
Actors	Administrator, Customer
Description	The user will require authorization through the login page to access the application.
Normal Flow	1. User will access log-in page. 2. System will request username and password. 3. User will enter the required fields 4. System validates the information and logs into system.
Pre-Condition	None
Post-Condition	If successful, the actor will be logged into the system.

Table 4.3: Use-Case 3

Use Case ID	**UC-3**
Use Case Name	View/Update Personal Information
Actors	Customer
Description	The actor will be able to view personal information and update if required.
Normal Flow	1. User will access personal information page 2. If user wished to update information a. System will validate information b. Confirmation Page
Pre-Condition	Actor must be logged in.
Post-Condition	If update required, the system will update the database.

Table 4.4: Use-Case 4

Use Case ID	**UC-4**
Use Case Name	Licence Plate Renewal
Actors	Administrator, Customer
Description	The actor will be able to renew licence plate and pay through the application.
Normal Flow	1. User will access renewal page 2. The user will enter required information 3. The system will update changes and send information to MTO database.
Pre-Condition	The actor must be logged in.
Post-condition	The changes must reflect in the database.

Table 4.5: Use-Case 5

Use Case ID	**UC-5**
Use Case Name	View/Pay Energy Consumption
Actors	Administrator, Customer
Description	The actor will be able to view the energy consumed and energy send back to the grid, furthermore the actor will be able to pay the bill.
Normal Flow	1. The user will access the page. 2. The user will enter the required information. 3. The system will update the changes and send information to the power grid database.
Pre-condition	The actor must be logged in.
Post-condition	The changes must reflect in the database.

Table 4.6: Use-Case 6

Use Case ID	**UC-6**
Use Case Name	View Tracking Information
Actors	Administrator, Customer
Description	The actor will be able to view the movement of the licence plate
Normal Flow	1. The user will access the page 2. The user will request tracking information 3. A map will be displayed with the Coordinates
Pre-condition	The user must be logged in.
Post-condition	None

Table 4.7: Use-Case 7

Use Case ID	**UC-7**
Use Case Name	Manage Users and Applications
Actors	Administrator
Description	The user will be able to view/modify all the licence plate
Normal Flow	1. The user will access the page 2. The user will access to view all the licence plates 3. The user may choose to make changes or updates a. If user made changes, update the database
Pre-condition	The user must be logged in
Post-condition	The changes must reflect in the database

[the remainder of this page has been intentionally left blank]

5 Stakeholder Requirements and Traceability Matrix

5.1 Stakeholder Requirements

Table 5.0: Stakeholder Requirements Specifications

Stakeholder Requirement	Description
STRQ-1	**THE USER WILL REGISTER TO CREATE AN ACCOUNT** *FEAT1: The user will register and input the following information: First Name, Last Name, Email, Password, and Licence Plate Number.* *FEAT2: It shall indicate all the mandatory fields.*
STRQ-2	**THE USER SHALL LOGIN WITH USERNAME AND PASSWORD** *FEAT2: The user shall login with the registered username and password.*
STRQ-3	**THE USER SHALL CHOOSE TO PAY FOR RENEWAL TICKET** *FEAT3: The user shall be able to pay the renewal fee which will be reflected in the MTO database.*
STRQ-4	**THE USER SHALL CHOOSE TO PAY FOR THE ENERGY CONSUMED** *FEAT4: The user shall be able to pay the energy consumed which will be reflected in the power grid database.*
STRQ-5	**THE USER SHALL BE ABLE TO UPDATE PERSONAL INFORMATION** FEAT5: The user shall be able to add or remove the licence plate.
STRQ-6	**THE USER SHALL BE ABLE TO VIEW THE LOCATION OF THE LICENCE PLATE** *FEAT6: The user shall be able to keep track of the movement of the licence plate.*
STRQ-7	**THE USER SHALL BE NOTIFIED IF THE LICENCE PLATE IS REMOVED** *FEAT7: The user shall be notified if the licence plate is removed from the chassis.* *FEAT8: The user shall be allowed to report the plate stolen.*
STRQ-8	**THE APPLICATION WILL UPDATE THE REQUIRED DATABASE WITH THE USER PAYMENTS/RENEWED DATE.** *FEAT9: The user will not be able to see the changes made but the updated renewal date and payments will be kept.*
STRQ-9	**THE USER SHALL BE ABLE TO DISABLE VEHICLES WHEN STOLEN** FEAT10: The user shall have access to disable the electrical vehicle IF STOLEN ONLY!

5.2 Traceability Matrix

Table 5.1: Traceability Matrix

		Requirements								
		STRQ-1	**STRQ-2**	**STRQ-3**	**STRQ-4**	**STRQ-5**	**STRQ-6**	**STRQ-7**	**STRQ-8**	**STRQ-9**
Test Cases	**TC-1**	✓								
	TC-2		✓							
	TC-3			✓						
	TC-4				✓					
	TC-5					✓				
	TC-6						✓			
	TC-7							✓		
	TC-8				✓				✓	
	TC-9							✓		✓

[the remainder of this page has been intentionally left blank]

6 Acceptance Testing

6.1 Definition of Acceptance Tests

The acceptance tests in this section are written to ensure that we can verify that our product meets of stakeholder requirements.

Table 6.0: Test Case #1 – User Account Creation

Test Writer:	Abdul Bhutta, Emran Soltani, Kumail Syed, Walid Ayub, Yussef Elzein					
Test Case Name:	TC #1			**Test ID:**	Smart-TC-01	
Description:	The user will register to create an account			**Type:**	Black Box: ✓ White Box: ☐	
Tester Information						
Tester Name:	Abdul Bhutta, Walid Ayub			**Date:**		
Environment:	The acceptance testing will be done on a web browser (Google Chrome, Safari)			**Time:**		
Steps	**Action**	**Expected Results**	**Pass**	**Fail**	**N/A**	**Comments**
1	The user will input correct information in the displayed textbox	The application will display a confirmation page.				
2	The results of registration must be correct	Account created in the database must match information				
3	Incorrect or missing information	Error message will be displayed				
Test Result:						

Table 6.1: Test Case #2 – User Login

Test Writer:	Abdul Bhutta, Emran Soltani, Kumail Syed, Walid Ayub, Yussef Elzein					
Test Case Name:	TC #2		**Test ID:**	Smart-TC-02		
Description:	User shall be to login with user ID and password		**Type:**	Black Box: ✓ White Box: ☐		
Tester Information						
Tester Name:	Abdul Bhutta, Walid Ayub		**Date:**			
Environment:	The acceptance testing will be done on a web browser (Google Chrome, Safari)		**Time:**			
Steps	**Action**	**Expected Results**	**Pass**	**Fail**	**N/A**	**Comments**
1	The user will input correct information in the displayed textbox	The application will display a confirmation page				
2	Incorrect or missing information	The application will display an error message				
Test Result:						

Table 6.2: Test Case #3 – User Plate Renewal Payment

Test Writer:	Abdul Bhutta, Emran Soltani, Kumail Syed, Walid Ayub, Yussef Elzein		
Test Case Name:	TC #3	**Test ID:**	Smart-TC-03
Description:	The user shall choose to pay for a renewal plate	**Type:**	Black Box: ✓ White Box: ☐
Tester Information			
Tester Name:	Abdul Bhutta, Walid Ayub	**Date:**	
Environment:	The acceptance testing will be done on a web browser (Google Chrome, Safari)	**Time:**	

Steps	**Action**	**Expected Results**	**Pass**	**Fail**	**N/A**	**Comments**
1	Incorrect or missing information	Error message will be displayed				
2	User successfully entered all fields correctly	Show confirmation receipt of payment				
3	User taken to a confirmation page	Information is updated on MTO database				
Test Result:						

Table 6.3: Test Case #4 – User Energy Payment

Test Writer:	Abdul Bhutta, Emran Soltani, Kumail Syed, Walid Ayub, Yussef Elzein					
Test Case Name:	TC #4				**Test ID:**	Smart-TC-01
Description:	The user shall choose to pay for the energy consumed				**Type:**	Black Box: ✓ White Box: ☐
Tester Information						
Tester Name:	Abdul Bhutta, Walid Ayub				**Date:**	
Environment:	The acceptance testing will be done on a web browser (Google Chrome, Safari)				**Time:**	
Steps	**Action**	**Expected Results**	**Pass**	**Fail**	**N/A**	**Comments**
1	Incorrect or missing information	Error message will be displayed				
2	User successfully entered all fields correctly	Show confirmation receipt of payment				
3	User taken to a confirmation page	Information is updated on PowerGrid database				
Test Result:						

Table 6.4: Test Case #5 – User Updates Personal Information

Test Writer:	Abdul Bhutta, Emran Soltani, Kumail Syed, Walid Ayub, Yussef Elzein					
Test Case Name:	TC #5				**Test ID:**	Smart-TC-0
Description:	The user shall be able to update personal information				**Type:**	Black Box: ✓ White Box: ☐
Tester Information						
Tester Name:	Abdul Bhutta, Walid Ayub				**Date:**	
Environment:	The acceptance testing will be done on a web browser (Google Chrome, Safari)				**Time:**	
Steps	**Action**	**Expected Results**	**Pass**	**Fail**	**N/A**	**Comments**
1	Incorrect or missing information	Error message will be displayed				
2	The user will input correct information in the displayed textbox	The application will display a confirmation page.				
3	Results of update should be correct	Account updated in the database must match information				
Test Result:						

Table 6.5: Test Case #6 – Location Licence Plate Location Viewing

Test Writer:	Abdul Bhutta, Emran Soltani, Kumail Syed, Walid Ayub, Yussef Elzein					
Test Case Name:	TC # 6				**Test ID:**	Smart-TC-06
Description:	The user shall be able to view the location of the licence plate				**Type:**	Black Box: ✓ White Box: ☐
Tester Information						
Tester Name:	Abdul Bhutta, Walid Ayub				**Date:**	
Environment:	The acceptance testing will be done on a web browser (Google Chrome, Safari)				**Time:**	
Steps	**Action**	**Expected Results**	**Pass**	**Fail**	**N/A**	**Comments**
1	The user request's location	The device enables location service				
2	Application forwards IP address to Google API	Google API return geo-location				
3	The User selects view on map	Coordinates are displayed on the map				
Test Result:						

Table 6.6: Test Case #7 – Licence Plate Removal

Test Writer:	Abdul Bhutta, Emran Soltani, Kumail Syed, Walid Ayub, Yussef Elzein					
Test Case Name:	TC # 7				**Test ID:**	Smart-TC-07
Description:	The user shall be notified if the licence plate is removed				**Type:**	Black Box: ✓ White Box: ☐
Tester Information						
Tester Name:	Abdul Bhutta, Walid Ayub				**Date:**	
Environment:	The acceptance testing will be done on a web browser (Google Chrome, Safari)				**Time:**	
Steps	**Action**	**Expected Results**	**Pass**	**Fail**	**N/A**	**Comments**
1	The plate is disconnected from the chassis	The device sends a notification to the user				
2	The user is required to select an option	A notification popup will be displayed to the user				
2a	The user selects stolen	The updated result will show on the webpage and the licence plate will display “stolen”				
2b	The user selects “user removed”	No changes will be made to the licence plate				
Test Result:						

Table 6.7: Test Case #8 – Application Database Refresh

Test Writer:	Abdul Bhutta, Emran Soltani, Kumail Syed, Walid Ayub, Yussef Elzein					
Test Case Name:	TC # 8				**Test ID:**	Smart-TC-08
Description:	The application will update the required database with the user payments/renewed date				**Type:**	Black Box: ✓ White Box: ☐
Tester Information						
Tester Name:	Abdul Bhutta, Walid Ayub				**Date:**	
Environment:	The acceptance testing will be done on a web browser (Google Chrome, Safari)				**Time:**	
Steps	**Action**	**Expected Results**	**Pass**	**Fail**	**N/A**	**Comments**
1	The updated payment request will be sent to the MTO database.	The payment update will be reflected in the MTO database				
2	The renewal data will be updated	The date of renewal will be received by the application database				
3	Sticker update on licence Plate	The date of renewal will be updated and displayed on the licence plate				
Test Result:						

Table 6.8: Test Case #9 – Vehicle Stolen Mode

Test Writer:	Abdul Bhutta, Emran Soltani, Kumail Syed, Walid Ayub, Yussef Elzein					
Test Case Name:	TC # 9				**Test ID:**	Smart-TC-09
Description:	The user shall be able to disable vehicle when stolen				**Type:**	Black Box: ✓ White Box: ☐
Tester Information						
Tester Name:	Abdul Bhutta, Walid Ayub				**Date:**	
Environment:	The acceptance testing will be done on a web browser (Google Chrome, Safari)				**Time:**	
Steps	**Action**	**Expected Results**	**Pass**	**Fail**	**N/A**	**Comments**
1	The user selects stolen mode	The licence plate will display stolen				
2	The user selects disable vehicle	The device will send a signal to the EV. Signal shuts down the EV.				
Test Result:						

7 Project Plan

7.1 Fall Semester Deliverable Breakdown

The table below shows the task breakdown for all deliverables due during the Fall semester.

Table 7: Fall Semester Deliverable Breakdown

Deliverable	Report Section Name	Section Deliverables	Assigned Team Member(s)	Duration (Days)
Report #1	**Report Introduction**	Abstract, Dedication, and Acknowledgements	Emran Kumail Walid	2
Report #1	**Problem Identification**	Problem Statement Problem Objective Project Features	Yussef Emran Kumail	3
Report #1	**Background and Research Review**	**Research Topics:** V2G Raspberry Pi Security Cloud Computing Measurement of Battery State & Health Smart Metering & Smart Charging Auto-Brightness Ontario Licence Plate Legalities & Design Aspects Competitor Product Comparison	All Members	5
Report #1	**Design Process**	Overall Design Process Software Design Process Electrical Design Process Sequence Diagrams	Abdul Yussef	3
Report #1	**Use-Cases**	Use-Case Model Use-Case Definitions	Abdul Walid	2
Report #1	**Stakeholder Requirements / Traceability Matrix**	Stakeholder Requirements Definition Traceability Matrix	Abdul Walid	2
Report #1	**Definition of Acceptance Tests**	Acceptance Tests	Abdul Walid	2
Report #1	**Project Plan**	Task Breakdown (Fall) Task Breakdown (Winter)	Abdul Yussef	2

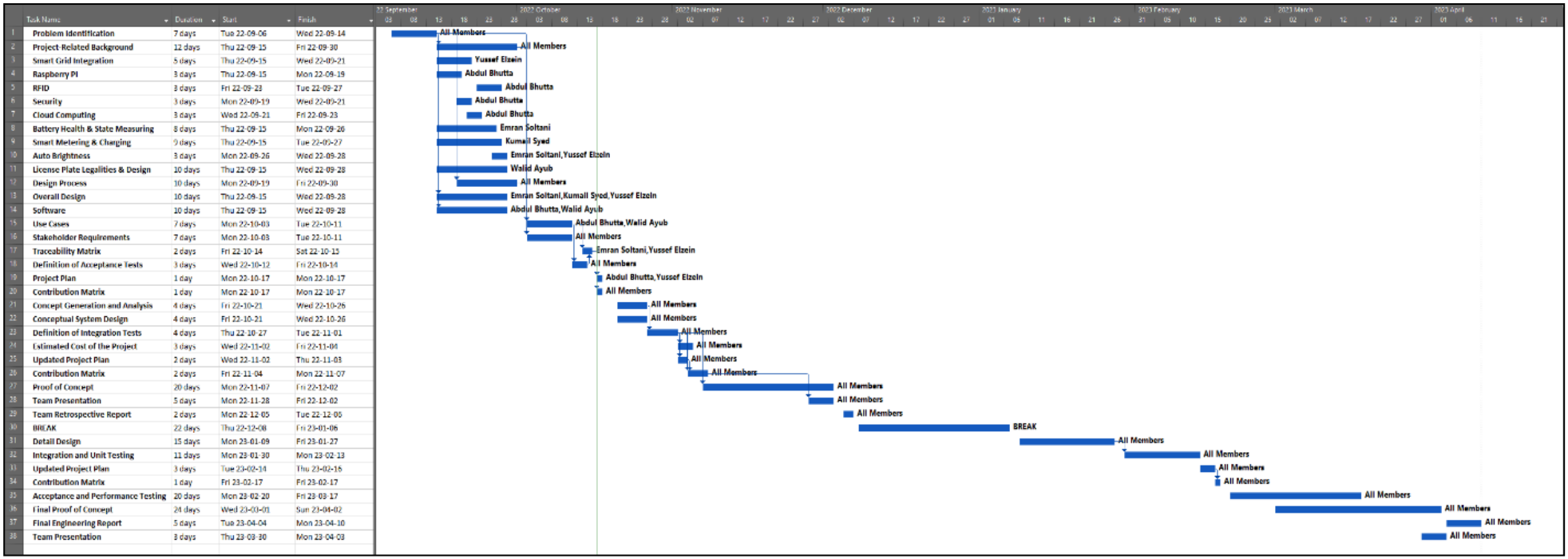
		Gantt Chart		
Report #1	**Contribution Matrix**	Matrix Creation and Completion	Yussef	1
Report #1	**Report Corrections**	Proofreading Consistency Check General Flow Check	Emran Kumail	1
Report #1	**Report Formatting**	Format Report Naming/Organizing Tables & Figures	Yussef	1
Report #1	**Report Submission**	Submission to Capstone Advisor	Yussef	>1
Report #2	**Report Introduction**	Abstract, Dedication, and Acknowledgements	All Members	1
Report #2	**Concept Generation/Analysis**	Concept Generation Table Creation	All Members	5
Report #2	**Conceptual System Design**	Software System Designs Electrical System Design Overall System Design Design Review	All Members	10
Report #2	**Definition of Integration Tests**	Creation of Integration Tests Review of Tests	Abdul Kumail Walid	4
Report #2	**Estimated Project Cost**	Cost Estimation Cost Analysis Cost Tracking	Emran Yussef Walid	2
Report #2	**Project Plan**	Update Task Breakdown (Winter) Update Gantt Chart	Abdul Yussef	2
Report #2	**Contribution Matrix**	Matrix Creation and Completion	Yussef	1
Report #2	**Report Corrections**	Proofreading Consistency Check General Flow Check	Emran Kumail	1
Report #2	**Report Formatting**	Format Report Naming/Organizing Tables & Figures	Yussef	1
Report #2	**Report Submission**	Submission to Capstone Advisor	Yussef	>1
Team Presentation & Demo	**Presentation Assembly**	Construction of PowerPoint Presentation	All Members	12
Team Presentation & Demo	**Presentation Proofreading and Formatting**	Proofreading Consistency Check General Flow Check	Emran Kumail Walid	1

Team Presentation & Demo	**Prototype Assembly**	Assembly of Prototype	Abdul Yussef	5
Team Presentation & Demo	**Presentation Rehearsals**	Assign sections for presentation Practice Presenting	All Members	3
Team Presentation & Demo	**Final Presentation**	Present to Capstone Advisor/Coordinator	All Members	1
Team Retrospective Report	**Report Preparation**	Write Team Report	All Members	10
Team Retrospective Report	**Report Corrections**	Proofreading Consistency Check General Flow Check	Emran Kumail	2
Team Retrospective Report	**Report Formatting**	Format Report Naming/Organizing Tables & Figures	Yussef	1
Team Retrospective Report	**Report Submission**	Submission to Capstone Coordinator	Yussef	>1
END OF FALL SEMESTER				

[the remainder of this page has been intentionally left blank]

7.2 Gantt Chart

Figure 17 below shows a Gantt chart demonstrating the project plan deliverables throughout the course of the project and the timeframe for their completion.



	Task Name	Duration	Start	Finish
1	Problem Identification	7 days	Tue 22-09-06	Wed 22-09-14
2	Project-Related Background	12 days	Thu 22-09-15	Fri 22-09-30
3	Smart Grid Integration	5 days	Thu 22-09-15	Wed 22-09-21
4	Raspberry PI	3 days	Thu 22-09-15	Mon 22-09-19
5	RFID	3 days	Fri 22-09-23	Tue 22-09-27
6	Security	3 days	Mon 22-09-19	Wed 22-09-21
7	Cloud Computing	3 days	Wed 22-09-21	Fri 22-09-23
8	Battery Health & State Measuring	8 days	Thu 22-09-15	Mon 22-09-26
9	Smart Metering & Charging	9 days	Thu 22-09-15	Tue 22-09-27
10	Auto Brightness	3 days	Mon 22-09-26	Wed 22-09-28
11	License Plate Legalities & Design	10 days	Thu 22-09-15	Wed 22-09-28
12	Design Process	10 days	Mon 22-09-19	Fri 22-09-30
13	Overall Design	10 days	Thu 22-09-15	Wed 22-09-28
14	Software	10 days	Thu 22-09-15	Wed 22-09-28
15	Use Cases	7 days	Mon 22-10-03	Tue 22-10-11
16	Stakeholder Requirements	7 days	Mon 22-10-03	Tue 22-10-11
17	Traceability Matrix	2 days	Fri 22-10-14	Sat 22-10-15
18	Definition of Acceptance Tests	3 days	Wed 22-10-12	Fri 22-10-14
19	Project Plan	1 day	Mon 22-10-17	Mon 22-10-17
20	Contribution Matrix	1 day	Mon 22-10-17	Mon 22-10-17
21	Concept Generation and Analysis	4 days	Fri 22-10-21	Wed 22-10-26
22	Conceptual System Design	4 days	Fri 22-10-21	Wed 22-10-26
23	Definition of Integration Tests	4 days	Thu 22-10-27	Tue 22-11-01
24	Estimated Cost of the Project	3 days	Wed 22-11-02	Fri 22-11-04
25	Updated Project Plan	2 days	Wed 22-11-02	Thu 22-11-03
26	Contribution Matrix	2 days	Fri 22-11-04	Mon 22-11-07
27	Proof of Concept	20 days	Mon 22-11-07	Fri 22-12-02
28	Team Presentation	5 days	Mon 22-11-28	Fri 22-12-02
29	Team Retrospective Report	2 days	Mon 22-12-05	Tue 22-12-06
30	BREAK	22 days	Thu 22-12-08	Fri 23-01-06
31	Detail Design	15 days	Mon 23-01-09	Fri 23-01-27
32	Integration and Unit Testing	11 days	Mon 23-01-30	Mon 23-02-13
33	Updated Project Plan	3 days	Tue 23-02-14	Thu 23-02-16
34	Contribution Matrix	1 day	Fri 23-02-17	Fri 23-02-17
35	Acceptance and Performance Testing	20 days	Mon 23-02-20	Fri 23-03-17
36	Final Proof of Concept	24 days	Wed 23-03-01	Sun 23-04-02
37	Final Engineering Report	5 days	Tue 23-04-04	Mon 23-04-10
38	Team Presentation	3 days	Thu 23-03-30	Mon 23-04-03

Figure 17: Gantt Chart for Digital Licence Plate Capstone Project

8 Contribution Matrix

The contribution matrix in the table below displays how the work for Report #1 was divided.

Table 8: Contribution Matrix for Report #1

	Group Members				
Report #1 Sections	**Abdul Bhutta**	**Yussef Elzein**	**Emran Soltani**	**Kumail Syed**	**Walid Ayub**
Section 1: Background and Research Review					
Problem Identification	✓	✓	✓	✓	✓
Section 2: Background and Research Review					
Smart Grid Integration		✓			
Raspberry Pi	✓				
Security	✓				
Cloud Computing	✓				
Battery Health & State Measuring			✓		
Smart Metering & Charging				✓	
Auto-Brightness Circuit Design			✓		
Licence Plate Legalities & Design					✓
Section 3: Design Process					
Overall		✓	✓	✓	
Software	✓				✓
Electrical		✓	✓	✓	
Section 4: Scenarios & Use Cases					
Use Cases	✓				✓
Section 5: Requirements / Traceability					
Stakeholder Requirements		✓		✓	✓
Traceability Matrix		✓	✓		
Section 6: Acceptance Tests					
Test Cases	✓	✓	✓	✓	✓
Section 7: Project Plan					
Task Breakdown		✓			
Gantt Chart	✓				
Section 8: Contribution Matrix					
Contribution Matrix	✓	✓	✓	✓	✓
Other: Report Corrections/Formatting		✓	✓	✓	

References

1. Virta Ltd., “Vehicle-to-grid (V2G): Everything you need to know,” Virta Global, 09-Jul-2021. [Online]. Available: https://www.virta.global/vehicle-to-grid-v2g#one. [Accessed: 09-Oct-2022].

2. EV Connect, “What is vehicle-to-grid for electric vehicles?: EV Connect,” EV Connect, 20-Dec-2021. [Online]. Available: https://www.evconnect.com/blog/what-is-vehicle-to-grid-for-electric-vehicles#:~:text=Pecan%20Street%2C%20a%20transportation%20electrification,it%20takes%20is%20V2G%20technology. [Accessed: 08-Oct-2022].

3. J. Svarc, “Bidirectional Chargers explained - V2G vs V2H VS V2L,” CLEAN ENERGY REVIEWS, 12-Oct-2022. [Online]. Available: https://www.cleanenergyreviews.info/blog/bidirectional-ev-charging-v2g-v2h-v2l. [Accessed: 08-Oct-2022].

4. “Learning how V2G is the future of energy,” Cornerstone Technologies, 03-Mar-2022. [Online]. Available: https://www.cstl.com.hk/charging/v2g/. [Accessed: 11-Oct-2022].

5. H. Mafukidze, “How to use RFID cards with a Raspberry Pi,” Circuit Basics, 02-Dec-2021. [Online]. Available: https://www.circuitbasics.com/what-is-an-rfid-reader-writer/. [Accessed: 06-Oct-2022].

6. VikashG2 and Instructables, “Raspberry pi location tracker,” Instructables, 04-Oct-2017. [Online]. Available: https://www.instructables.com/Raspberry-Pi-Location-Tracker/. [Accessed: 07-Oct-2022].

7. “What is cloud computing? A beginner's guide: Microsoft azure,” What Is Cloud Computing? A Beginner's Guide | Microsoft Azure. [Online]. Available: https://azure.microsoft.com/en-us/resources/cloud-computing-dictionary/what-is-cloud-computing/#cloud-deployment-types. [Accessed: 03-Oct-2022].

8. H. Liu, X. Zhu, Z. Xiao, Y. Wu, P. Li, D. Li, K. Deng, and S. Liu, “The application of smart meter in the management of Electric Vehicle Charging Facilities,” Procedia Computer Science, 06-Aug-2020. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S1877050920318159. [Accessed: 10-Oct-2022].

9. “Smart meters will help electric vehicles move into the mainstream,” Financial Times - Paid Post by Iberdrola. [Online]. Available: https://iberdrola.ft.com/smart-meters-will-help-electric-vehicles-move-into-the-mainstream. [Accessed: 11-Oct-2022].

10. “Connecting today. powering tomorrow.,” Independent Electricity System Operator (IESO). [Online]. Available: https://www.ieso.ca/. [Accessed: 12-Oct-2022].

11. D. Team, “What is Smart EV charging?,” Driivz, 21-Sep-2022. [Online]. Available: https://driivz.com/blog/ev-smart-charging-benefits/. [Accessed: 13-Oct-2022].

12. Virta Ltd., “Smart charging of electric vehicles: The ultimate guide ⚡,” Virta Global, 20-Jun-2022. [Online]. Available: https://www.virta.global/smart-charging. [Accessed: 14-Oct-2022].

13. J. Wood, “Despite Ford promises, failed Ontario licence plates increased costs by 26 per cent,” Newsroom, 16-Jun-2021. [Online]. Available: https://www.taxpayer.com/newsroom/despite-ford-promises,-failed-ontario-licence-plates-increased-costs-by-26-per-cent#:~:text=Throughout%20the%20entirety%20of%20the,have%20added%20up%20to%20%24913%2C867. [Accessed: 10-Oct-2022].

14. “Licence plate,” How Products Are Made. [Online]. Available: http://www.madehow.com/Volume-5/Licence-Plate.html#:~:text=identification%20of%20vehicles.-,Raw%20Materials,institutions%20or%20other%20plate%20makers. [Accessed: 10-Oct-2022].

15. “State of charge SOC estimation methods | battery management system,” YouTube, 20-Mar-2022. [Online]. Available: https://www.youtube.com/watch?v=7DTzShuFN6M16. “How to estimate battery state of charge using Deep Learning, part 1: An introduction to battery state of charge Estimation Video,” Video - MATLAB. [Online]. Available: . [Accessed: 05-Oct-2022].

16. “How to estimate battery state of charge using Deep Learning, part 1: An introduction to battery state of charge Estimation Video,” Video - MATLAB. [Online]. Available: https://www.mathworks.com/videos/how-to-estimate-battery-state-of-charge-using-deep-learning-part-1-an-introduction-to-battery-state-of-charge-estimation-1622098521470.html. [Accessed: 05-Oct-2022].

17. “State of Health of Battery | Battery SOH | Battery Management System,” YouTube, 03-Jul-2022. [Online]. Available: https://www.youtube.com/watch?v=KhfGivA2UMM18. T. Agarwal, “Ambient light sensor: Types, circuit and applications,” ElProCus, 29-Jul-2019. [Online]. Available: . [Accessed: 05-Oct-2022].

18. T. Agarwal, “Ambient light sensor: Types, circuit and applications,” ElProCus, 29-Jul-2019. [Online]. Available: https://www.elprocus.com/ambient-light-sensor-working-and-applications/19. “Silicon Lightworks,” Battery Powered Trade Show Exhibit Lighting. [Online]. Available: . [Accessed: 07-Oct-2022].

19. “Silicon Lightworks,” Battery Powered Trade Show Exhibit Lighting. [Online]. Available: https://siliconlightworks.com/li-ion-voltage20. C. Tran and P. Mullins, “Simple Ambient Light Sensor Circuit,” Simple Ambient Light Sensor Circuit | Analog Devices. [Online]. Available: . [Accessed: 08-Oct-2022].

20. C. Tran and P. Mullins, “Simple Ambient Light Sensor Circuit,” Simple Ambient Light Sensor Circuit | Analog Devices. [Online]. Available: https://www.analog.com/en/analog-dialogue/articles/simple-ambient-light-sensor-circuit.html. [Accessed: 07-Oct-2022].

21. MATLAB, “Introduction to battery state of charge estimation | estimate battery SOC with Deep Learning, part 1,” YouTube, 07-Jun-2021. [Online]. Available: https://www.youtube.com/watch?v=0v4IWgx83RA. [Accessed: 05-Oct-2022].

22. D. Daly, “Plates,” New York DMV, 01-Dec-2021. [Online]. Available: https://dmv.ny.gov/plates. [Accessed: 18-Oct-2022].

23. “Law document english view,” Ontario.ca, 19-Nov-2018. [Online]. Available: https://www.ontario.ca/laws/regulation/900628. [Accessed: 18-Oct-2022].

24. “Register a vehicle (permit and licence plate),” ontario.ca. [Online]. Available: https://www.ontario.ca/page/register-vehicle-permit-and-licence-plate. [Accessed: 18-Oct-2022].

25. Complete Car, “Can you drive without a licence plate in Ontario?,” Complete Car, 24-Jan-2022. [Online]. Available: https://completecar.ca/resources/can-you-drive-without-a-licence-plate/. [Accessed: 18-Oct-2022].

26. “Licence plate,” How Products Are Made. [Online]. Available: http://www.madehow.com/Volume-5/Licence-Plate.html. [Accessed: 18-Oct-2022].

27. “Royal Symbols and the Canadian car,” Canadian Automotive Museum. [Online]. Available: https://www.canadianautomotivemuseum.com/royal-symbols-and-the-canadian-car. [Accessed: 18-Oct-2022].

28. “Licence Plate fonts of the united states, Canada, and Mexico,” Licence Plate Fonts of the United States, Canada, and Mexico. [Online]. Available: https://www.leewardpro.com/articles/licplatefonts/licplate-fonts-nam.html. [Accessed: 18-Oct-2022].

29. City*News*. [Online]. Available: https://toronto.citynews.ca/2022/02/15/ontario-blue-licence-plates/. [Accessed: 18-Oct-2022].

Smart Grid Integrated Digital Licence Plate

Capstone Project Report #2

Team Members:

Abdul Bhutta - 100785884

Yussef Elzein - 100641407

Emran Soltani - 100618333

Kumail Syed - 100661596

Walid Ayub - 100695612

Report #2 submitted in partial fulfillment for the final year Capstone Project in the Faculty of Engineering and Applied Science.

Project Advisor: Dr. Tarlochan Sidhu, P.Eng.

Capstone Coordinator: Dr. Vijay K. Sood, P.Eng., ECSE

Submitted to Ontario Tech University

November 8th, 2022

Abstract

In recent years, it has become evident that traditional licence plates have many flaws such as security, durability, and functionality. Current licence plates have proven time and time again that it is time for an update. The world is quickly going digital as technological advancements are being made every day. Licence plates have not yet caught up to the times. A smart digital licence plate would be a tremendous upgrade moving into this electric and digital world. Current technologies such as displays, communications, and electric vehicles have created a possibility for revolutionary smart digital licence plates with features such as theft detection, renewal updates, smart grid integration, and web information access. The following capstone project report is a follow-up of report 1. It includes all the design aspects of the smart grid-integrated digital licence plate. It contains all the test cases that will be conducted to ensure the proper function and safety of the product. Furthermore, during the concept generation, we found it feasible to program the digital licence plate on a Raspberry Pi. It was also found logical to power the system using a rechargeable power bank. The system will also utilize a GPS module alongside a RFID tag and reader to support anti-theft measures. Moreover, the assembly of the product will be enclosed in a 3D-printed case designed using SolidWorks. Finally, the integration of a website will be included to manage all the features. According to the Gantt chart, the product is currently on track to be fully established by April 2023.

Dedication

We would like to dedicate this report to each of our group members' families who have continuously supported us throughout the university in both moral and material needs. Moreover, we would like to dedicate this report to all our professors, peers, and friends for their consistent encouragement and motivation.

Acknowledgments

We would like to express our gratitude to our supervisor Dr. Tarlochan Sidhu who made this project possible. With his guidance, we were able to get a thorough understanding of the project and how to execute our ideas. His continuous support fed our ambition to take this project above and beyond.

We would also like to acknowledge our capstone coordinator Dr. Vijay Sood. He was able to give us a strong detailed understanding of producing reports and how to have a complete presentation on our project.

Our sincere appreciation to Dr. Sheldon Williamson for offering his knowledge and guidance with this project. In our first meeting, he provided us with many ideas on smart grid technology and possible recommendations on how to implement them.

Lastly, we would like to thank our friends and family for their continued support, especially Siear Lutfi for attending one of our meetings and encouraging us throughout.

We will be forever grateful for this capstone project as it has not only challenged us but helped us understand the process of designing, testing, building, and implementing a product from start to finish.

Table of Contents

List of Figures

List of Tables

List of Acronyms Used

Acronym	Meaning
3D	Three Dimensional
BMS	Battery Management System
BMS	Battery Management System
CVV	Card Verification Value
EV	Electric Vehicle
GB	Gigabyte
GPS	Global Positioning System
HDMI	High-Definition Multimedia Interface
HTTP	Hypertext Transfer Protocol
ID	Identification
IESO	Independent Electricity System Operator
IP	Internet Protocol
IT	Integration Test
kWh	Kilowatt-hour
LTE	Long-Term Evolution
MW	Megawatt
RFID	Radio-Frequency Identification
SD	Secure Digital
TCP	Transmission Control Protocol
USB	Universal Serial Bus
USB-A	Universal Serial Bus Type A
USB-C	Universal Serial Bus Type C
Wi-Fi	Wireless Fidelity

1 Introduction

This report will include a concept analysis to show the required key components for our prototype and some viable options we can eliminate. A system design will be provided to clearly outline the software aspect of the project, with diagrams explaining how everything will operate and coordinate for the system to run. Furthermore, visuals for a website example, using a wireframe, will show how the actual website will look and specify how a user can navigate around the services. An electrical design will give a visual representation of how the licence plate circuit will operate and the connections it has with every component, along with other circuit diagrams of how the plate features will work. Multiple integration testing will be done to explain where the software aspects can be logically integrated and tested. The test will describe the scenario, and procedures being taken, alongside the expected result. A cost breakdown will also be provided with information on all parts.

Problem Statement

Many advancements have been made in technology and there is no reason for vehicles today not to be equipped with smart licence plates. The current licence plates endure issues such as peeling, theft, and readability. Moreover, the province of Ontario had recently updated its plates to blue ones with a new slogan. The goal was to refresh the plates and solve the peeling issue but, instead, it made matters worse as law authorities found it difficult to see the plates at night as they were not reflective. These new plates cost the province about 1 million dollars and shortly after were discontinued [1]. Introducing a smart digital licence plate would automatically eliminate all the problems with the current licence plates. Furthermore, designing, integrating, and implementing digital licence plates would not only save the province issues like legibility at night, but also create cost-effective solutions for plate updates in the future.

Overview of the Report

The remaining portion of this report is structured as follows. Section 2 is the concept generation & analysis, where it explains how and why the specific parts were chosen. Section 3 includes design schematics for both the website and the digital licence plate. Section 4 includes all the integration testing that will take place to ensure the proper function of the licence plate. Section 5 reports our budget and the amount spent. Lastly, section 6 explains the project plan and section 7 explains our contribution to this report.

2 Concept Generation & Analysis

2.1 Initial Concept Generation

In order to have an efficient and functional smart grid integrated licence plate, our product will require many key components. The main components we will need to have include: a controller, a power source for the plate, a digital display screen, a security method, a user interface, and a method for GPS tracking. In **Table 1.0** below, we list our top picks for each of the main components.

Table 1.0: Prototype Main Component Options

Controller	Plate Power Source	Display Screen	Security	User Interface	GPS
Raspberry Pi 3 Model B+ (1GB Only)	Rechargeable Li-Battery Pack	Portable Monitor from Amazon	Pressure Switch	Website	Apple AirTag
Raspberry Pi 4 Model B (2GB)	Rechargeable Power Bank	Portable Monitor from a Chinese Manufacturer	RFID RC522	Mobile Application	Location Services
Raspberry Pi 4 Model B (4GB)	Connection to Vehicle's 12V Battery	Laptop Screen Replacement			GT-U7 GPS Module
LattePanda 2G/32GB	Solar Rechargeable Power Bank				

After reviewing the list of options for our prototype's main components, we eliminated several options due to the cost or their complexity of integration. For the controller, we have chosen to proceed with a Raspberry Pi 4 Model B for our controller as it would have ample processing power for our prototype. The LattePanda was also a reasonable option, but we decided not to select it as we are not very familiar with it and are more comfortable with the Raspberry Pi. For the plate's power source, we quickly eliminated the option of having a direct connection to the vehicle's 12V battery. This is because it would rapidly discharge the battery causing it to fail when the vehicle is not in motion. For the display screen, we discarded the laptop screen option due to the difficulty of connection. We decided to either go with the portable monitor from Amazon or from a Chinese Manufacturer. The Amazon screen is higher quality than the China sourced screen however, it is comparatively expensive. Moreover, upon deciding the user interface, we chose to create a website and if time permits, a mobile application as well for the user. Finally, we abandoned the idea of using an Apple AirTag as it is costly and would require us to send the user to a 3rd party app for GPS tracking making it difficult to integrate.

2.2 Model Creation

The following table shows 4 different models that we have created which we will analytically compare in order to determine which model is best suited for our project. Each model contains a different combination of options for the main components.

Table 2.0: Model Alternatives

Concept Model	Controller	Power Type	Display Screen	User Interface	Security	GPS
Model 1	Raspberry Pi 4 Model B (2GB)	Solar Rechargeable Power Bank	Portable Monitor from Amazon	Website	Pressure Switch	Location Services
Model 2	Raspberry Pi 4 Model B (2GB)	Rechargeable Power Bank	Portable Monitor from a Chinese Manufacturer	Website	RFID RC522	GT-U7 GPS Module
Model 3	Raspberry Pi 4 Model B (4GB)	Rechargeable Li-Battery Pack	Portable Monitor from a Chinese Manufacturer	Website	Pressure Switch	GT-U7 GPS Module
Model 4	Raspberry Pi 4 Model B (4GB)	Rechargeable Power Bank	Portable Monitor from Amazon	Website	RFID RC522	Location Services

2.3 Model Analysis

This section contains tables where all 4 models are compared in regards to their complexity, cost, as well as strengths and weaknesses. These comparisons will prove useful in the model decision making process.

Table 2.1: Complexity Comparison

Concept Model	Software Complexity Level 0 (Simple) to 100 (Complex)	Electrical Complexity Level 0 (Simple) to 100 (Complex)
Model 1	30	50
Model 2	40	20
Model 3	35	40
Model 4	35	35

Table 2.2: Estimated Cost of Models

Concept Model	Estimated Cost of Parts	Total Estimated Cost
Model 1	Raspberry Pi 4 Model B Starter Kit (2GB) – $192 Solar Rechargeable Power Bank – $70 Portable Monitor (Amazon) – $382 Pressure Switch – $14 Location Services – $0 Various Small Parts/Cables – $40	$698
Model 2	Raspberry Pi 4 Model B Starter Kit (2GB) – $192 Rechargeable Power Bank – $44 Portable Monitor (Chinese Manufacturer) – $191 RFID RC522– $16 GT-U7 GPS Module – $29 Various Small Parts/Cables – $40	$512
Model 3	Raspberry Pi 4 Model B (4GB) – $271 Rechargeable Li-Battery Pack – $232 Portable Monitor (Chinese Manufacturer) – $191 Pressure Switch – $14 GT-U7 GPS Module – $18 Various Small Parts/Cables – $60	$786
Model 4	Raspberry Pi 4 Model B (4GB) – $271 Rechargeable Power Bank – $44 Portable Monitor (Amazon) – $382 RFID RC522 – $16 Location Services – $0 Various Small Parts/Cables – $60	$773

[the remainder of this page has been intentionally left blank]

Table 2.3: Model Strength & Weakness Comparison

Concept Model	Strengths	Weaknesses
Model 1	• Self-rechargeable with sunlight • Easy to implement security features • No cost associated to GPS • Easily replaceable power bank	• Difficult to implement solar power bank • High cost • Low theft security • Easy to trick security pressure switch • Lower computing power
Model 2	• Very cost-effective • Least complex to design • Minimal points of failure • High security with RFID • Accurate GPS location • Easily replaceable power bank	• Lower computing power • Connection to vehicle's electrical required
Model 3	• Easy to implement security Feature • Accurate GPS location • Higher computing power	• Very high cost • Low theft security • Easy to trick security pressure switch • Li-Battery is very large • Connection to vehicle's electrical required
Model 4	• High security with RFID • Accurate GPS location • Higher computing power • Easily replaceable power bank	• Very high cost • Connection to vehicle's electrical required

[the remainder of this page has been intentionally left blank]

2.4 Model Ranking

2.4.1 Pairwise Comparison Matrix

In order to decide on which model is the best for our project, we must analyze them analytically based on predetermined selection criteria. For the purposes of our project, we have chosen 4 unique criteria for selection: Simplicity, Cost, Size, and Security. **Table 2.4** compares the selection criteria and computes their individual weights for the decision-making process. Assume that the scale ranges from 1 to 7 where 1 means both criteria are of equal importance up to 7 where the first criterion is extremely more important.

Table 2.4: Pairwise Comparison Matrix

	Simplicity	Cost	Size	Security	Total	Weight
Simplicity	1	3	5	1/3	9.33	0.315
Cost	1/3	1	3	1/5	4.53	0.153
Size	1/5	1/3	1	1/5	1.73	0.059
Security	3	5	5	1	14	0.473
Total:					**29.59**	**1**

2.4.2 Selection Criteria Per Model Weighting

In the following tables, we will be calculating our selection criteria's normalized weighting in order to be able to eventually score each model to determine the best model for our established needs and criteria.

Table 2.5: Simplicity Weighting Calculation Table

	Model 1	Model 2	Model 3	Model 4
Simplicity Score	80	60	75	70
Total	80 + 60 + 75 + 70 = 285			
Normalizing	80/285	60/285	75/285	70/285
Normalized Weighting	**0.281**	**0.210**	**0.263**	**0.246**

Table 2.6: Cost Weighting Calculation Table

	Model 1	Model 2	Model 3	Model 4
Estimated Cost ($)	698	512	786	773
Lowest Cost to Model Ratio	512/698= 0.734	512/512 = 1	512/786 = 0.651	512/773 = 0.662
Total	0.734 + 1 + 0.651 + 0.662 = 3.047			
Normalizing	0.734/3.047	1/3.047	0.651/3.047	0.662/3.047
Normalized Weighting	**0.241**	**0.328**	**0.214**	**0.217**

Table 2.7: Size Weighting Calculation Table

	Model 1	Model 2	Model 3	Model 4
Estimated Casing Size for All Parts (cm^3)	2520	2520	4410	2520
Ratio to Lowest Size	1	1	2520/4410 = 0.571	1
Total	1 + 1 + 0.571 + 1 = 3.571			
Normalizing	1/3.571	1/3.571	0.571/3.571	1/3.571
Normalized Weighting	**0.280**	**0.280**	**0.160**	**0.280**

In order to calculate the weighting for security, we came up with the original security score by rating the efficiency for each of the security components from 0 to 100. We then continued by adding the total up for each model. The first model has a pressure switch which we rated at 25 and uses location services for GPS tracking which we rated at 50. Therefore, the total for Model 1 equates to 75. Model 2 uses an RFID reader which we rated at 90 along with a GT-U7 GPS module which we rated at 80. This makes Model 2's security score equal to 170. Model 3 contains a pressure switch rated at 25 and a GPS module rated at 80 adding to a total of 105. Model 4 contains a RFID reader (90) and uses location services (50) totalling to a score of 140. These scores can be seen in **Table 2.8** below.

Table 2.8: Security Weighting Calculation Table

	Model 1	Model 2	Model 3	Model 4
Security Score	75	170	105	140
Total	75 + 170 + 105 + 140 = 490			
Normalizing	75/490	170/490	105/490	140/490
Normalized Weighting	**0.153**	**0.347**	**0.214**	**0.286**

[the remainder of this page has been intentionally left blank]

2.4.2 Decision Matrix

The model decision matrix in **Table 2.9** above suggest that Model 2 would be the optimal design for our prototype as it aligns best with our selected criteria.

Table 2.9: Model Decision Matrix

		Model 1	Model 2	Model 3	Model 4
Simplicity	0.315	0.281	0.210	0.263	0.246
Cost	0.153	0.241	0.328	0.214	0.217
Size	0.059	0.280	0.280	0.160	0.280
Security	0.473	0.153	0.347	0.214	0.286
Score		**0.214**	**0.297**	**0.226**	**0.262**

For the purposes of our project, we have thus decided to use Model 2 for the initial design of our product. The subsequent sections in this report will be completed using the components outlined in the Model 2 concept in **Table 2.0**.

[the remainder of this page has been intentionally left blank]

3 Conceptual System Design

The following section will include designs for Model 2 that was chosen in section 2 of this report.

3.1 Software Design

3.1.1 Deployment Diagram

The diagram below represents a deployment diagram for the embedded system, which shows a high-level abstraction of the interaction and links among the physical components at run-time. A solid line within the system indicates an association relationship, and a dotted line represents a dependency. The RFID tag is dependent on the reader to authorize access to the microcontroller, and the microcontroller is dependent on the RFID reader to allow access and fetch the licence plate number from the database. Please note in the diagram that cloud service will have its physical infrastructure somewhere in the world, but the system acts as one rather than individual components through transparency. Each physical module contains an artifact or a component. An artifact is displayed by the following syntax <<Artifact>> and described by the product or information generated from the software. A component is shown by two rectangular tabs and represents a software element.

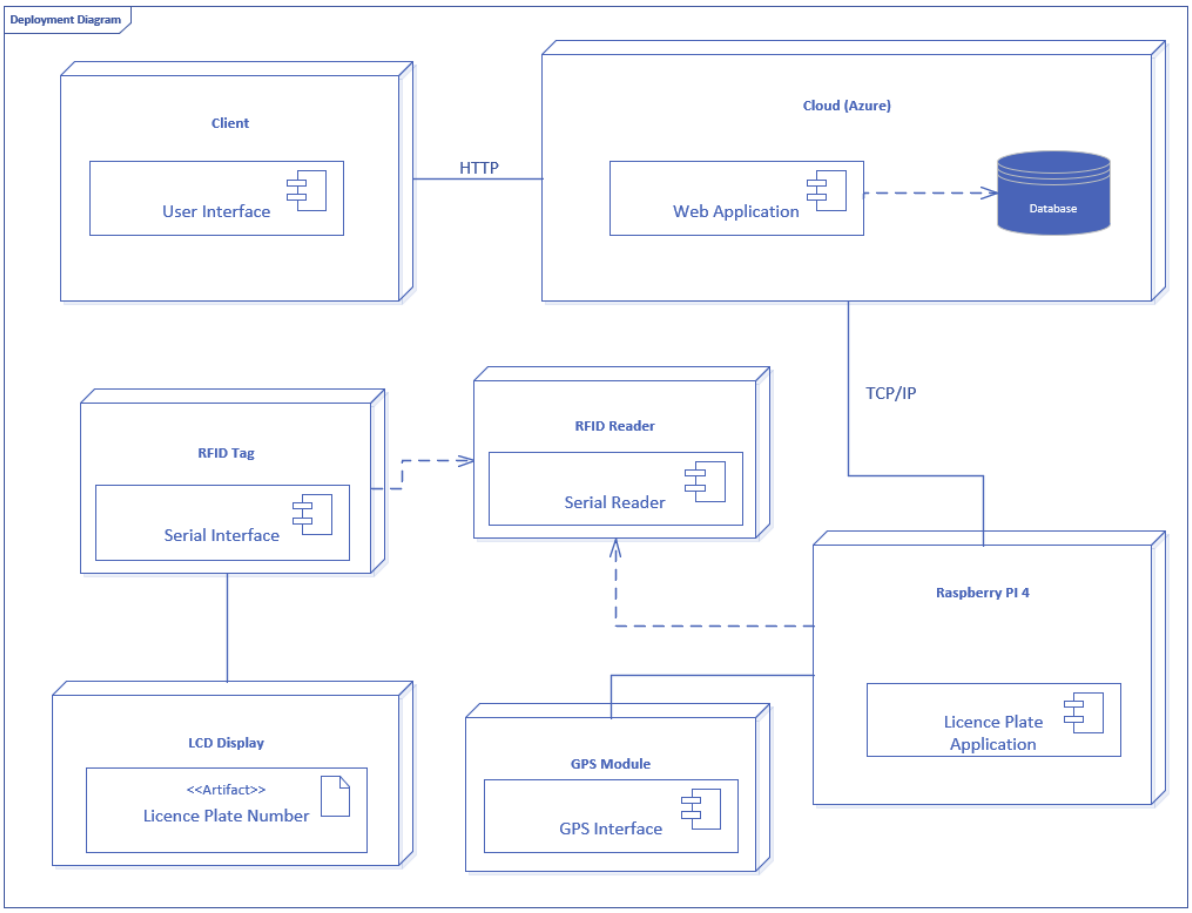


Figure 1: Deployment Diagram

3.1.2 Functional Decomposition Conceptual Model

The diagram below shows a conceptual model of the functional decomposition for our smart licence plate application. This model's outline will be followed when designing the application.

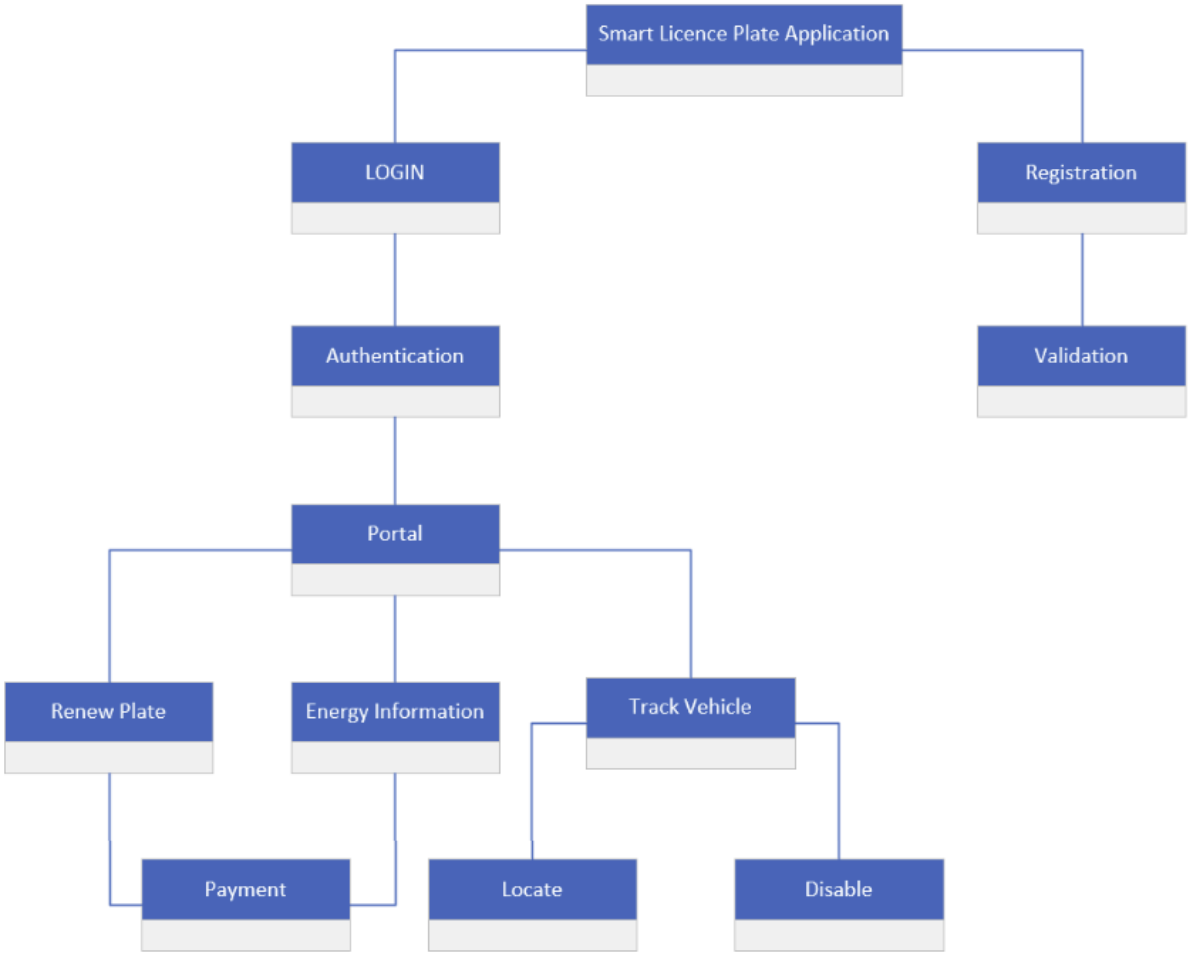


Figure 2: Functional Decomposition of Software System

[the remainder of this page has been intentionally left blank]

3.1.3 Architecture (3-Tier)

The diagram below shows our system's 3-Tier architecture.

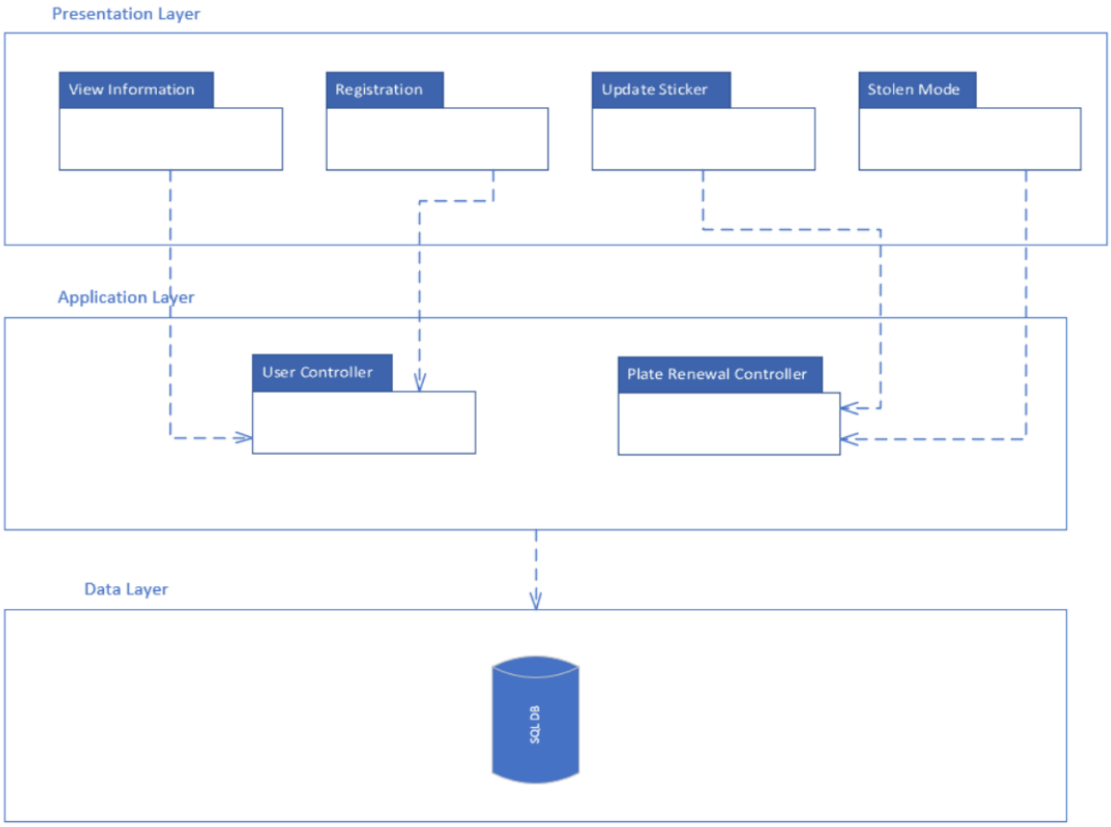


Figure 3: 3-Tier Architecture Diagram

[the remainder of this page has been intentionally left blank]

3.1.4 Website Wireframe

In this section, we will show the basic wireframes for each of the fundamental pages on our website.

3.1.4.1 User Portal

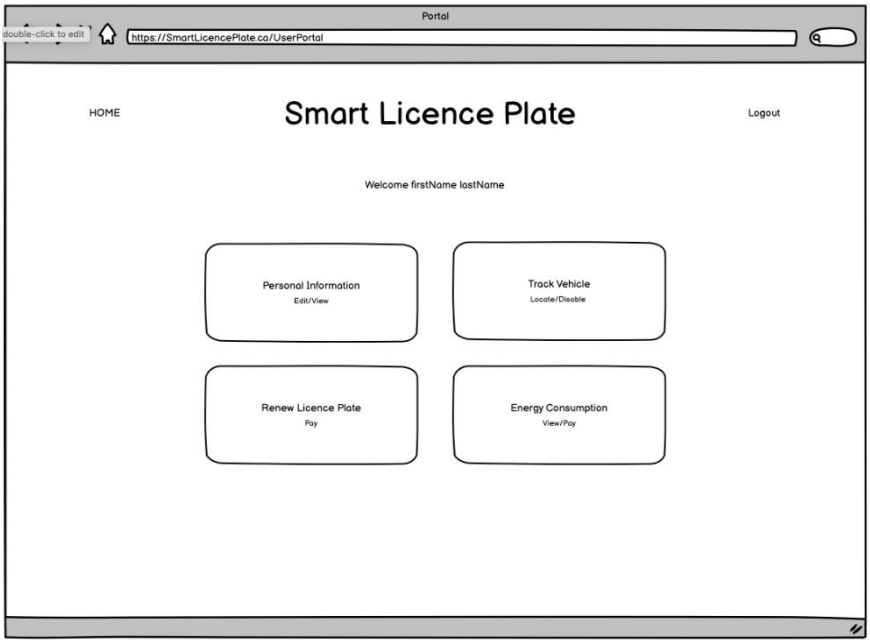


Figure 4: User Portal Wireframe

3.1.4.2 Registration Page

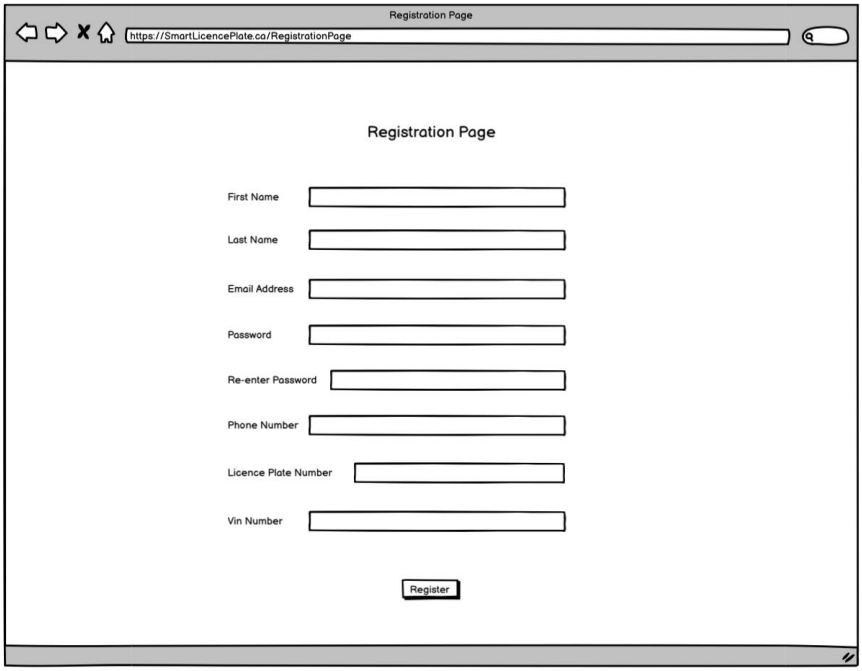


Figure 5: Registration Page Wireframe

3.1.4.3 Login Page

Figure 6: Login Page Wireframe

3.1.4.4 Tracking Page

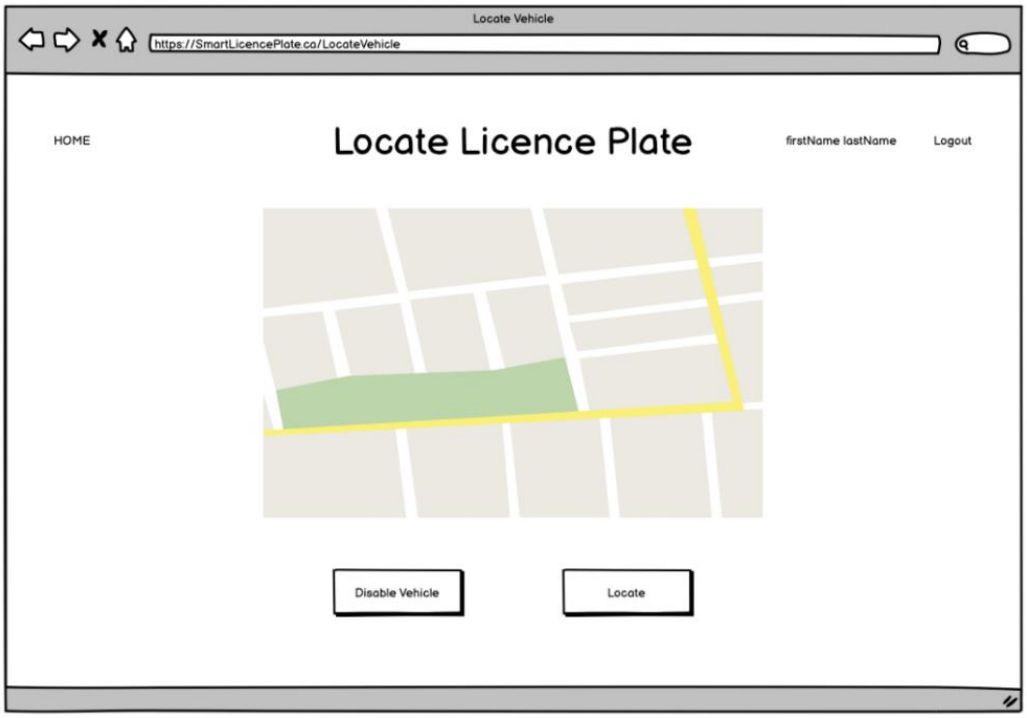


Figure 7: Location Page Wireframe

3.1.4.5 Renewal Page

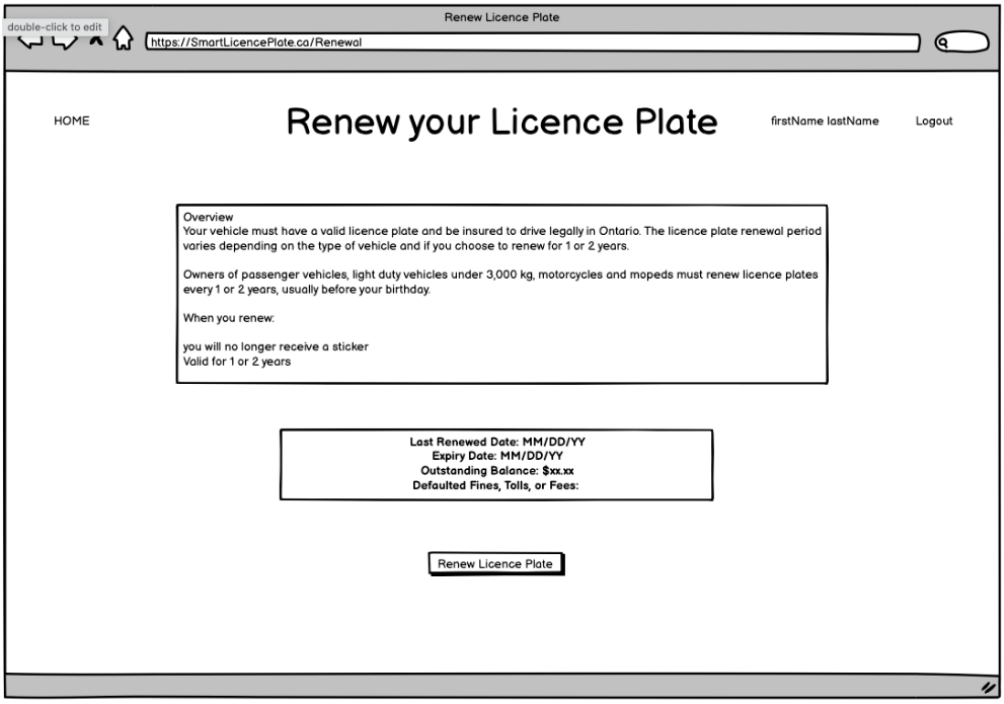


Figure 8: Renewal Page Wireframe

3.1.4.6 Energy Consumption Page

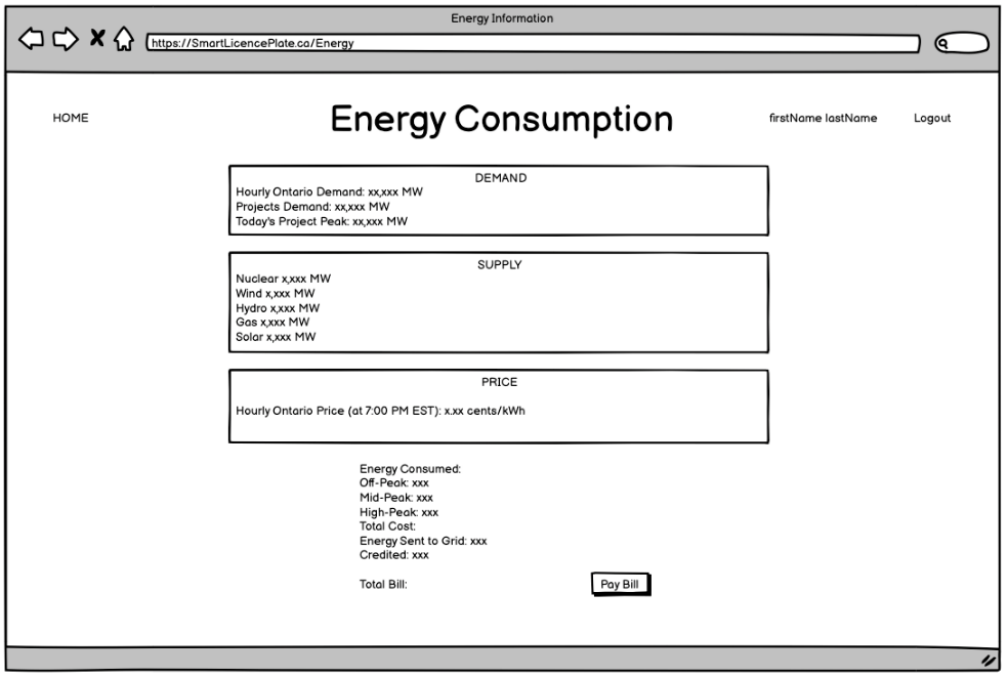


Figure 9: Energy Consumption Wireframe

3.1.4.7 Payment Page

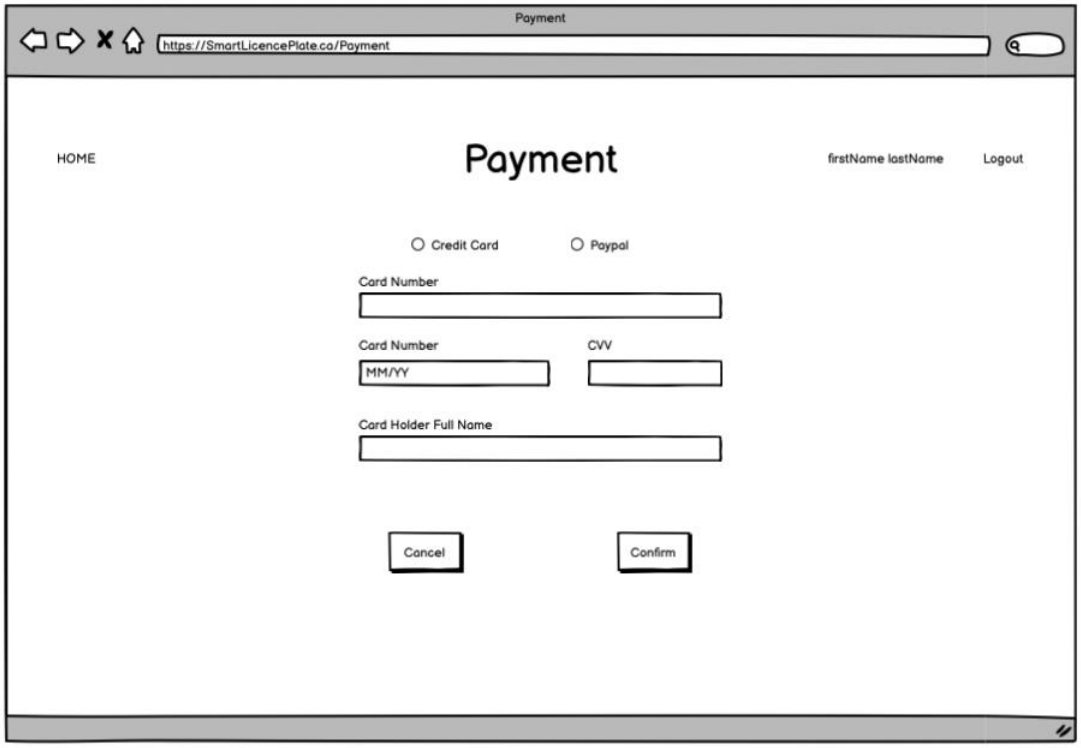


Figure 10: Payment Page Wireframe

[the remainder of this page has been intentionally left blank]

3.2 Electrical Design

3.2.1 Plate Display Connection Diagram

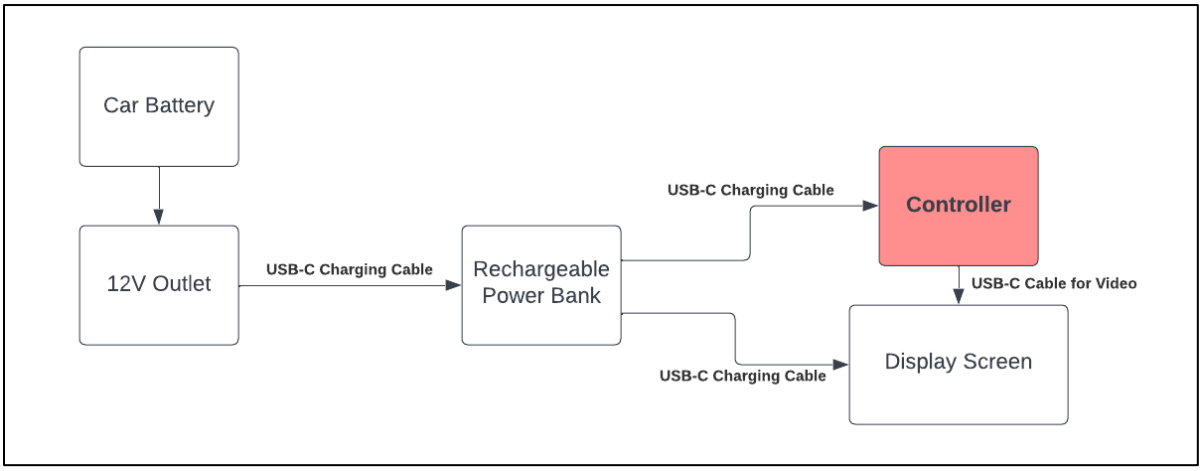


Figure 11: Plate Display Connection Diagram

Figure 11 shows a diagram of the connections for our plate's display. The car battery will be plugged into the 12V power outlet which gives power to the rechargeable power bank using the USB-C charging cable. This provides a connection to the controller (Raspberry Pi) as well as the display screen for the output.

3.2.2 Security Connection Diagram

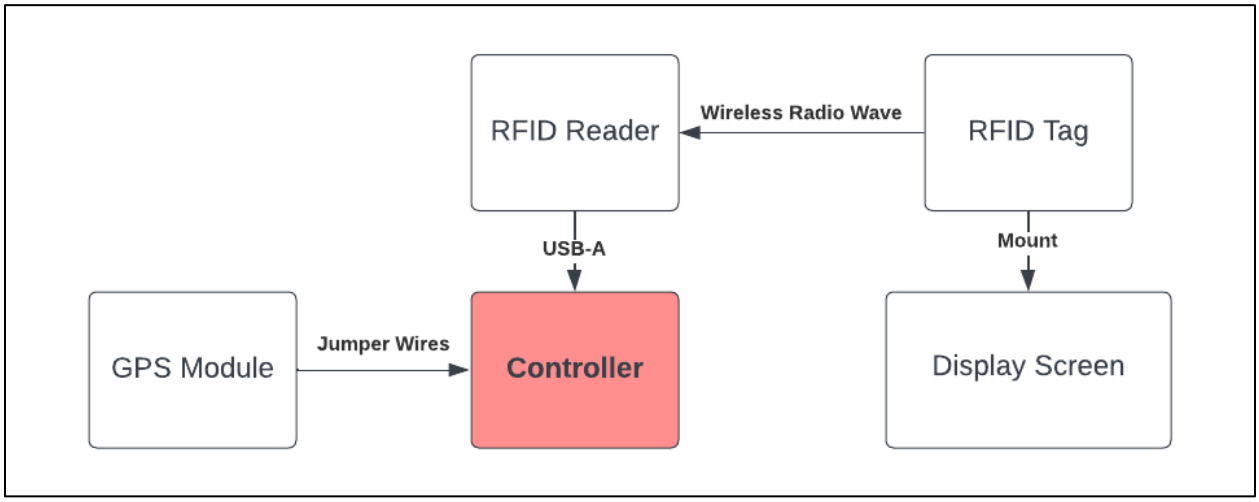


Figure 12: Security Connection Diagram

Figure 12 displays a basic connection diagram for the security components in our circuit. An RFID tag attached to the backside of our display screen will wirelessly send a signal to the RFID reader via wireless radio wave. When the display screen is removed, the controller will be notified which will prompt an alert to the user that the plate has been dismounted from the backplate. The GT-U7 GPS module is also connected directly to the Raspberry Pi controller via jumper wires.

3.2.3 EV Diagram

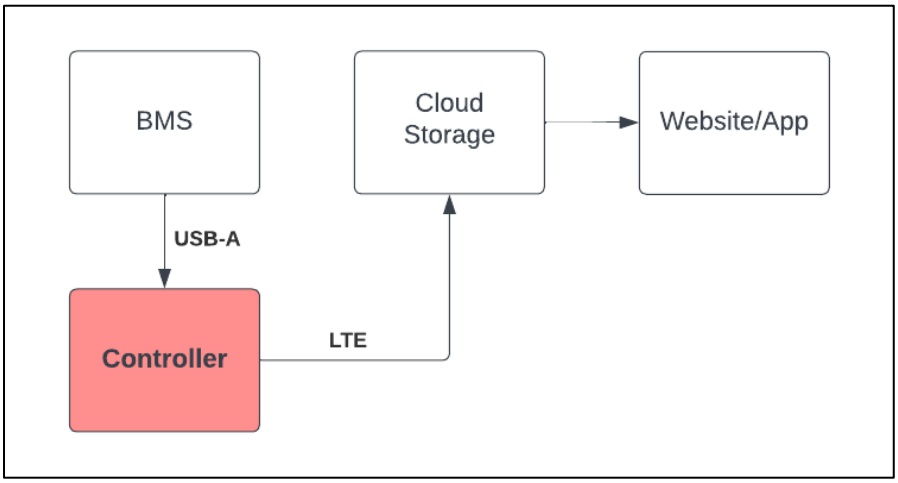


Figure 13: EV Connection Diagram

Figure 13 demonstrates the smart grid electrical setup for electric vehicles. The EV's battery management system, or BMS for short, is connected to the controller through a USB-A input. The BMS will provide real-time battery data and pass it to the controller. The controller will then communicate the data to our cloud storage system using an LTE connection and ergo to our website. The website will be available to users who want to check their vehicle's electrical consumption data along with its battery health and state information. Note that this circuit can only be implemented into EV vehicles.

3.2.4 Complete Electrical Connection Diagram

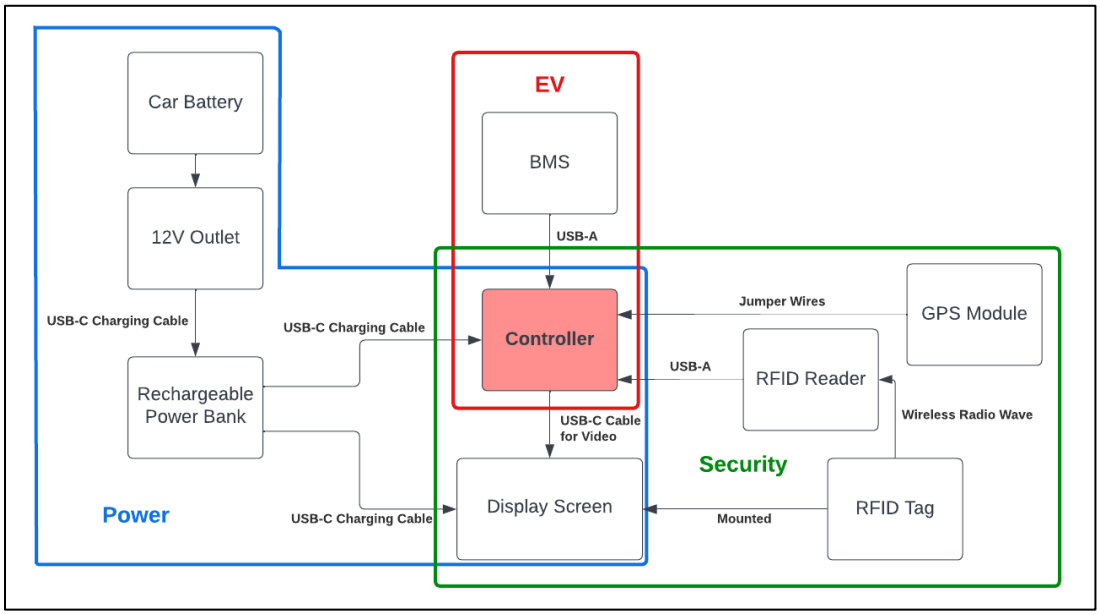


Figure 14: Complete Electrical Diagram

Figure 14 represents the complete electrical connection diagram. There are three major components presented in the diagram: Power (blue), Security (green) and EV (red).

3.3 Functional Decompositions

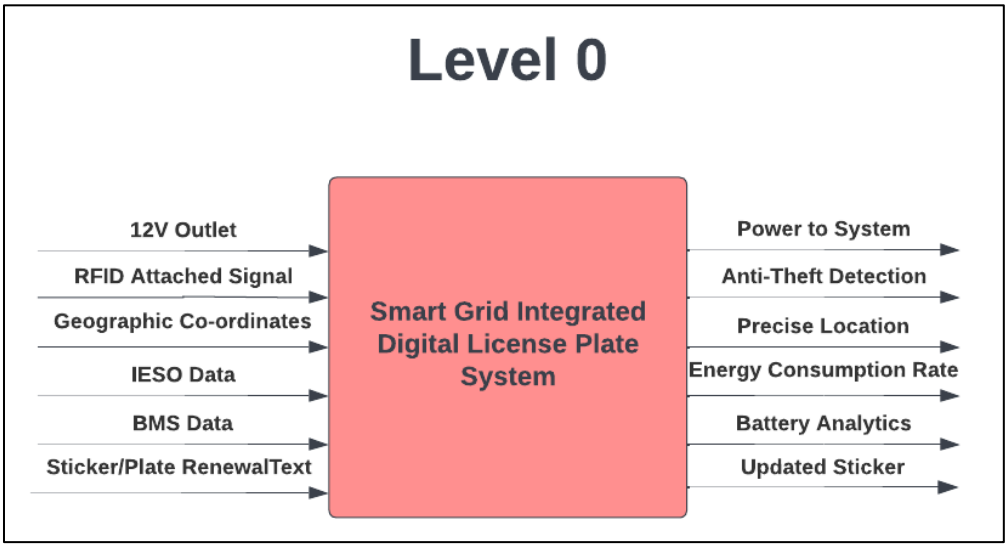


Figure 15: Level 0 Functional Decomposition

Table 3.0: Functional Decomposition for Level 0 System

Module	**Smart Grid Integrated Digital Licence Plate**
Inputs	**12V Outlet –** Power source for providing energy to the controller and plate. **RFID Attach Signal –** The plate would receive a signal from the RFID Reader to indicate whether the plate (display) is attached to the vehicle or not. **Geographical Co-ordinates –** The controller will use a GPS module for location services. **IESO Data –** Data from this website will help determine electricity costs and current conditions. **BMS Data –** The BMS will help provide real time EV battery analytics. **Sticker/Plate Renewal -** The user through the website will pay any renewal fees.
Outputs	**Power to System –** The power would allow the controller and the system to turn on and function. **Anti-Theft Detection –** The user would be notified immediately of a possible plate theft or removal. **Precise Location –** The precise location will be displayed on the website when requested. **Energy Consumption Rate –** The user would be able to see the peak electricity hours and costs as well as the demand and supply data. **Battery Analytics –** The user would benefit from this feature and keep a track of their battery health, range, and state. **Updated Sticker –** After the payment has been the sticker will be updated.
Functionality	The Smart Grid Integrated Digital Licence Plate will utilize specific parts to output a futuristic digital licence plate.

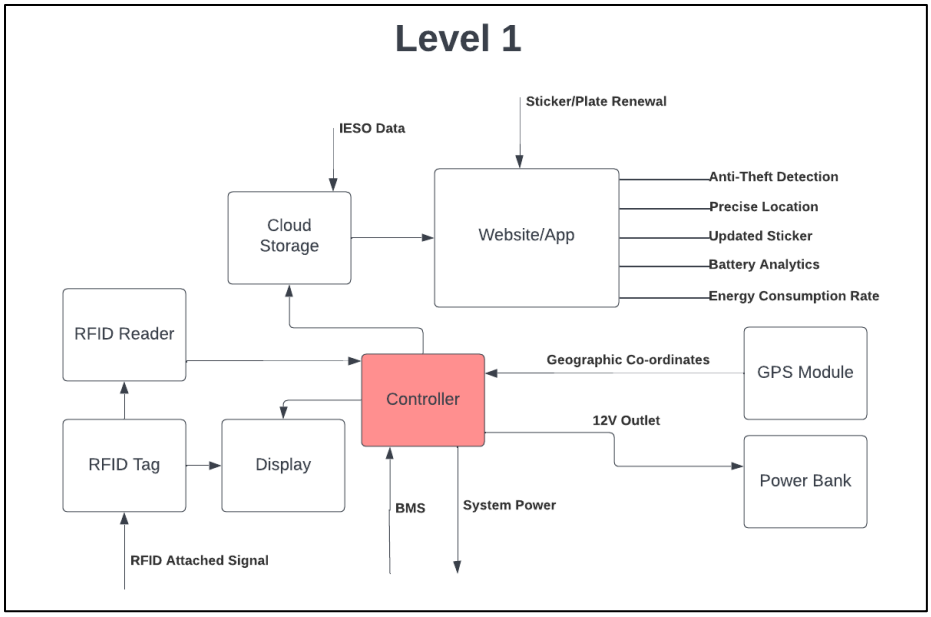


Figure 16: Level 1 Functional Decomposition

Table 3.1: Functional Decomposition for Level 1 System

Module	**Total Decomposition of Licence Plate**
Inputs	**12V outlet –** The 12V outlet is connected to the rechargeable power bank which powers the whole system through the controller (Raspberry Pi). **RFID Attached Signal –** The RFID reader is connected to the controller and is in communication with the RFID tag. **IESO Data –** The data is pulled from the IESO website and stored in the cloud storage. The data is then displayed on the website for the user. **Geographic Co-ordinates –** The geographic co-ordinates will be acquired through a GPS module. The information will be sent to the cloud through the controller. **Sticker/Plate Renewal –** The user will make their plate/sticker renewal fee through the website. **BMS –** The battery information will be drawn from the EV's BMS.
Outputs	**Power to System** – The power connected to the controller (Raspberry Pi) provides power to the whole system. **Anti-Theft Detection** – The user would be notified immediately of a possible plate theft or removal. **Precise Location** – The licence plate will be continuously tracked using the GPS module. **Energy Consumption Rate** - The user would be able to see the peak electricity hours and costs as well as the demand and supply data. **Battery Analytics** – The user would benefit from this feature and keep track of their battery health, range, and state. **Updated Sticker –** The sticker will be updated and displayed on the screen.
Functionality	This level 1 function decomposition reveals all the parts that support the features.

3.3.1 Level 1 Functional Decomposition Module Descriptions

Table 3.2: Module Description for Raspberry Pi Controller

Module	**Controller (Raspberry Pi)**
Inputs	Power, BMS, RFID Reader, GPS Module
Outputs	Display, Power to GPS Module, Power to RFID Reader
Functionality	The Raspberry Pi will be powered by a rechargeable power bank which would be connected to the Battery Management System and RFID Reader to provide battery information and security. It will also have a GPS module attached to provide location services.

Table 3.3: Module Description for Rechargeable Power Bank

Module	**Rechargeable Power Bank**
Inputs	Power
Outputs	Power to Controller, Power to Display
Functionality	The rechargeable power bank will be connected to a 12V outlet. This will allow the power bank to recharge when the vehicle is in motion. Furthermore, utilizing this method will allow for an efficient recharge all while efficiently providing power to the controller and display screen.

Table 3.4: Module Description for Display Screen

Module	**Display Screen**
Inputs	Video, Power
Outputs	Licence Plate Display
Functionality	The display screen will be powered directly from the power bank and receive a video signal from the controller (Raspberry Pi). The RFID tag will be mounted on the display screen to security measures.

Table 3.5: Module Description for RFID Reader

Module	**RFID Reader**
Inputs	Unique Digital ID (Wireless Radio Frequency)
Outputs	Pass Signal to Controller (Raspberry Pi)
Functionality	The RFID reader would communicate with the controller via a USB A cable to notify the user of the status of the licence plate for anti-theft detection purposes.

Table 3.6: Module Description for BMS

Module	**BMS**
Inputs	EV Battery System
Outputs	Power Consumption and Battery State
Functionality	The BMS system would connect to the controller (Raspberry Pi) and retrieve all necessary data to display battery analytics.

Table 3.7: Module Description for RFID Tag

Module	**RFID Tag**
Inputs	None
Outputs	Unique Digital ID (Wireless Radio Frequency)
Functionality	If the licence plate is stolen, the RFID tag will send a radio frequency signal to the RFID reader which would then notify the user of a stolen licence plate.

Table 3.8: Module Description for GT-U7 GPS Module

Module	**GPS Module**
Inputs	Satellite Location
Outputs	Precision Location
Functionality	The GPS module will obtain precise geographical co-ordinates via satellite. The co-ordinates will then be transferred to the data base (cloud storage) via the controller, allowing the user to view the exact location when requested.

3.4 Casing Design

The licence plate will have a casing to enclose all parts for a clean and complete look. The case will eventually be designed using SolidWorks and then printed using a 3D printer. Currently, the design for the case cannot proceed as parts of the plate are not completely assembled. Once all parts are received and assembled, we will take measurements and design a backplate that will fit all our smart licence plates elements in a single casing. All components including the Raspberry Pi, power bank, and other main parts should be condensed and have a spot to be securely mounted in our backplate. The goal is to have the most thin and sleek backplate possible for the plate (display screen) to be mounted onto. The **Figure 17** below shows a rough idea of the look of our backplate.

A full 3D model and breakdown of the casing measurements will be included in a future report.

Figure 17: Licence Plate Back Plate Concept [2]

[the remainder of this page has been intentionally left blank]

4 Integration Tests

4.1 List of Integration Tests

Below, **Table 4.0** lists the integration test cases that will be described in the next section.

Table 4.0: List of Integration Tests

Integration Test Case Name	Test ID	Description
IT #1	Plate-IT-01	Test the interface link between the login and the portal module
IT #2	Plate-IT-02	Test the interaction between the RFID tag and Raspberry Pi 4
IT #3	Plate-IT-03	Test interaction between LCD display and Raspberry Pi 4
IT #4	Plate-IT-04	Test the interaction between the LCD display and renewal module.
IT #5	Plate-IT-05	Test the interaction between Raspberry PI and power bank.
IT #6	Plate-IT-06	Test the interaction between energy consumed and payment module.

[the remainder of this page has been intentionally left blank]

4.2 Definition of Integration Tests

Table 4.1: Integration Test Case #1

Test Writer(s):	Abdul Bhutta, Emran Soltani, Kumail Syed, Walid Ayub, Yussef Elzein		
Test Case Name:	IT #1	**Test ID:**	Plate-IT-01
Description:	Test the interface link between the login and the portal module	**Type:**	Black Box: ✓ White Box: ☐
Tester Information			
Tester Name(s):	Abdul Bhutta, Walid Ayub	**Date:**	-
Hardware Version:	V1.0	**Time:**	-
Setup:	The user accessing the login page must be within the database.		

Step	Action	Expected Results	Pass	Fail	N/A	Comments
1	Enter Login Information	No error messages should be displayed				
2	Click on login button	Redirected to the portal page				
3						
4						
Test Result:						

Table 4.2: Integration Test Case #2

Test Writer(s):	Abdul Bhutta, Emran Soltani, Kumail Syed, Walid Ayub, Yussef Elzein		
Test Case Name:	IT #2	**Test ID:**	Plate-IT-02
Description:	Test the interaction between the RFID tag and Raspberry Pi 4	**Type:**	Black Box: ✓ White Box: ☐
Tester Information			
Tester Name(s):	Abdul Bhutta, Walid Ayub	**Date:**	-
Hardware Version:	V1.0	**Time:**	-
Setup:	The Raspberry Pi 4 must have the RFID unique ID authorized within the microcontroller. The RFID reader must be installed and running on the Raspberry Pi.		

Step	**Action**	**Expected Results**	**Pass**	**Fail**	**N/A**	**Comments**
1	Connect the LCD onto the case	The RFID reader should validate the RFID tag.				
2	Remove the LCD from the case	The RFID reader should disable the microcontroller and will enter sleep mode				
3						
4						
Test Result:						

Table 4.3: Integration Test Case #3

Test Writer(s):	Abdul Bhutta, Emran Soltani, Kumail Syed, Walid Ayub, Yussef Elzein		
Test Case Name:	IT #3	**Test ID:**	Plate-IT-03
Description:	Test interaction between LCD display and Raspberry Pi 4	**Type:**	Black Box: ✓ White Box: ☐
Tester Information			
Tester Name(s):	Abdul Bhutta, Walid Ayub	**Date:**	-
Hardware Version:	V1.0	**Time:**	-
Setup:	The Raspberry Pi 4 must have the RFID unique ID authorized within the microcontroller. The RFID reader must be installed and running on the Raspberry Pi.		

Step	**Action**	**Expected Results**	**Pass**	**Fail**	**N/A**	**Comments**
1	Remove LCD from the case	Raspberry Pi should enter sleep mode				
2	Connect LCD on the case	Raspberry Pi should turn on and validate LCD display				
3	Verify output on the LCD	The LCD will display the linked plate number				
4						
Test Result:						

Table 4.4: Integration Test Case #4

Test Writer(s):	Abdul Bhutta, Emran Soltani, Kumail Syed, Walid Ayub, Yussef Elzein		
Test Case Name:	IT #4	**Test ID:**	Plate-IT-04
Description:	Test the interaction between the LCD display and renewal module.	**Type:**	Black Box: ✓ White Box: ☐
Tester Information			
Tester Name(s):	Abdul Bhutta, Walid Ayub	**Date:**	-
Hardware Version:	V1.0	**Time:**	-
Setup:	The Raspberry Pi must be running the application and the RFID unique ID should be authorized to access the microcontroller. The Raspberry Pi must be connected to a reliable Wi-Fi network.		

Step	**Action**	**Expected Results**	**Pass**	**Fail**	**N/A**	**Comments**
1	Login as “user”	The webpage will display the personal portal				
2	Access renewal plate	The webpage will be updated to the renewal page while allowing the user to pay the fee				
3	Pay the amount	A confirmation update will appear				
4	Verify updated sticker	The expiry date on the sticker will be updated				
Test Result:						

Table 4.5: Integration Test Case #5

Test Writer(s):	Abdul Bhutta, Emran Soltani, Kumail Syed, Walid Ayub, Yussef Elzein		
Test Case Name:	IT #5	**Test ID:**	Plate-IT-05
Description:	Test the interaction between Raspberry Pi and power bank.	**Type:**	Black Box: ✓ White Box: ☐
Tester Information			
Tester Name(s):	Abdul Bhutta, Walid Ayub	**Date:**	-
Hardware Version:	V1.0	**Time:**	-
Setup:			

Step	**Action**	**Expected Results**	**Pass**	**Fail**	**N/A**	**Comments**
1	Connect the Raspberry PI to the power bank	The Raspberry Pi should be powered on.				
2	Remove source power	No change on the Raspberry Pi and power bank.				
3	Verify battery usage	The Raspberry Pi should stay powered on for 72-96 hours.				
4						
Test Result:						

Table 4.6: Integration Test Case #6

Test Writer(s):	Abdul Bhutta, Emran Soltani, Kumail Syed, Walid Ayub, Yussef Elzein		
Test Case Name:	IT #6	**Test ID:**	Plate-IT-06
Description:	Test the interaction between energy consumed and payment module.	**Type:**	Black Box: ✓ White Box: ☐
Tester Information			
Tester Name(s):	Abdul Bhutta, Walid Ayub	**Date:**	-
Hardware Version:	V1.0	**Time:**	-
Setup:	The user must exist within the database and have an outstanding balance.		

Step	**Action**	**Expected Results**	**Pass**	**Fail**	**N/A**	**Comments**
1	Login as “User”	The webpage will display the personal portal.				
2	Access the Energy Consumption page	The webpage will display the outstanding payment.				
3	Click on payment	The webpage will be redirected to the payment page.				
4	Confirm payment	A confirmation message will appear, and the outstanding balancing will be updated.				
Test Result:						

5 Estimated Project Cost

5.1 Project Part Cost Breakdown

Below is a table breaking down each the parts to be used for our protype and their cost.

Table 5.0: Purchased Part Cost Breakdown

Part	Part Cost	Total Running Cost	Purchase Date
13.3" Display	$159.73	$159.73	09/29/2022
13.3" Display Import Fee	$32.07	$191.80	09/30/2022
Raspberry Pi w/ SD Card	$192.09	$383.89	10/21/2022
Rechargeable Power Bank	$44.06	$427.95	11/06/2022
Right Angle USB-A to USB-C Charging Cables (3-Pack)	$11.29	$439.24	11/06/2022
RFID Tag & Reader	$15.68	$454.92	11/07/2022
Mini Breadboards	$12.42	$467.34	11/07/2022
Jumper Wires	$16.94	$484.28	11/07/2022
GT-U7 GPS Module	$29.32	$513.60	11/07/2022
HDMI Cable	$11.29	$524.89	11/07/2022
3D Printed Case	$0 (Estimated)	$524.89	Not Yet Purchased
	Total:	**$524.89**	
	Total Budget Remaining:	**$475.11**	

[the remainder of this page has been intentionally left blank]

6 Project Plan

6.1 Fall Semester Deliverable Breakdown

Table 6.0 below shows a breakdown of the remaining Fall semester deliverables from Report #2 onwards.

Table 6.0: Remaining Fall Semester Deliverable Breakdown

Deliverable	Report Section Name	Section Deliverables	Assigned Team Member(s)	Duration (Days)
Report #2	**Report Introduction**	Abstract, Dedication, Acknowledgements, Report Introduction	All Members	2
Report #2	**Concept Generation/Analysis**	Concept Generation Table Creation	All Members	5
Report #2	**Conceptual System Design**	Software System Designs Electrical System Design Overall System Design Design Review	All Members	10
Report #2	**Definition of Integration Tests**	Creation of Integration Tests Review of Tests	Abdul Kumail Walid	4
Report #2	**Estimated Project Cost**	Cost Estimation Cost Analysis Cost Tracking	Emran Yussef Walid	2
Report #2	**Project Plan**	Updated Task Breakdown Update Gantt Chart	Abdul Yussef	2
Report #2	**Contribution Matrix**	Matrix Creation and Completion	Yussef	1
Report #2	**Report Corrections**	Proofreading Consistency Check General Flow Check	Emran Kumail	1
Report #2	**Report Formatting**	Format Report Naming/Organizing Tables & Figures Table of Contents	Yussef	1
Report #2	**Report Submission**	Submission to Capstone Advisor	Yussef	>1
Team Presentation & Demo	**Presentation Assembly**	Construction of PowerPoint Presentation	All Members	5
Team Presentation & Demo	**Presentation Proofreading and Formatting**	Proofreading Consistency Check General Flow Check	Emran Kumail Walid	1

Team Presentation & Demo	**Prototype Assembly**	Assembly of Prototype	Abdul Yussef	5
Team Presentation & Demo	**Presentation Rehearsals**	Assign Sections for Presentation Practice Presenting	All Members	3
Team Presentation & Demo	**Final Presentation**	Present to Capstone Advisor/Coordinator	All Members	1
Team Retrospective Report	**Report Preparation**	Write Team Report	All Members	10
Team Retrospective Report	**Report Corrections**	Proofreading Consistency Check General Flow Check	Emran Kumail	2
Team Retrospective Report	**Report Formatting**	Format Report Naming/Organizing Tables & Figures Table of Contents	Yussef	1
Team Retrospective Report	**Report Submission**	Submission to Capstone Coordinator	Yussef	>1
END OF FALL SEMESTER				

6.2 Winter Semester Deliverable Breakdown

Table 6.1: Winter Semester Deliverable Breakdown

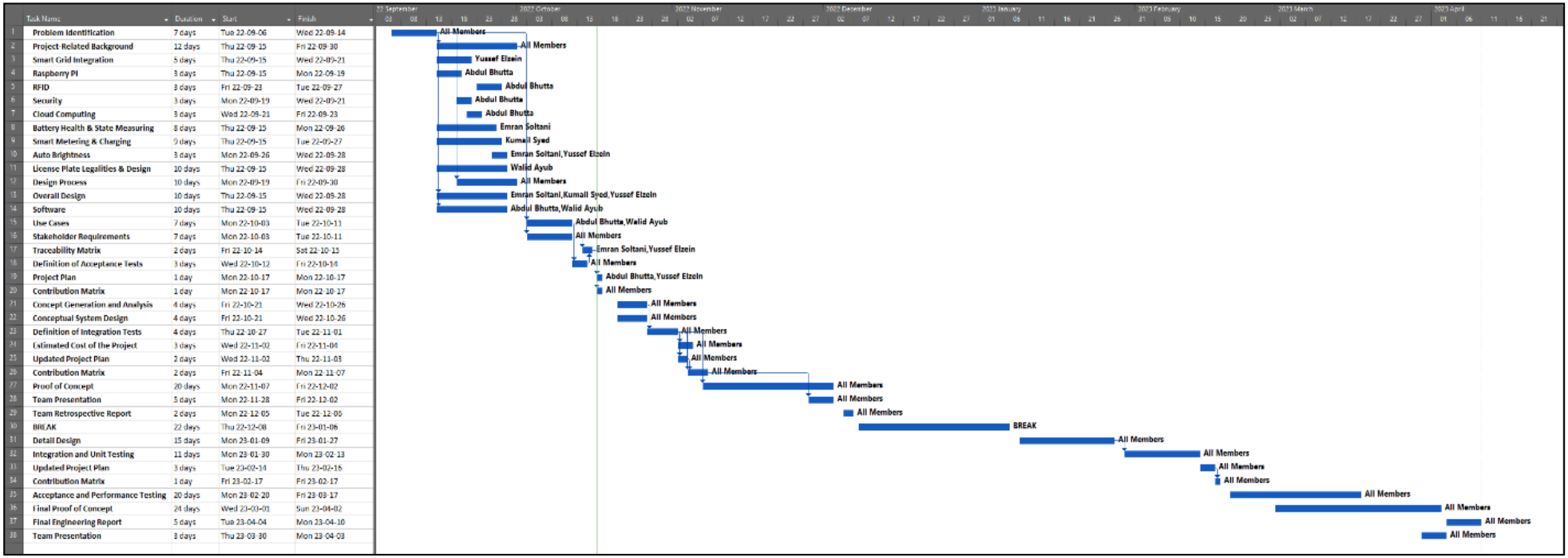
Deliverable	Report Section Name	Section Deliverables	Assigned Team Member(s)	Duration (Days)
Detail Design & Integration Testing Report	**Report Introduction**	Abstract, Dedication, Acknowledgements, Report Introduction	All Members	2
Detail Design & Integration Testing Report	**Detail Design**	Diagram Creation Design Analysis Detailed Schematics	All Members	7
Detail Design & Integration Testing Report	**Integration Testing / Unit Testing**	Refine Integration Tests Complete Integration Tests	All Members	5
Detail Design & Integration Testing Report	**Project Plan**	Updated Task Breakdown Update Gantt Chart	Abdul Yussef	2
Detail Design & Integration Testing Report	**Contribution Matrix**	Matrix Creation and Completion	Yussef	1
Detail Design & Integration Testing Report	**Report Corrections**	Proofreading Consistency Check General Flow Check	Emran Kumail	2
Detail Design & Integration Testing Report	**Report Formatting**	Format Report Organizing Tables & Figures Table of Contents	Yussef	1
Detail Design & Integration Testing Report	**Report Submission**	Submission to Capstone Advisor	Yussef	>1
Acceptance Test Demonstration Report	**Acceptance Testing**	Complete Acceptance /Performance Testing Refine Acceptance Tests	All Members	3
Acceptance Test Demonstration Report	**Demonstration Rehearsals**	Assign Sections for Presentation Practice Presenting	All Members	2
Acceptance Test Demonstration Report	**Acceptance Test Demonstration**	Present to Capstone Advisor	All Members	>1
Acceptance Test Demonstration Report	**Report Introduction**	Abstract, Dedication, Acknowledgements, Report Introduction	All Members	2

Acceptance Test Demonstration Report	**Report Corrections**	Proofreading Consistency Check General Flow Check	Emran Kumail	2
Acceptance Test Demonstration Report	**Report Formatting**	Format Report Organizing Tables & Figures Table of Contents	Yussef	1
Acceptance Test Demonstration Report	**Report Submission**	Submission to Capstone Advisor	Yussef	>1
Final Engineering Report	**Report Introduction**	Title Page, Abstract, Dedication, Acknowledgements, Report Introduction Executive Summary	All Members	3
Final Engineering Report	**Addition of Previous Reports**	Add Report #1 Add Report #2	Yussef	1
Final Engineering Report	**Revised Design Report**	Revise Designs	All Members	4
Final Engineering Report	**Ethical Considerations**	Comments of Ethical Considerations of Project	All Members	3
Final Engineering Report	**Safety Considerations**	Comments of Safety Considerations of Project	All Members	3
Final Engineering Report	**Report Conclusion**	Write Project's Closing Remarks	All Members	1
Final Engineering Report	**Report Corrections**	Proofreading Consistency Check General Flow Check	Emran Kumail	2
Final Engineering Report	**Report Formatting**	Format Report Organizing Tables & Figures Table of Contents	Yussef	1
Final Engineering Report	**Report Submission**	Submission to Capstone Advisor	Yussef	>1
Team Presentation & Video Clip	**Presentation Assembly**	Construction of Presentation	All Members	5
Team Presentation & Video Clip	**Presentation Rehearsals**	Assign Sections for Presentation Practice Presenting	All Members	2

Team Presentation & Video Clip	**In-Class Final Presentation**	Present to Class / Faculty Advisors	All Members	>1
Team Presentation & Video Clip	**Video Clip Planning**	Writing of Script Review of Script Overall Plan of Video	All Members	4
Team Presentation & Video Clip	**Video Clip Filming**	Filming of Prototype Clips	Yussef	2
Team Presentation & Video Clip	**Video Clip Editing**	Assemble Clips Overall Video Editing	Yussef	4
Team Presentation & Video Clip	**Video Compilation & Review**	Finalize Video Review Final Video	Yussef	2
Capstone Design Annual Exhibition	**Presentation Assembly**	Construction of Presentation	All Members	5
Capstone Design Annual Exhibition	**Presentation Rehearsals**	Assign Sections for Presentation Practice Presenting	All Members	3
Capstone Design Annual Exhibition	**Poster Creation**	Design of Poster Assembly of Poster	All Members	5
Capstone Design Annual Exhibition	**Preparation of Final Prototype**	Test Final Prototype Ensure All Parts Assembled	Yussef	2
Team Retrospective Report	**Report Preparation**	Write Team Report	All Members	10
Team Retrospective Report	**Report Corrections**	Proofreading Consistency Check General Flow Check	Emran Kumail	2
Team Retrospective Report	**Report Formatting**	Format Report Naming/Organizing Tables & Figures Table of Contents	Yussef	1
Team Retrospective Report	**Report Submission**	Submission to Capstone Coordinator	Yussef	>1
END OF WINTER SEMESTER				

6.3 Project-Long Gantt Chart

Figure 18 below shows a Gantt chart demonstrating the project plan deliverables throughout to the end of the project and a timeframe for their completion.



	Task Name	Duration	Start	Finish
1	Problem Identification	7 days	Tue 22-09-06	Wed 22-09-14
2	Project-Related Background	12 days	Thu 22-09-15	Fri 22-09-30
3	Smart Grid Integration	5 days	Thu 22-09-15	Wed 22-09-21
4	Raspberry PI	3 days	Thu 22-09-15	Mon 22-09-19
5	RFID	3 days	Fri 22-09-23	Tue 22-09-27
6	Security	3 days	Mon 22-09-19	Wed 22-09-21
7	Cloud Computing	3 days	Wed 22-09-21	Fri 22-09-23
8	Battery Health & State Measuring	8 days	Thu 22-09-15	Mon 22-09-26
9	Smart Metering & Charging	9 days	Thu 22-09-15	Tue 22-09-27
10	Auto Brightness	3 days	Mon 22-09-26	Wed 22-09-28
11	License Plate Legalities & Design	10 days	Thu 22-09-15	Wed 22-09-28
12	Design Process	10 days	Mon 22-09-19	Fri 22-09-30
13	Overall Design	10 days	Thu 22-09-15	Wed 22-09-28
14	Software	10 days	Thu 22-09-15	Wed 22-09-28
15	Use Cases	7 days	Mon 22-10-03	Tue 22-10-11
16	Stakeholder Requirements	7 days	Mon 22-10-03	Tue 22-10-11
17	Traceability Matrix	2 days	Fri 22-10-14	Sat 22-10-15
18	Definition of Acceptance Tests	3 days	Wed 22-10-12	Fri 22-10-14
19	Project Plan	1 day	Mon 22-10-17	Mon 22-10-17
20	Contribution Matrix	1 day	Mon 22-10-17	Mon 22-10-17
21	Concept Generation and Analysis	4 days	Fri 22-10-21	Wed 22-10-26
22	Conceptual System Design	4 days	Fri 22-10-21	Wed 22-10-26
23	Definition of Integration Tests	4 days	Thu 22-10-27	Tue 22-11-01
24	Estimated Cost of the Project	3 days	Wed 22-11-02	Fri 22-11-04
25	Updated Project Plan	2 days	Wed 22-11-02	Thu 22-11-03
26	Contribution Matrix	2 days	Fri 22-11-04	Mon 22-11-07
27	Proof of Concept	20 days	Mon 22-11-07	Fri 22-12-02
28	Team Presentation	5 days	Mon 22-11-28	Fri 22-12-02
29	Team Retrospective Report	2 days	Mon 22-12-05	Tue 22-12-06
30	BREAK	22 days	Thu 22-12-08	Fri 23-01-06
31	Detail Design	15 days	Mon 23-01-09	Fri 23-01-27
32	Integration and Unit Testing	11 days	Mon 23-01-30	Mon 23-02-13
33	Updated Project Plan	3 days	Tue 23-02-14	Thu 23-02-16
34	Contribution Matrix	1 day	Fri 23-02-17	Fri 23-02-17
35	Acceptance and Performance Testing	20 days	Mon 23-02-20	Fri 23-03-17
36	Final Proof of Concept	24 days	Wed 23-03-01	Sun 23-04-02
37	Final Engineering Report	5 days	Tue 23-04-04	Mon 23-04-10
38	Team Presentation	3 days	Thu 23-03-30	Mon 23-04-03

Figure 18: Smart Grid Integrated Digital Licence Plate Project Gantt Chart

7 Contribution Matrix

The contribution matrix in the table below displays how the work for report #2 was divided.

Table 7.0: Report #2 Contribution Matrix

Report #2 Sections	Group Members				
	Abdul Bhutta	**Yussef Elzein**	**Emran Soltani**	**Kumail Syed**	**Walid Ayub**
Section 1: Introduction					
			✓	✓	✓
Section 2: Concept Generation & Analysis					
Initial Concept Generation	✓	✓	✓	✓	
Model Creation	✓	✓			
Model Analysis		✓			
Model Ranking		✓			
Section 3: Conceptual System Design					
Software Design	✓				✓
Electrical Design		✓	✓	✓	
Functional Decompositions	✓	✓	✓	✓	
Casing Design			✓	✓	
Section 4: Integration Tests					
List of Integration Tests		✓			
Definition of Integration Test Cases	✓				✓
Section 5: Estimated Project Cost					
Project Cost Breakdown	✓	✓	✓	✓	✓
Section 6: Project Plan					
Updated Fall Task Breakdown		✓			
Winter Task Breakdown		✓			
Gantt Chart	✓				
Section 7: Contribution Matrix					
Contribution Matrix		✓			
Other:					
Report Formatting		✓			
Report Corrections			✓	✓	

References

1. J. Wood, “Despite Ford promises, failed Ontario licence plates increased costs by 26 per cent,” Newsroom, 16-Jun-2021. [Online]. Available: https://www.taxpayer.com/newsroom/despite-ford-promises,-failed-ontario-licence-plates-increased-costs-by-26-per-ent#:~:text=Throughout%20the%20entirety%20of%20the,have%20added%20up%20to%20%24913%2C867. [Accessed: 10-Oct-2022].

2. “Cruiser vault licence plate frame, black/smoke | Canadian tire,” *Cruiser - Vault Licence Plate Frame*. [Online]. Available: https://www.canadiantire.ca/en/pdp/cruiser-vault-licence-plate-frame-black-smoke-0379870p.html. [Accessed: 06-Nov-2022].

Smart Grid Integrated Digital Licence Plate

Detail Design and Integration Testing Report

Team Members:

Abdul Bhutta - 100785884

Yussef Elzein - 100641407

Emran Soltani - 100618333

Kumail Syed - 100661596

Walid Ayub - 100695612

This report is submitted in partial fulfillment for the final year Capstone Project in the Faculty of Engineering and Applied Science.

Project Advisor: Dr. Tarlochan Sidhu, P.Eng.

Capstone Coordinator: Dr. Vijay K. Sood, P.Eng., ECSE

Submitted to Ontario Tech University

February 18th, 2023

Abstract

In recent years, it has become evident that traditional licence plates have many flaws such as security, durability, and functionality. Current licence plates have proven time and time again that it is time for an update. The world is quickly going digital as technological advancements are being made every day. Licence plates have not yet caught up to the times. A smart digital licence plate would be a tremendous upgrade moving into this electric and digital world. Current technologies such as displays, communications, and electric vehicles have created a possibility for revolutionary smart digital licence plates with features such as theft detection, renewal updates, smart grid integration, and web information access. The following capstone project report is a follow-up of report 1. It includes all the design aspects of the smart grid-integrated digital licence plate. It contains all the test cases that will be conducted to ensure the proper function and safety of the product. Furthermore, during the concept generation, we found it feasible to program the digital licence plate on a Raspberry Pi. It was also found logical to power the system using a rechargeable power bank. The system will also utilize a GPS module alongside a RFID tag and reader to support anti-theft measures. Moreover, the assembly of the product will be enclosed in a 3D-printed case designed using SolidWorks. Finally, the integration of a website will be included to manage all the features. According to the Gantt chart, the product is currently on track to be fully established by April 2023.

Dedication

We would like to dedicate this report to each of our group members' families who have continuously supported us throughout the university in both moral and material needs. Moreover, we would like to dedicate this report to all our professors, peers, and friends for their consistent encouragement and motivation.

Acknowledgments

We would like to express our gratitude to our supervisor Dr. Tarlochan Sidhu who made this project possible. With his guidance, we were able to get a thorough understanding of the project and how to execute our ideas. His continuous support fed our ambition to take this project above and beyond.

We would also like to acknowledge our capstone coordinator Dr. Vijay Sood. He was able to give us a strong detailed understanding of producing reports and how to have a complete presentation on our project.

Our sincere appreciation to Dr. Sheldon Williamson for offering his knowledge and guidance with this project. In our first meeting, he provided us with many ideas on smart grid technology and possible recommendations on how to implement them.

Lastly, we would like to thank our friends and family for their continued support and encouragement throughout our final year.t

We will be forever grateful for this capstone project as it has not only challenged us but helped us understand the process of designing, testing, building, and implementing a product from start to finish.

Table of Contents

List of Figures

List of Tables

List of Acronyms Used

Acronym	Meaning
12V	12-Volt
3.3V	3.3 Volt
3D	3-Dimensional
BMS	Battery Management System
CICD	Continuous Integration and Continuous Deployment/Delivery
EV	Electric Vehicle
GND	Ground
GPIO	General-Purpose Input/Output
GPS	Global Positioning System
HDMI	High-Definition Multimedia Interface
IT	Integration Test
LCD	Liquid Crystal Display
LTE	Long-Term Evolution
MISO	Master Input Slave Output
MOSI	Master Output Slave Input
RFID	Radio-Frequency Identification
RST	Reset
SCK	Serial Clock
SDA	Serial Data
UML	Unified modelling language
USB-A	Universal Serial Bus Type A
USB-C	Universal Serial Bus Type C

1 Introduction

This report will highlight the final design work for the licence plate. It includes the final software design components along with the UML sequence diagrams. Moreover, it includes the final electrical diagrams and components. The diagrams will clearly illustrate how the electrical connection between each component will be made to the controller (Raspberry Pi). The diagrams also include an “EV connection diagram” where it will display how the connections will be made in the event the ePlate is connected to an EV. Furthermore, section 2.4 includes the 3D renderings of the weather and dust proof casing. The measurements for both the front and back plate are shown in the schematics for a thorough understanding of the size. Lastly, the report will complete all the integration tests to ensure proper functionality of the cloud server, website, and licence plate.

Problem Statement

Many advancements have been made in technology and there is no reason for vehicles today not to be equipped with smart licence plates. The current licence plates endure issues such as peeling, theft, and readability. Moreover, the province of Ontario had recently updated its plates to blue ones with a new slogan. The goal was to refresh the plates and solve the peeling issue but, instead, it made matters worse as law authorities found it difficult to see the plates at night as they were not reflective. These new plates cost the province about 1 million dollars and shortly after were discontinued [1]. Introducing a smart digital licence plate would automatically eliminate all the problems with the current licence plates. Furthermore, designing, integrating, and implementing digital licence plates would not only save the province issues like legibility at night, but also create cost-effective solutions for plate updates in the future.

Overview of the Report

This report's remaining sections are organized as follows: Section 2 will outline the detailed design of the different aspects of our licence plate prototype including the final software, final electrical, and casing design of the prototype which is modeled in SolidWorks. Section 3 covers the completed integration testing demonstrating how our product operates properly and how we expected. Finally, sections 4 and 5 will outline our updated project plan and contribution to this report, respectively. The Gantt Chart and the deliverables have also been updated for this semester accordingly.

2 Detailed Design

2.1 Final Software Design

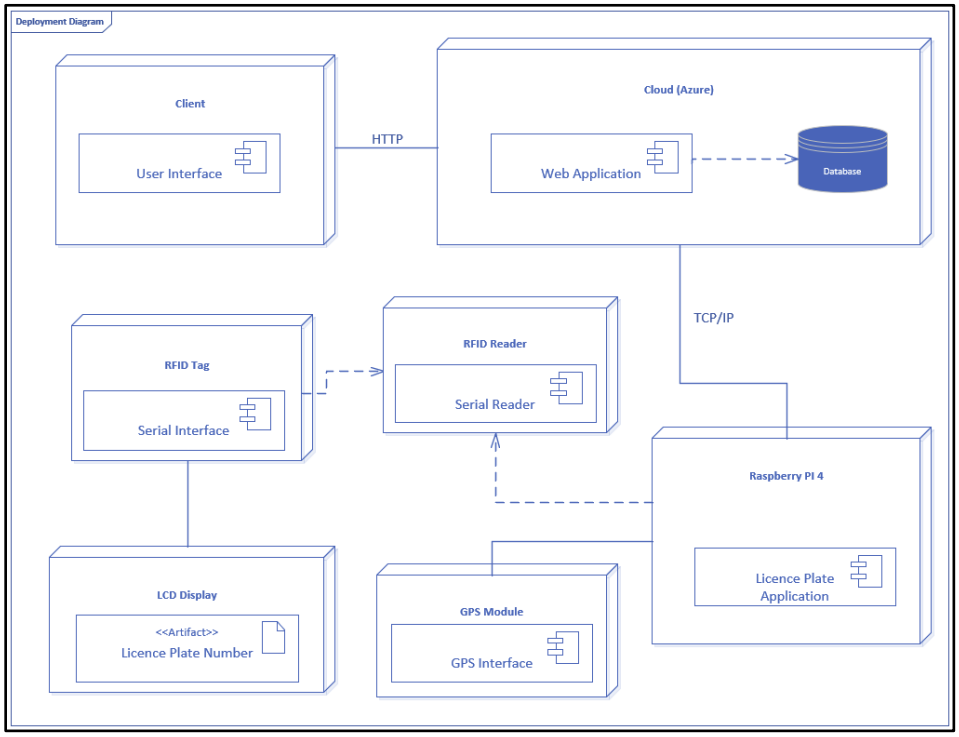


Figure 1: Deployment Diagram

The following is a visual diagram displaying the current process our group has implemented. It follows CICD practice which is deployed using GitHub and Microsoft Azure. The website is live with access to only the homepage. Our group is integrating additional features, which will be deployed once they pass the acceptance tests. These updates will be deployed without any downtime (99.8% Availability).

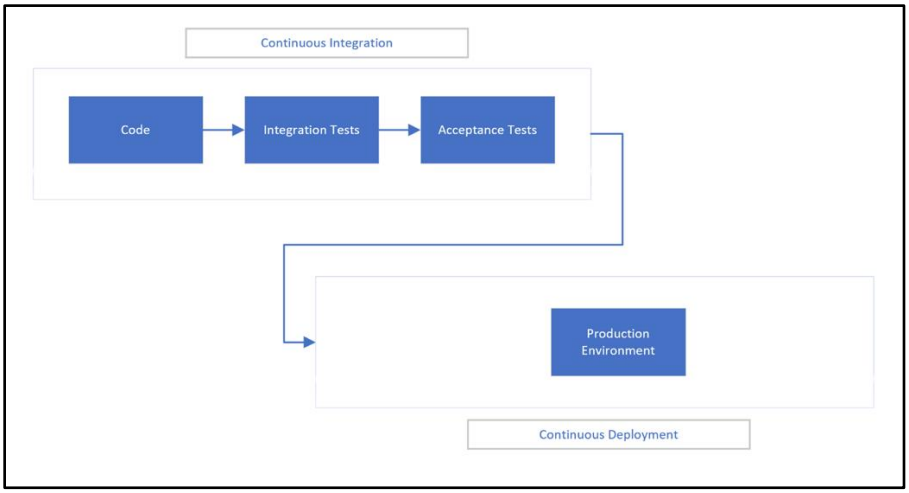


Figure 2: CICD pipeline through GitHub/Azure Diagram

2.1.1 UML Sequence Diagrams

The following is a sequence diagram displaying the various modules communicating with each other to update the outstanding balance for the energy consumed.

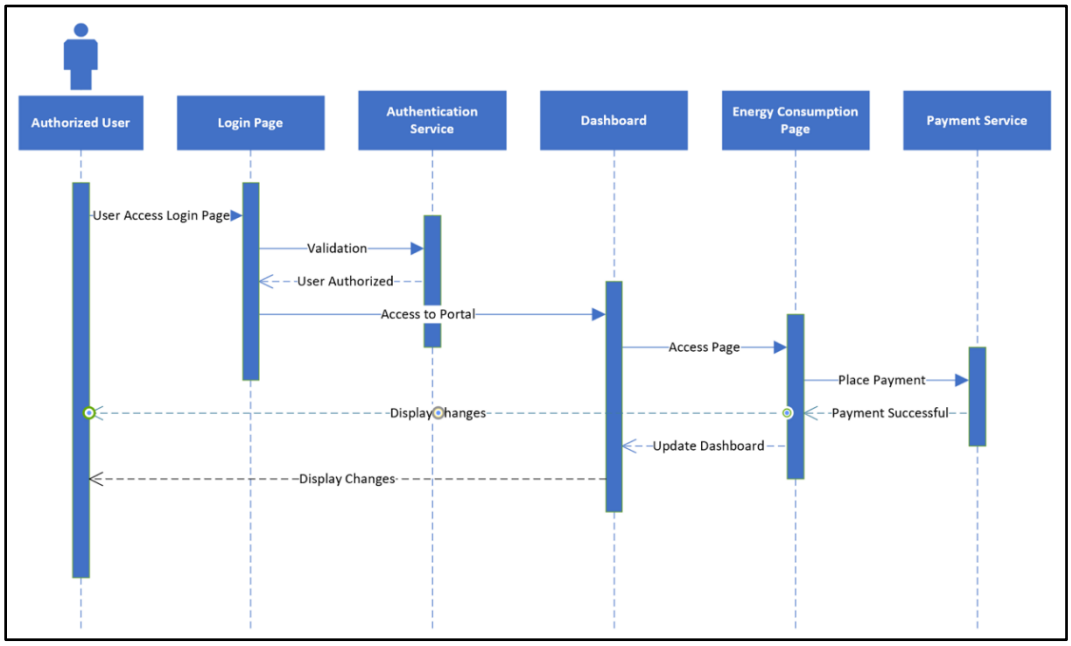


Figure 3: Sequence Diagram for Energy Consumed Payment

The following is a sequence diagram displaying the various modules communicating with each other to renew the licence plate for an authorized user.

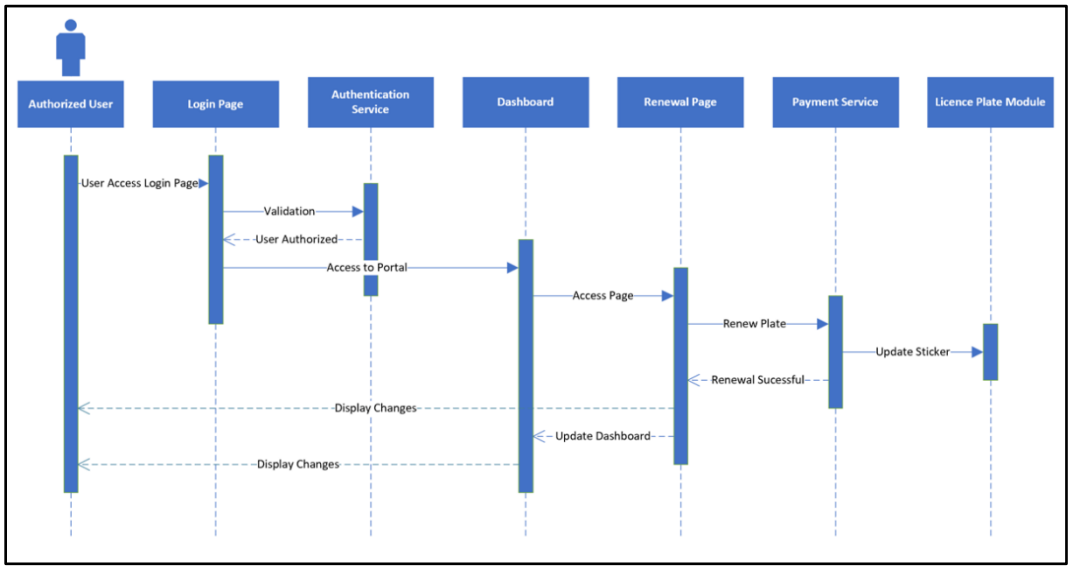


Figure 4: Sequence Diagram for Renewing a Licence Plate

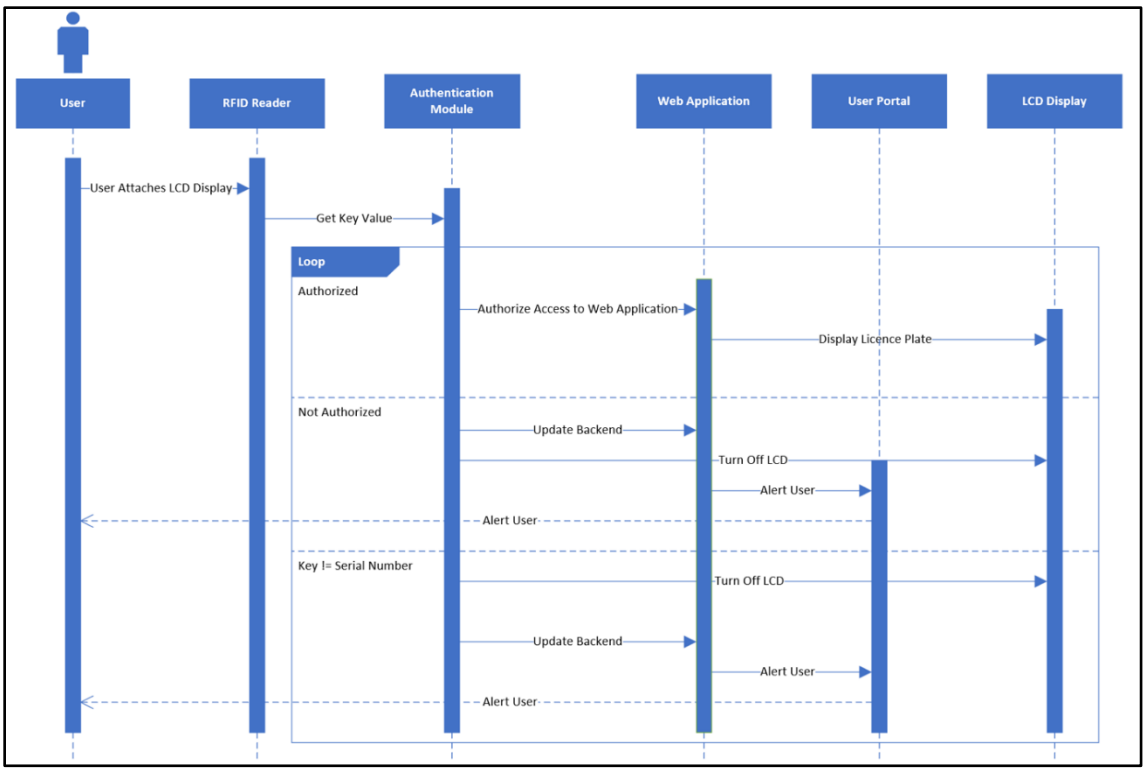


Figure 5: Interaction between RFID Reader and LCD Display

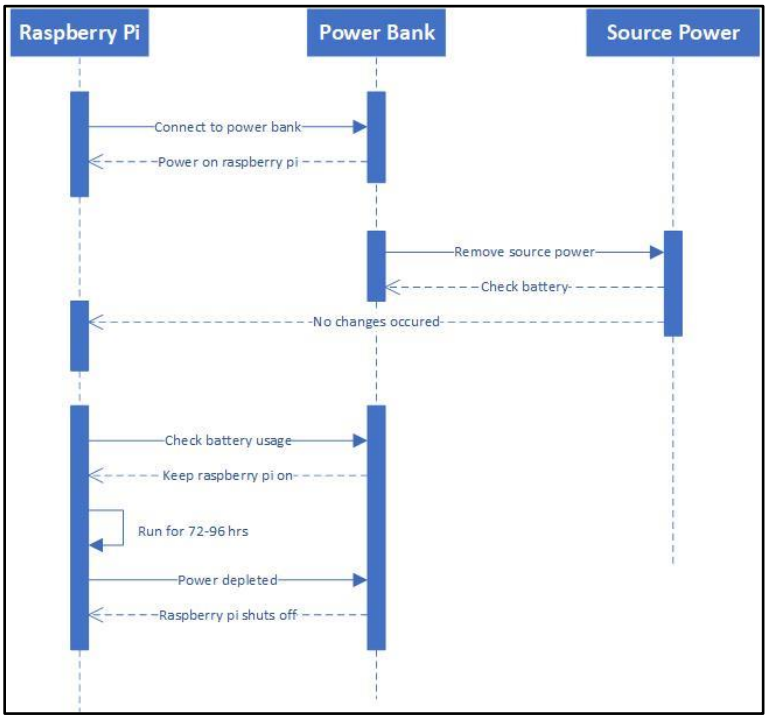


Figure 6: Interaction Between Consumed Energy & Payment Module

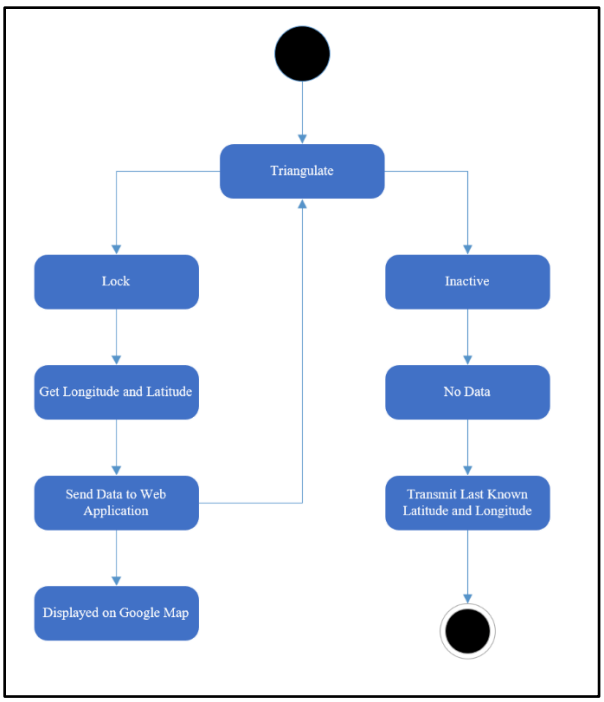


Figure 7: State Diagram for GPS Module

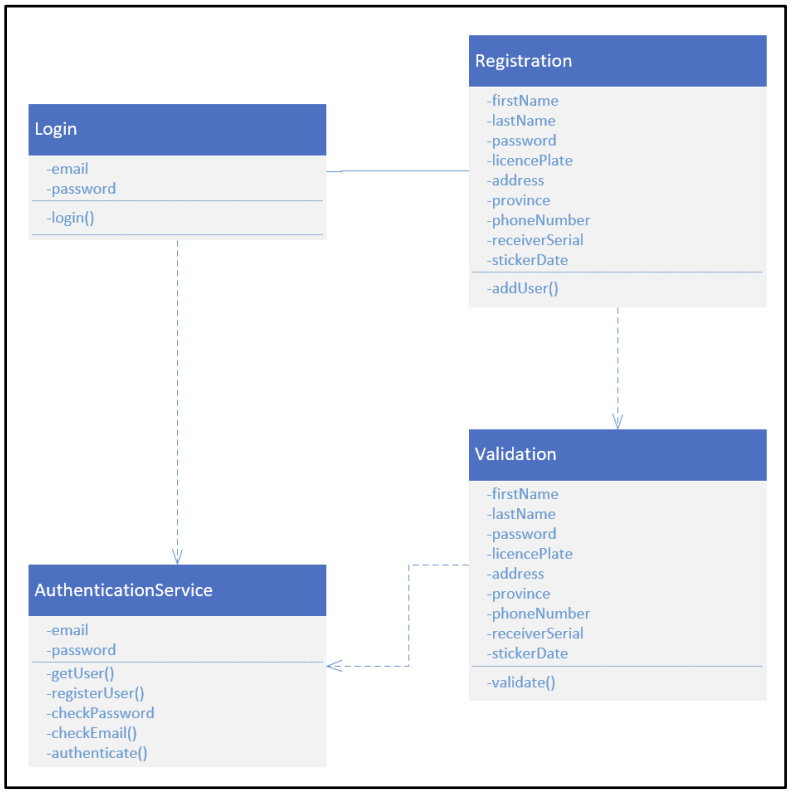


Figure 8: UML Class Diagram for Login Module

2.1.2 Scripts

Table 2.1 below lists the scripts and their descriptions for all programmed scripts currently being used to run our prototype.

Table 2.1: Current Functional Scripts

Scripts	Description
Writer.py	The script is executed to overwrite the current KEY value on the RFID tag.
Authorization.py	The main script allows access to an authorized LCD with an RFID tag while information the authorized user of an illicit user.
Reader.py	The script is executed to test the communication between the RFID reader and tag
GPS.py	The script is executed to get current location for the device using the GPS module

2.2 Final Electrical Design

The following figure is a complete and final diagram of the physical connections used for our smart licence plate. As can be seen from the figure, there are 3 major connection classifications we have defined for the electrical design: Power (blue), Security (green) and EV (red).

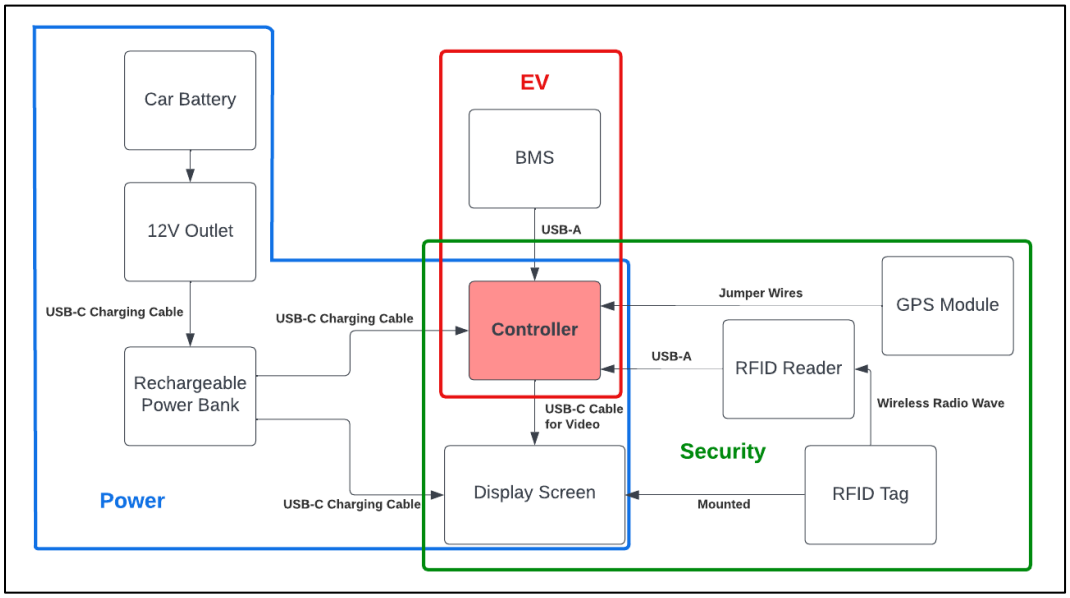


Figure 9: Complete Electrical Connection Diagram

2.3.1 Power & Display Connection Diagram

The figure below shows the detailed outline of the how the plate's display and power are connected to the main controller. The rechargeable power bank will be continuously recharged via a 12V outlet in the vehicle when the vehicle is turned on. The power bank will then power the controller and display screen via USB-C charging cables. Smaller devices like the RFID reader and GPS module will then draw power from the directly from their connections to controller (not shown).

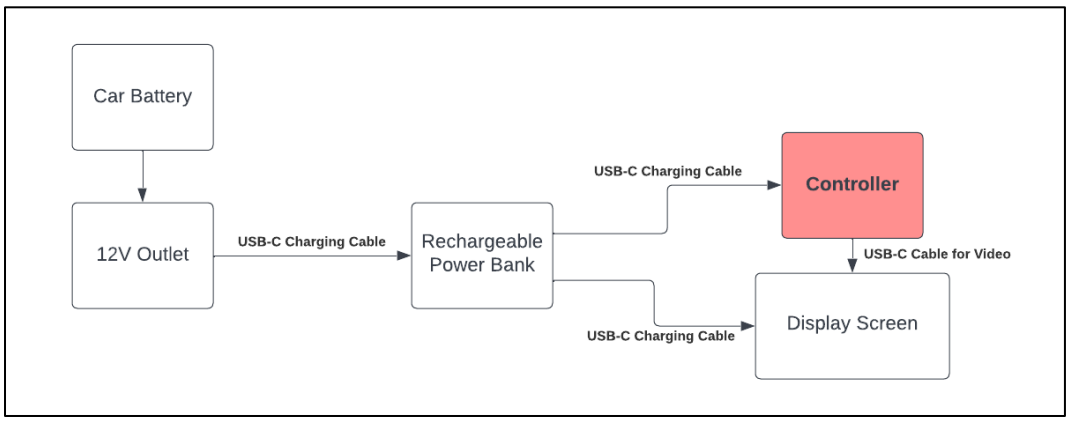


Figure 10: Power & Display Connection Diagram

2.3.2 Security Connection Diagram

The connections for the security devices are shown in **Figure 11** below. Both the GPS module and RFID reader will be connected to the Raspberry Pi controller via jumper wires. The RFID tag, which is attached to the back of the display screen, will wirelessly and continuously send a signal to the RFID reader when it is in close proximity. Once this signal is broken, due to the display being removed, an alarm will be triggered notifying the user of the removal of the plate. If the plate is then reconnected, it will show as "stolen" until the user resets via the website.

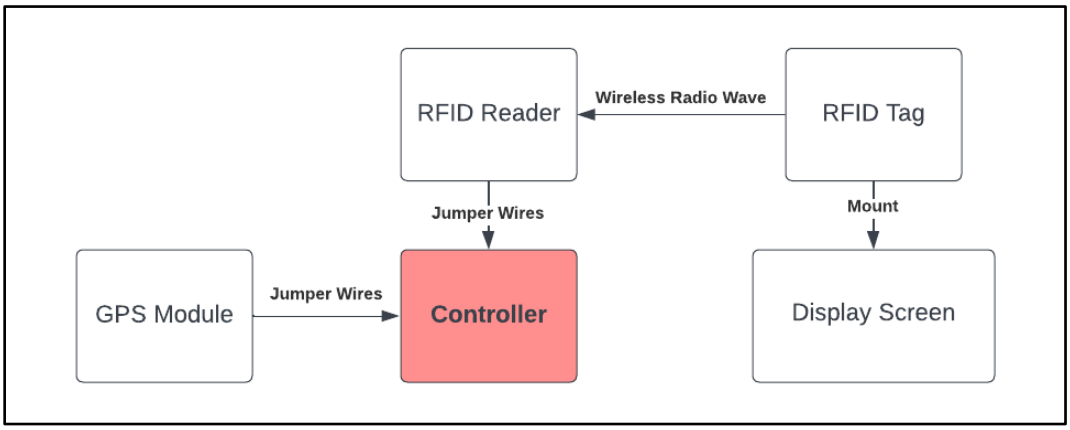


Figure 11: Plate Security Connection Diagram

2.3.2.1 RFID Reader

The RFID reader will have 7 jumped connections to the controller. All connections are outlined in the table below.

Table 2.2: List of RFID Reader to Raspberry Pi Pin Connections [2]

Connection #	RFID Reader Connection	Raspberry Pi Pin #
1	SDA	24
2	SCK	23
3	MOSI	19
4	MISO	21
5	GND	6
6	RST	22
7	3.3v	1

The following figure visually shows how the RIFD reader will connect to the Raspberry Pi through a breadboard.

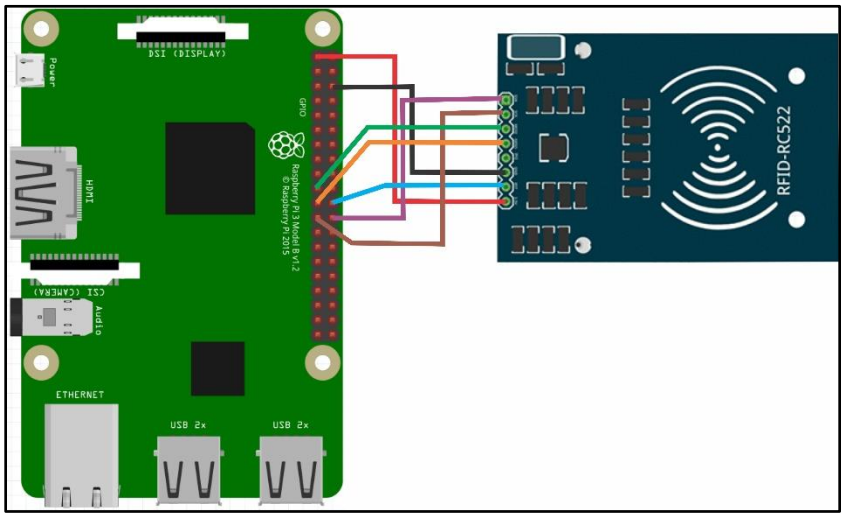


Figure 12: RFID Reader Connections to Raspberry Pi 4 [2]

Figure # outlines the Raspberry Pi's pin numbers as well as their names.

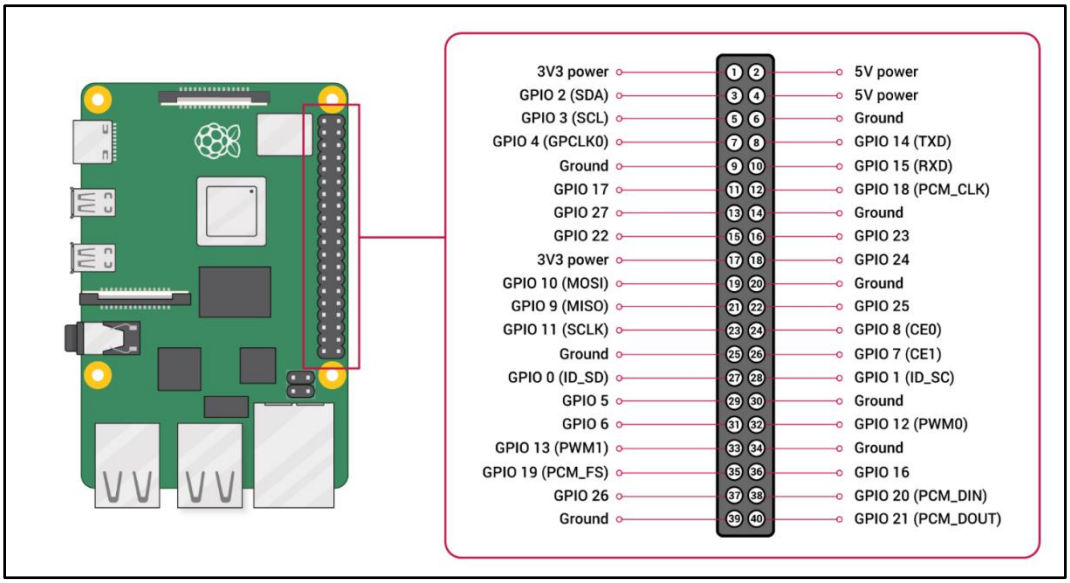


Figure 13: Raspberry Pi Pins [3]

2.3.2.2 GPS Module

The GPS Module will have 3 jumped connections to the controller. The connections are outlined in the table below.

Table 2.3: List of GPS Module to Raspberry Pi Pin Connections [2]

Connection #	GPS Module Connection	Raspberry Pi Pin #
1	GND	6
2	TX	10
3	UCC	2

The following is an image showing how the GPS module connects to the main controller (Raspberry Pi).

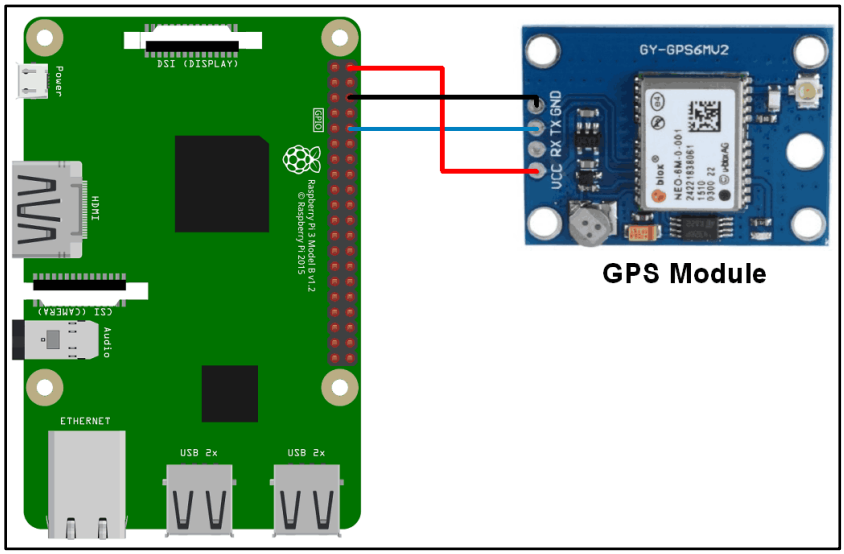


Figure 14: GPS Module Connections to Raspberry Pi 4 [4]

2.3.3 EV Connection Diagram

This diagram depicts the EV connectivity to the controller and cloud storage.

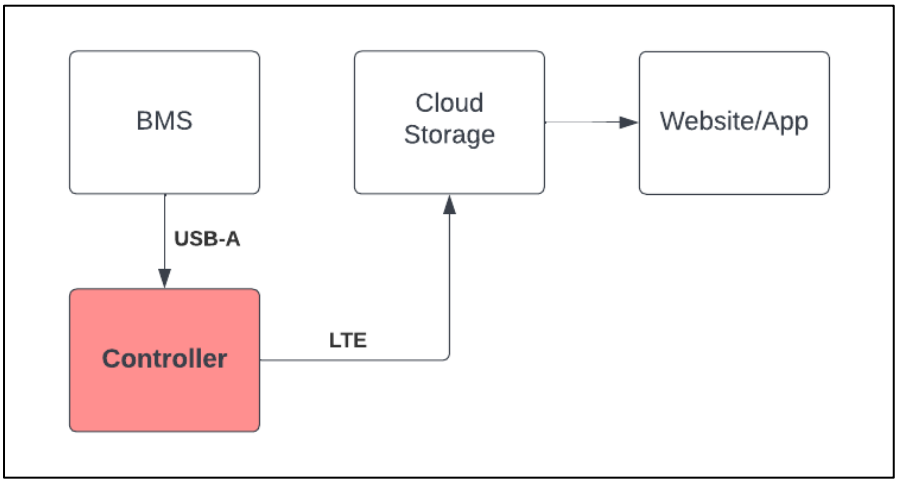


Figure 15: EV Connection Diagram

Figure 15 demonstrates the smart grid electrical setup for electric vehicles. The EV's battery management system, or BMS for short, is connected to the controller through a USB-A input. The BMS will provide real-time battery data and pass it to the controller. The controller will then communicate the data to our cloud storage system using an LTE connection and ergo to our website. The website will be available to users who want to check their vehicle's electrical consumption data along with its battery health and state information. Note that this circuit can only be implemented into EV vehicles.

2.4 Casing Design

This section consists of the casing design, measurements, and 3D modeling. Our prototype's housing will be separated into two separate pieces. The rear housing will be mounted to the vehicle using mounting screws similar to how regular plates are mounted. The front housing will slide over the rear housing securely locking it into place.

2.4.1 Front Housing Drawing

2.4.1.1 Front Housing 3D Renderings

The figures below are various 3D renderings of the front housing that will contain the screen and front protective plexiglass. This housing will tightly slide over the rear housing to secure the LCD display in place.

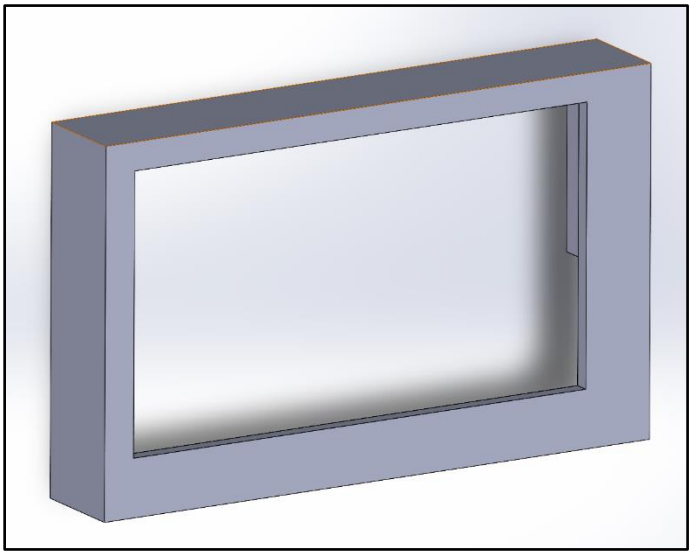


Figure 16: Front Housing 3D Rendering - Front View

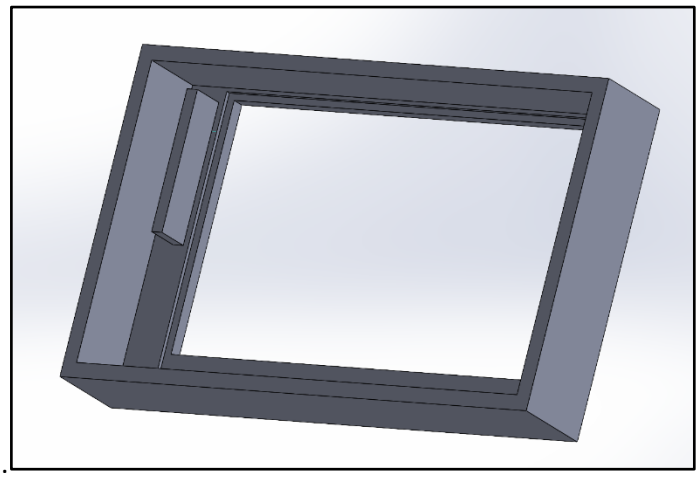


Figure 17: Front Housing 3D Rendering – Rear View

2.4.1.2 Front Housing Front View

The schematic below is the front view of the front housing with all the respective measurements.

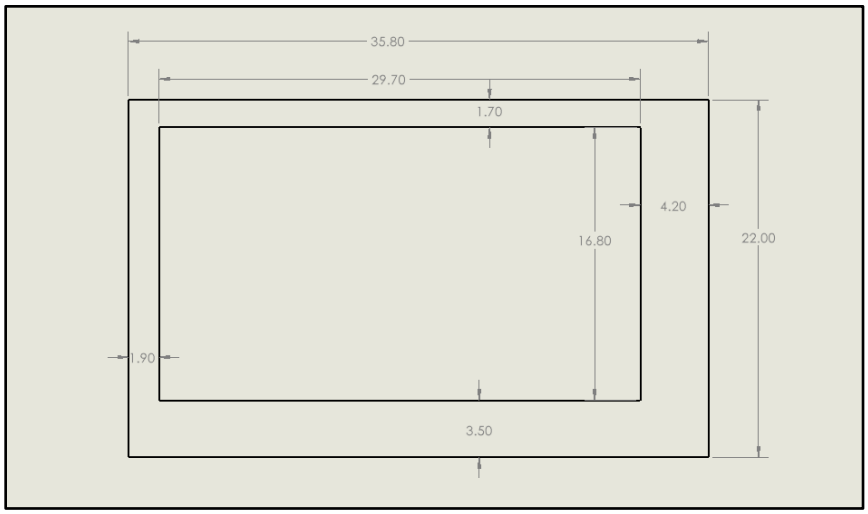


Figure 18: Front Housing Front View Drawing

2.4.1.3 Front Housing Rear View

The schematic below is the rear view of the front housing with all the respective measurements.

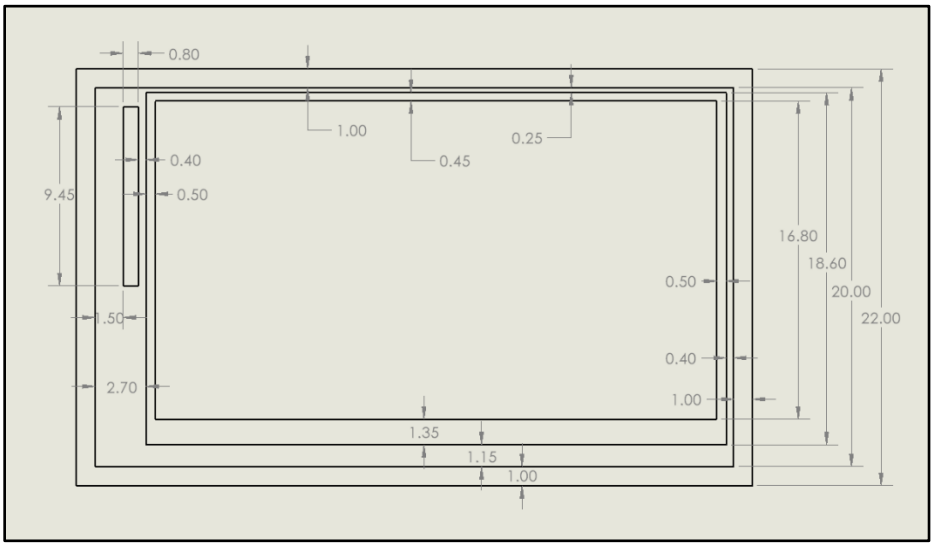


Figure 19: Front Housing Rear View Drawing

2.4.1.4 Front Housing Side View

The schematic below is the side view of the front housing with all the respective measurements.

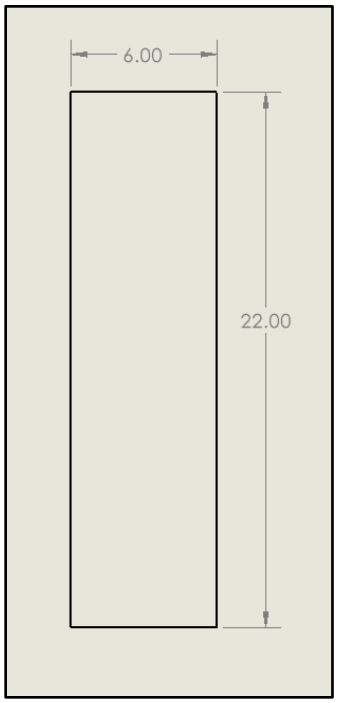


Figure 20: Front Housing Side View Drawing

2.4.1.5 Front Housing Top/Bottom View

The schematic below is the top/bottom view of the front housing with all the respective measurements.

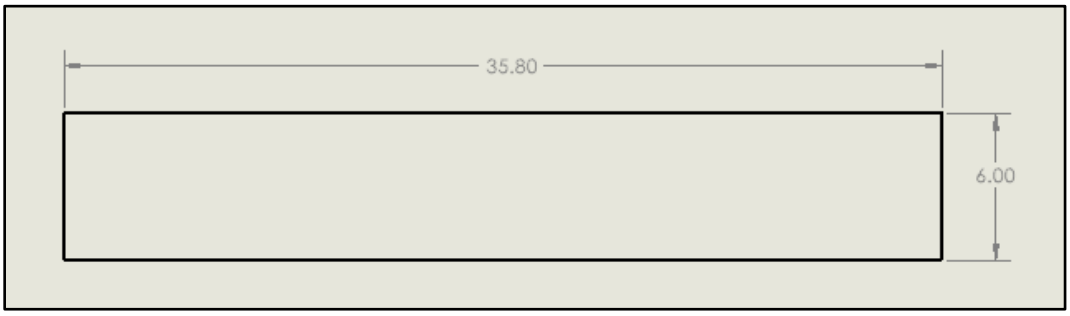


Figure 21: Front Housing Top/Bottom View Drawing

2.4.2 Rear Housing Drawings

2.4.2.1 Rear Housing 3D Renderings

The following is a 3D rendering of the rear housing. This housing will enclose the power bank, RFID reader, and GPS module. As can be seen from the picture below it has cut-outs to secure all devices within. There are two holes above passing through the housing in order for screws to be used to secure the housing to the vehicle. The large cut-out on the right side, seen on the right side in **Figure 22**, provides a space for the earlier mentioned retaining wall to pass as well as space for cables and other connections to pass through.

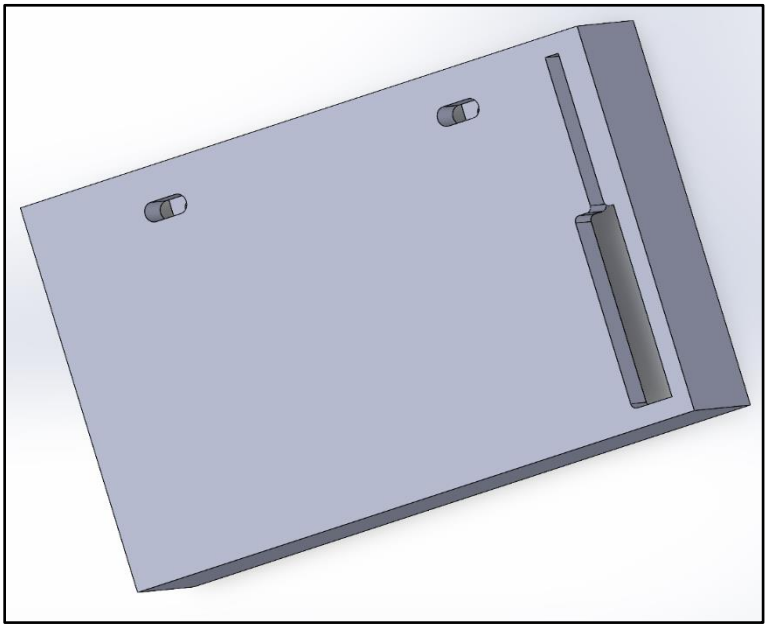


Figure 22: Rear Housing 3D Rendering – Front View

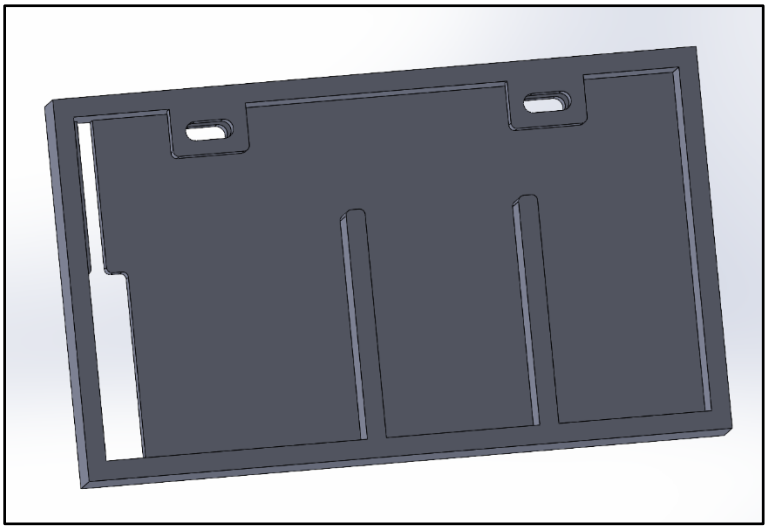


Figure 23: Rear Housing 3D Rendering – Rear View

2.4.2.2 Rear Housing Front View

The schematic below is the front view of the rear housing with all the respective measurements.

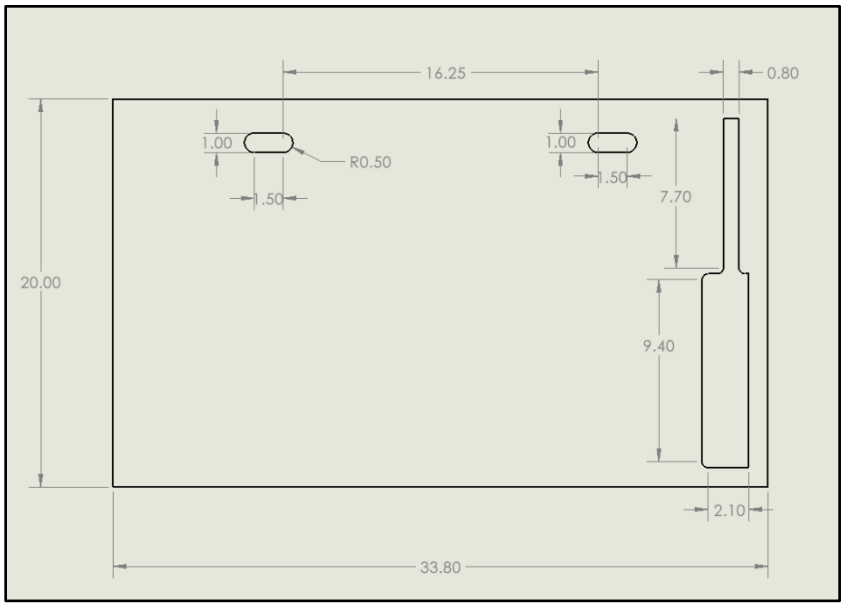


Figure 24: Rear Housing Front View Drawing

2.4.2.3 Rear Housing Rear View

The schematic below is the rear view of the rear housing with all the respective measurements.

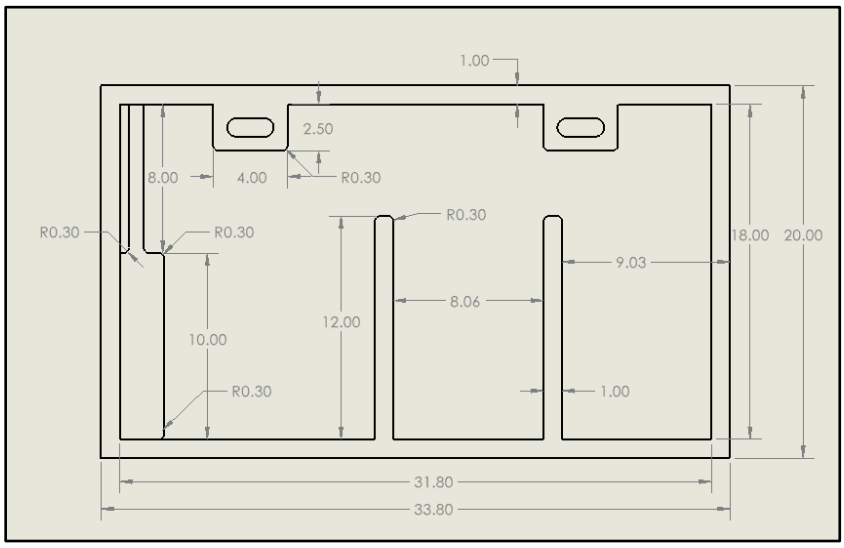


Figure 25: Rear Housing Rear View Drawing

2.4.2.4 Rear Housing Side View

The schematic below is the side view of the rear housing with all the respective measurements.

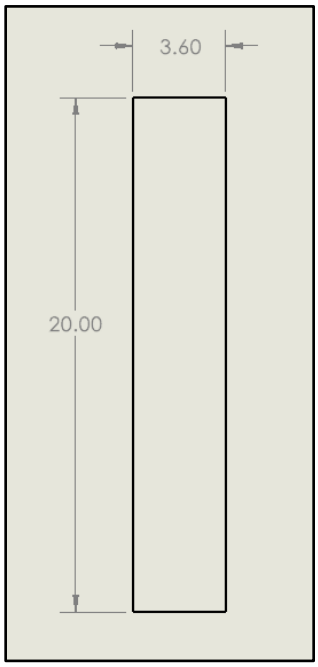


Figure 26: Rear Housing Side View Drawing

2.4.2.5 Rear Housing Top/Bottom View

The schematic below is the top/bottom view of the rear housing with all the respective measurements.

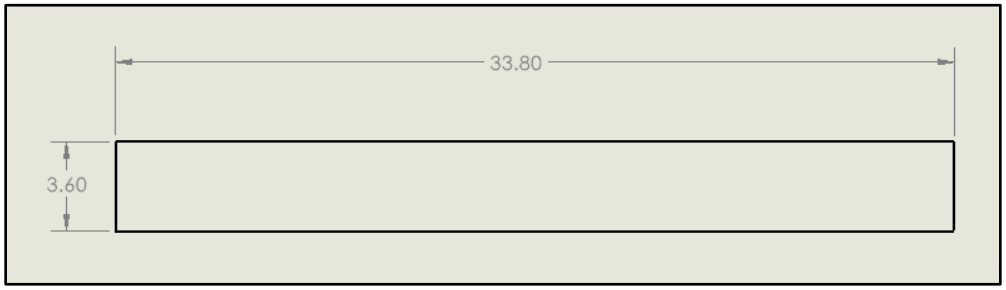


Figure 27: Rear Housing Top/Bottom View Drawing

3 Integration Tests

3.1 List of Integration Tests

Below, **Table 3.0** lists the integration test cases that will be described in the next section.

Table 3.0: List of Integration Tests

Integration Test Case Name	Test ID	Description
IT #1	Plate-IT-01	Test the interface link between the login and the portal module
IT #2	Plate-IT-02	Test the interaction between the RFID tag and Raspberry Pi 4
IT #3	Plate-IT-03	Test interaction between LCD display and Raspberry Pi 4
IT #4	Plate-IT-04	Test the interaction between the LCD display and renewal module.
IT #5	Plate-IT-05	Test the interaction between Raspberry PI and power bank.
IT #6	Plate-IT-06	Test the interaction between energy consumed and payment module.
IT #7	Plate-IT-07	Test the writing module with the Raspberry PI serial to the RFID tag and verify output
IT #8	Plate-IT-08	Test the interaction between the RFID reader and unauthorized LCD

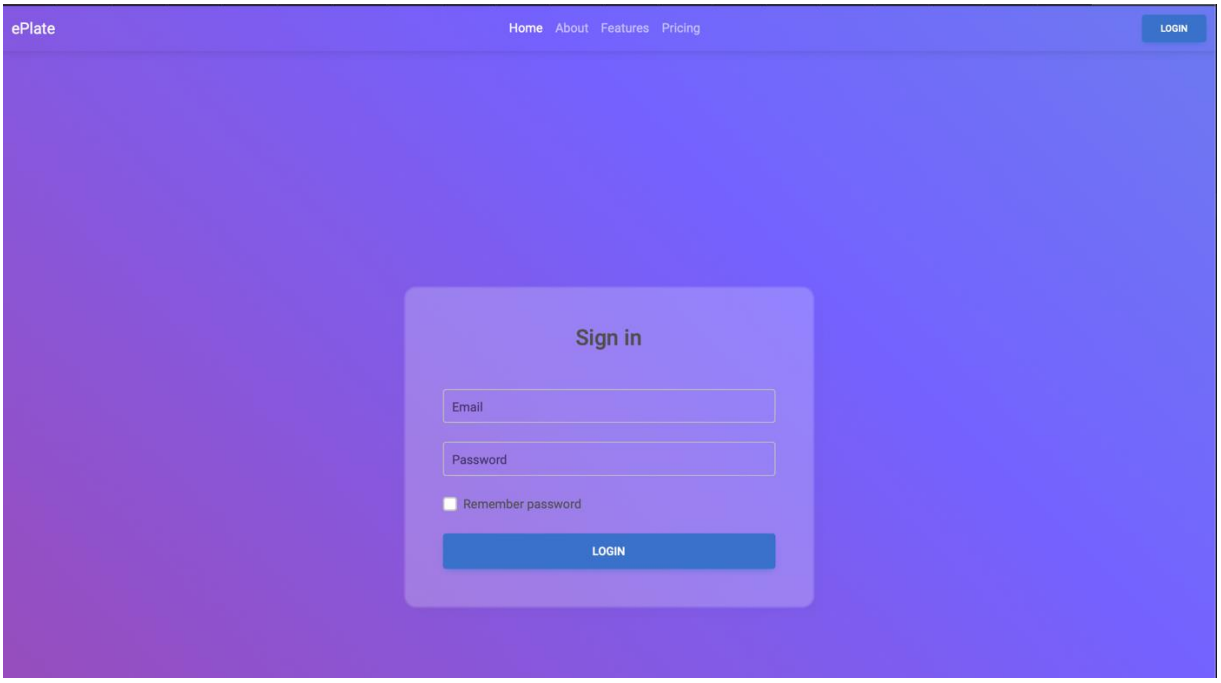
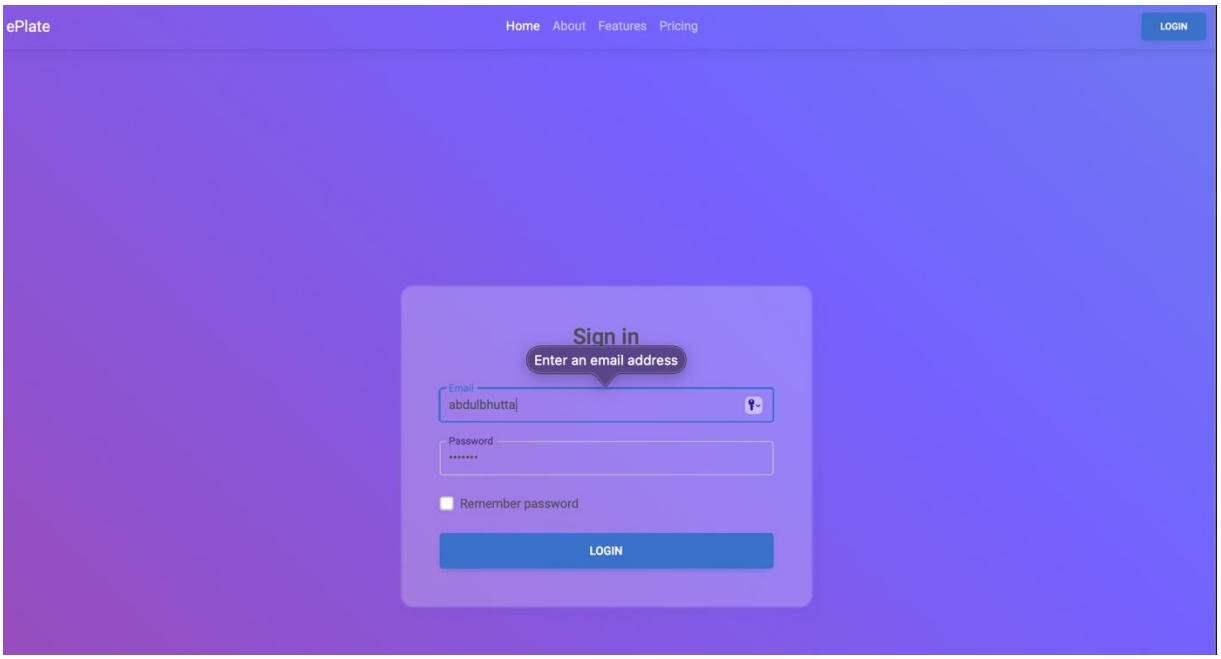
3.2 Completed Integration Tests

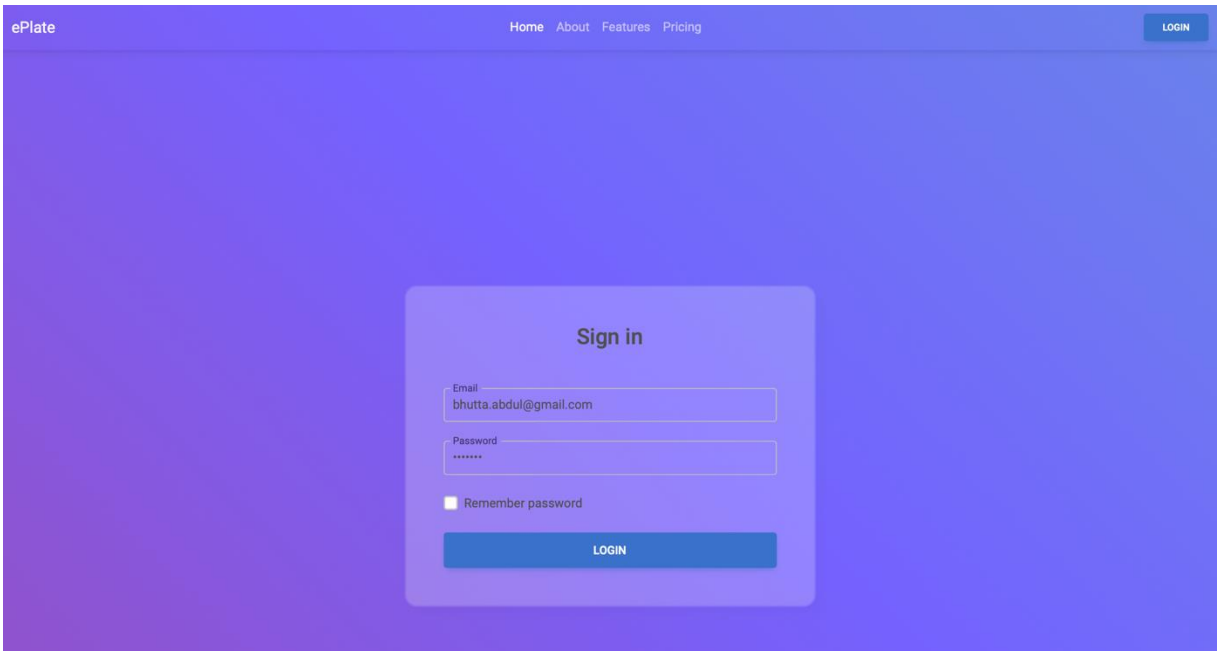
Table 3.1: Completed Integration Test Case #1

Test Writer(s):	Abdul Bhutta, Emran Soltani, Kumail Syed, Walid Ayub, Yussef Elzein		
Test Case Name:	IT #1	**Test ID:**	Plate-IT-01
Description:	Test the interface link between the login and the portal module	**Type:**	Black Box: ✓ White Box: ☐
Tester Information			
Tester Name(s):	Abdul Bhutta, Walid Ayub	**Date:**	02/14/2023
Hardware Version:	V1.0	**Time:**	8:10 PM
Setup:	The user accessing the login page must be within the database.		

Step	Action	Expected Results	Pass	Fail	N/A	Comments
1	Access the login page	The user shall be prompted with credential request	✓			
2	Validate user enters an email	If user enters an incorrect format, an error message should be displayed	✓			
3	User enters authorized credentials	User should not expect to see any error	✓			
4	User clicks on login button	The user shall be redirected to a portal page	✓			
Test Result:			**PASS**			

Plate-IT-01 Results

Step 1: Access Login page

Step 2: Validate user enters an email

Step 3: Users enters authorized credentials



Step 4: Users clicks on login button

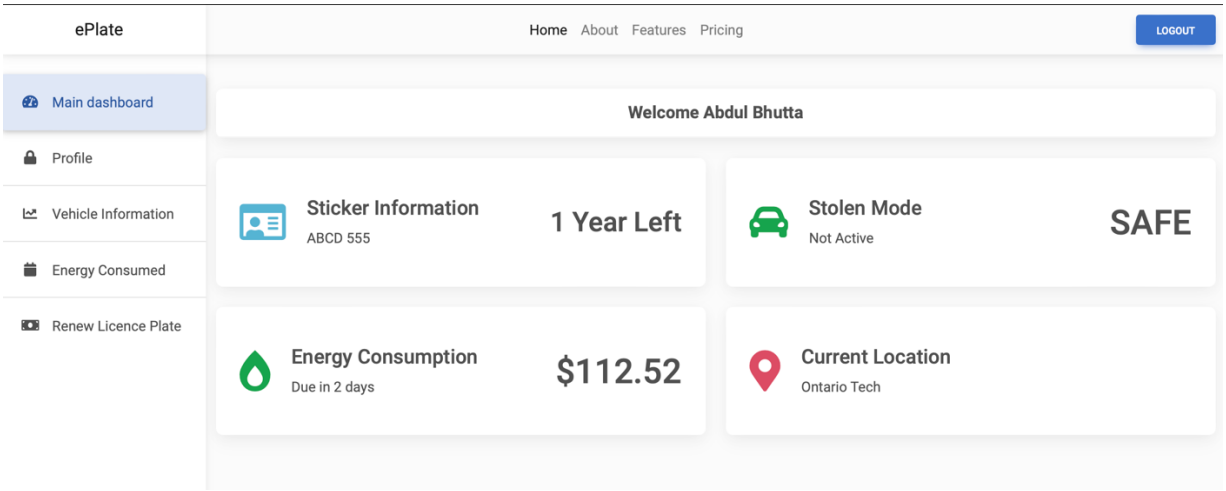


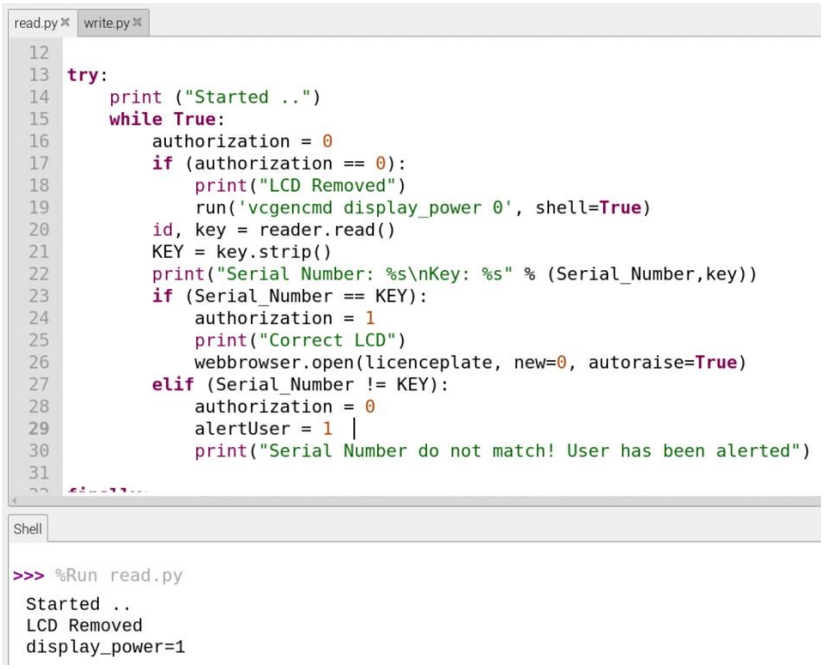
Table 3.2: Completed Integration Test Case #2

Test Writer(s):	Abdul Bhutta, Emran Soltani, Kumail Syed, Walid Ayub, Yussef Elzein		
Test Case Name:	IT #2	**Test ID:**	Plate-IT-02
Description:	Test the interaction between the RFID tag and Raspberry Pi 4	**Type:**	Black Box: ✓ White Box: ☐
Tester Information			
Tester Name(s):	Abdul Bhutta, Walid Ayub	**Date:**	-
Hardware Version:	V1.0	**Time:**	-
Setup:	The Raspberry Pi 4 must have the RFID unique ID authorized within the microcontroller. The RFID reader must be installed and running on the Raspberry Pi.		

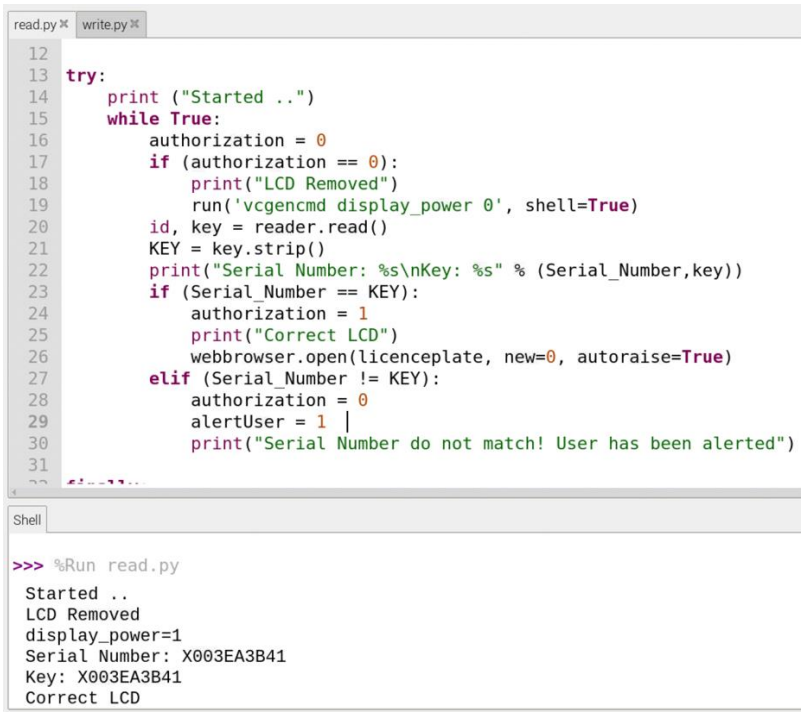
Step	Action	Expected Results	Pass	Fail	N/A	Comments
1	Verify the output	Initially, the lcd should be in sleep mode.	✓			
2	Connect the LCD (RFID tag) to the case (RFID Reader)	The microcontroller should grant access	✓			
3	Remove the LCD from the case	The RFID reader should detect the LCD has been removed	✓			
4	Verify LCD has been turned off				✓	Needs to be tested with the LCD. Currently working on the Raspberry Pi
Test Result:			**Pass**			

PLATE-IT-02 Results

Step 1: Verify the output



Step 2: Connect the LCD (RFID tag) to the case (RFID Reader)



Step 3: Remove the LCD from the case

read.py write.py

```
12
13 try:
14     print ("Started ..")
15     while True:
16         authorization = 0
17         if (authorization == 0):
18             print("LCD Removed")
19             run('vcgencmd display_power 0', shell=True)
20         id, key = reader.read()
21         KEY = key.strip()
22         print("Serial Number: %s\nKey: %s" % (Serial_Number,key))
23         if (Serial_Number == KEY):
24             authorization = 1
25             print("Correct LCD")
26             webbrowser.open(licenceplate, new=0, autoraise=True)
27         elif (Serial_Number != KEY):
28             authorization = 0
29             alertUser = 1
30             print("Serial Number do not match! User has been alerted")
31
```

Shell

```
LCD Removed
display_power=1
Serial Number: X003EA3B41
Key: X003EA3B41
Correct LCD
LCD Removed
display_power=1
```

Step 4: Verify LCD has been turned off

Shell

```
LCD Removed
display_power=1
Serial Number: X003EA3B41
Key: X003EA3B41
Correct LCD
LCD Removed
display_power=1
```

Table 3.3: Completed Integration Test Case #3

Test Writer(s):	Abdul Bhutta, Emran Soltani, Kumail Syed, Walid Ayub, Yussef Elzein		
Test Case Name:	IT #3	**Test ID:**	Plate-IT-03
Description:	Test interaction between LCD display and Raspberry Pi 4	**Type:**	Black Box: ✓ White Box: ☐
Tester Information			
Tester Name(s):	Abdul Bhutta, Walid Ayub	**Date:**	02/12/2023
Hardware Version:	V1.0	**Time:**	1:15 AM
Setup:	The Raspberry Pi 4 must have the RFID unique ID authorized within the microcontroller. The RFID reader must be installed and running on the Raspberry Pi.		

Step	Action	Expected Results	Pass	Fail	N/A	Comments
1	Verify the display is turned off	The LCD screen should not display any information and should be off.	✓			
2	Attach the LCD onto the case	Raspberry Pi should turn on and validate LCD display	✓			
3	Verify output on the LCD	The LCD will display the linked licence plate number	✓			Note: Browser needs to open in full screen mode
4						
Test Result:			**Pass**			

Plate-IT-03 Results

Step 1: Verify the display is turned off (display_power=1)

read.py write.py

```
Serial_Number = "X003EA3B41"
reader = SimpleMFRC522()
licenceplate = "https://licenceplatetemplate.azurewebsites.net"
alertUser = 0

try:
    print ("Started ..")
    while True:
        authorization = 0
        if (authorization == 0):
            print("LCD Removed")
            run('vcgencmd display_power 0', shell=True)
        id, key = reader.read()
        KEY = key.strip()
        print("Serial Number: %s\nKey: %s" % (Serial_Number,key))
        if (Serial_Number == KEY):
            authorization = 1
            print("Correct LCD")
            webbrowser.open(licenceplate, new=0, autoraise=True)
        elif (Serial_Number != KEY):
            authorization = 0
            alertUser = 1
            print("Serial Number do not match! User has been alerted")

finally:
    print("clean up")
    GPIO.cleanup() # cleanup all GPIO
```

Shell

```
>>> %Run read.py
  Started ..
  LCD Removed
  display_power=1
```

Step 2: Attach the LCD onto the case

read.py write.py

```
try:
    print ("Started ..")
    while True:
        authorization = 0
        if (authorization == 0):
            print("LCD Removed")
            run('vcgencmd display_power 0', shell=True)
        id, key = reader.read()
        KEY = key.strip()
        print("Serial Number: %s\nKey: %s" % (Serial_Number,key))
        if (Serial_Number == KEY):
            authorization = 1
            print("Correct LCD")
            webbrowser.open(licenceplate, new=0, autoraise=True)
        elif (Serial_Number != KEY):
            authorization = 0
            alertUser = 1
            print("Serial Number do not match! User has been alerted")
```

Shell

```
>>> %Run read.py
 Started ..
 LCD Removed
 display_power=1
 Serial Number: X003EA3B41
 Key: X003EA3B41
 Correct LCD
```

Step 3: Verify output on the LCD screen


192.168.2.53 (raspberrypi) - VNC Viewer
RFID_Reader
Thonny - /home/microco...
Licence Plate - Chromium
01:36
Licence Plate - Chromium
Licence Plate
licenceplatetemplate.azurewebsites.net
ONTARIO
DEC 2024
ABCD 555

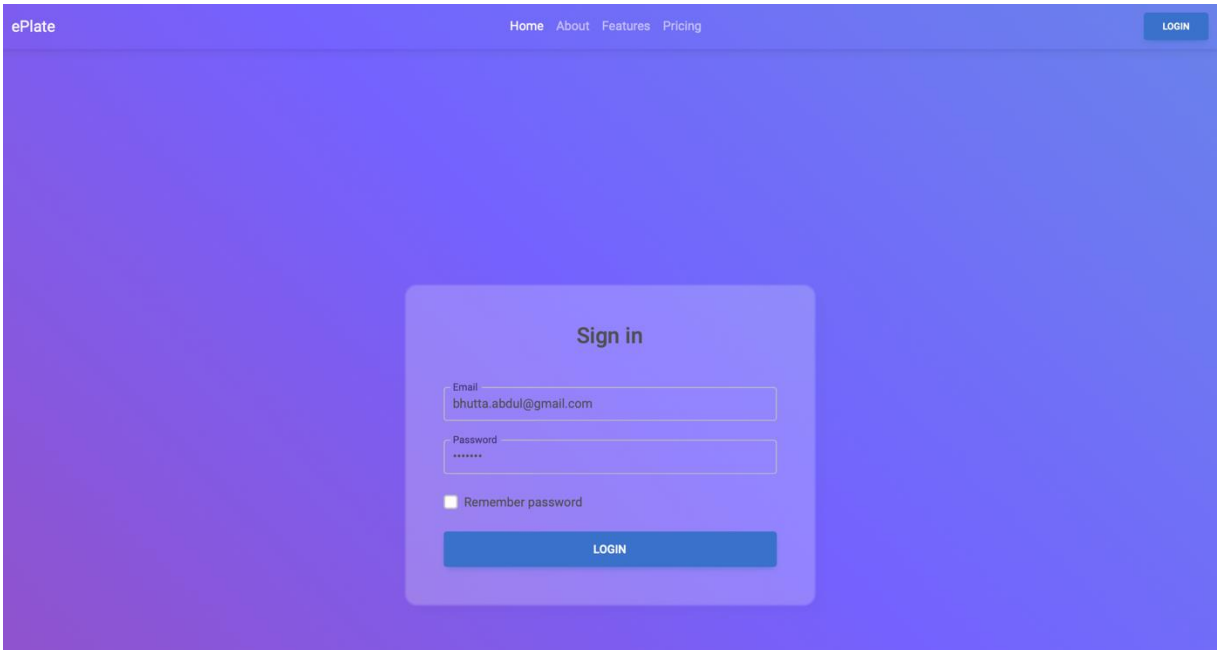
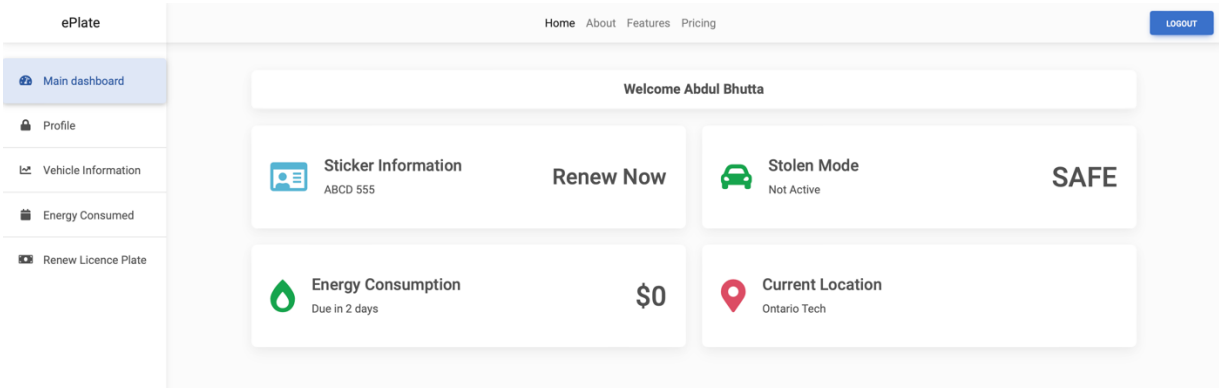

192.168.2.53 (raspberrypi) - VNC Viewer
ONTARIO
DEC 2024
ABCD 555
A PLACE TO GROW

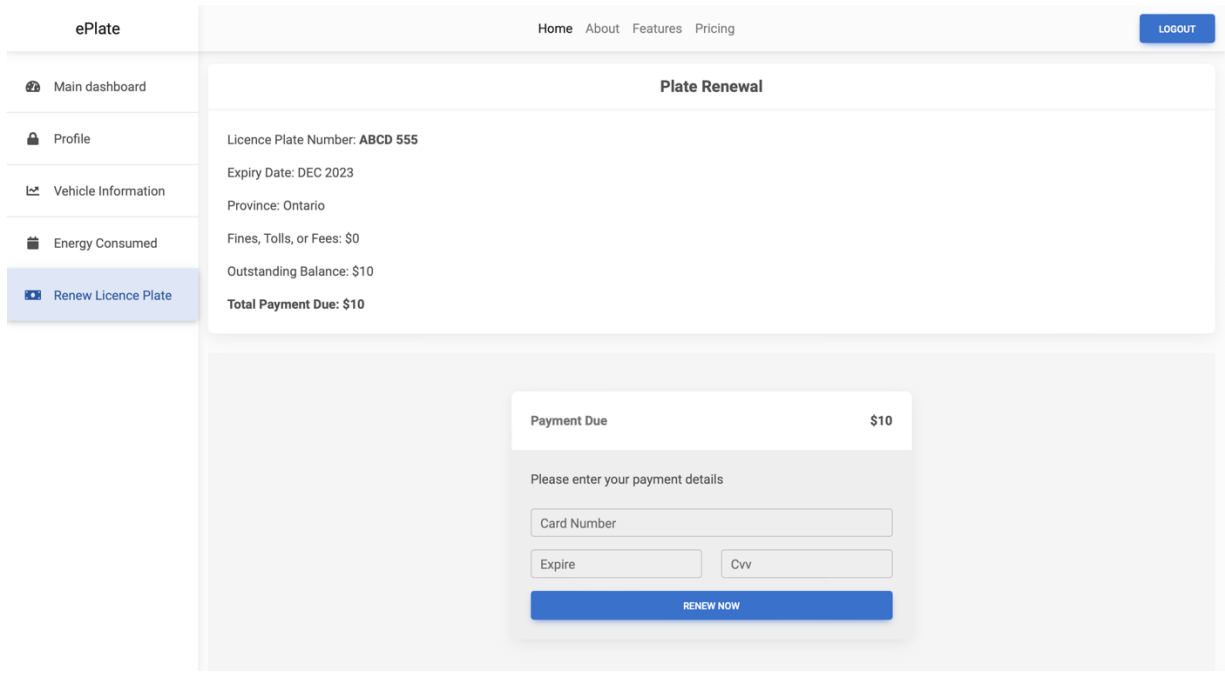
Table 3.4: Completed Integration Test Case #4

Test Writer(s):	Abdul Bhutta, Emran Soltani, Kumail Syed, Walid Ayub, Yussef Elzein		
Test Case Name:	IT #4	**Test ID:**	Plate-IT-04
Description:	Test the interaction between the LCD display and renewal module.	**Type:**	Black Box: ✓ White Box: ☐
Tester Information			
Tester Name(s):	Abdul Bhutta, Walid Ayub	**Date:**	02/10/2023
Hardware Version:	V1.0	**Time:**	1:30 PM
Setup:	The Raspberry Pi must be running the application and the RFID unique ID should be authorized to access the microcontroller. The Raspberry Pi must be connected to a reliable Wi-Fi network.		

Step	**Action**	**Expected Results**	**Pass**	**Fail**	**N/A**	**Comments**
1	Login as an authorized user to access the portal	The user shall be redirected to a personalized portal	✓			
2	Verify portal page	Verify it displays the correct information	✓			
3	Access renewal plate	The webpage will be updated to the renewal page while allowing the user to pay the fee	✓			
4	Verify output on licence plate	The current expiry date should appear on the licence plate	✓			
5	Pay the amount	Payment should be processed	✓			Simulated credit card and no actual payment module
6	Verify payment has been processed	The portal page should be updated with the correct value	✓			
7	Verify updated sticker	The expiry date on the sticker will be updated	✓			
Test Result:			**Pass**			

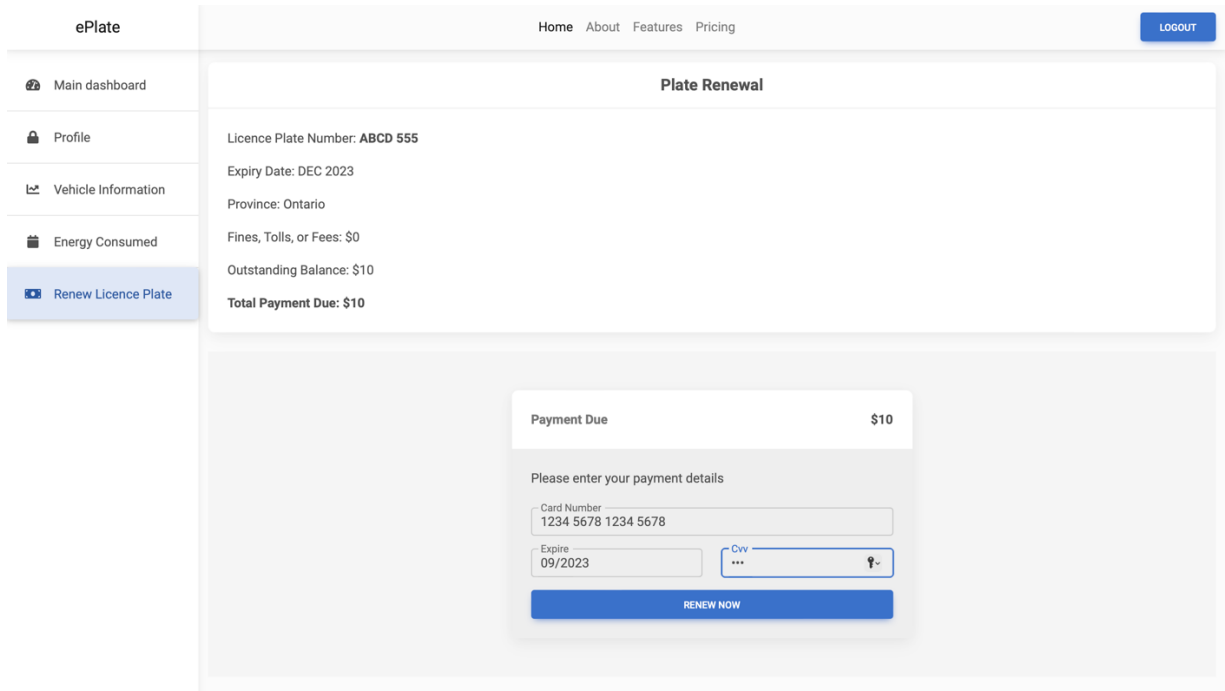
Plate-IT-04 Results

Step 1: Use an authorized user to access the portal

Step 2: Verify portal page

Step 3: Access Renewal page

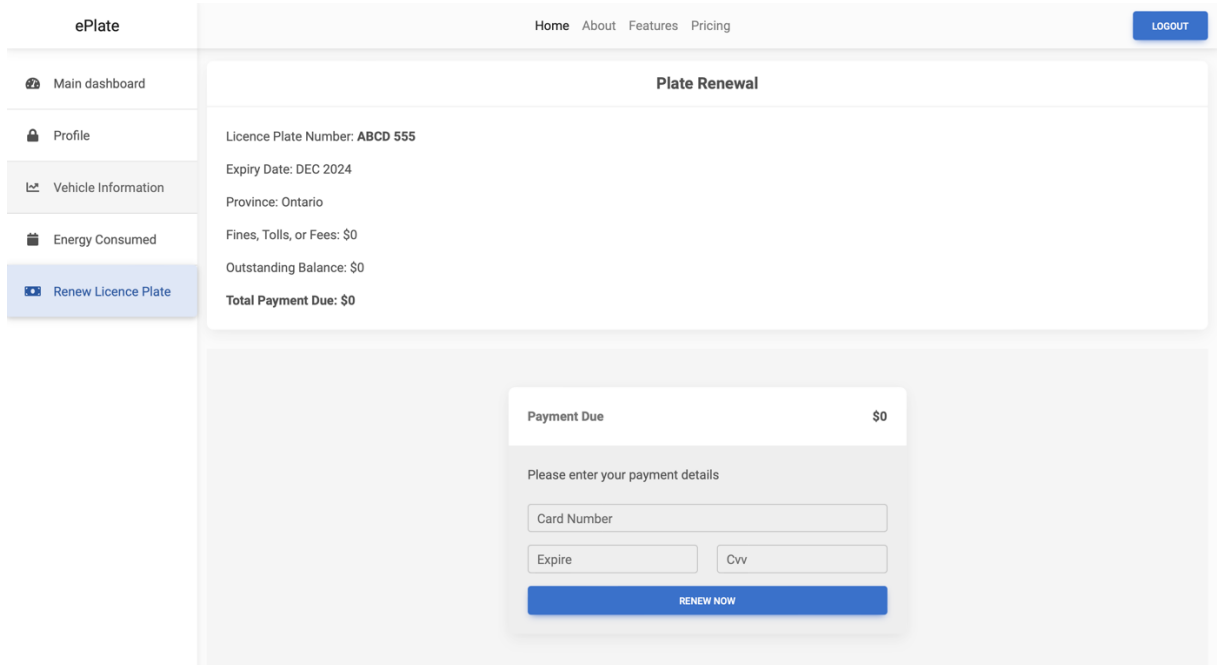


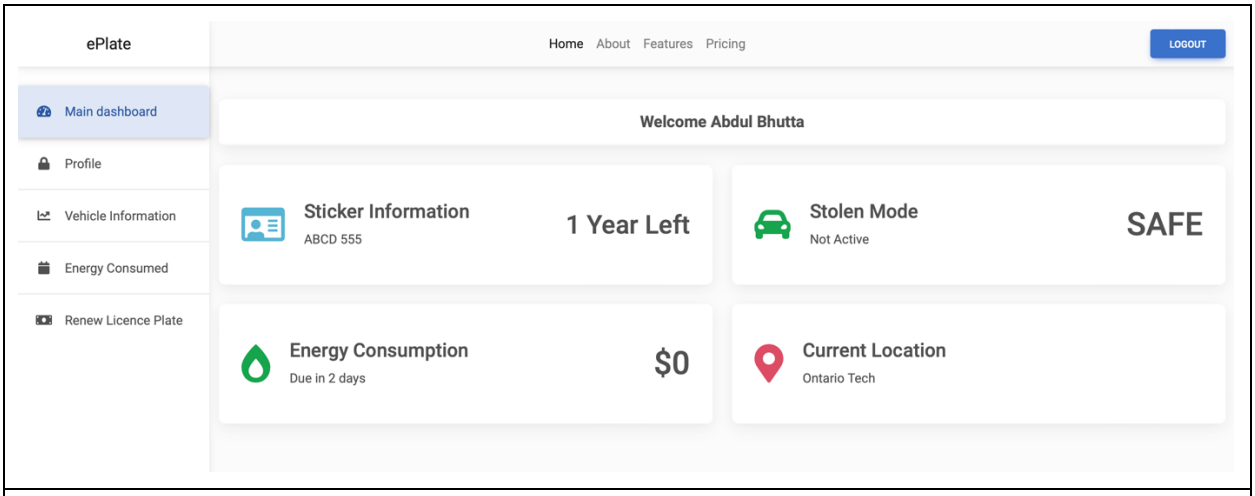
Step 4: Verify output on licence plate

Step 5: Pay the amount (Simulated credit card and no actual payment module)



Step 6: Verify payment has been processed





Step 7: Verify Licence Plate

Table 3.5: Completed Integration Test Case #5

Test Writer(s):	Abdul Bhutta, Emran Soltani, Kumail Syed, Walid Ayub, Yussef Elzein		
Test Case Name:	IT #5	**Test ID:**	Plate-IT-05
Description:	Test the interaction between Raspberry Pi and power bank.	**Type:**	Black Box: ✓ White Box: ☐
Tester Information			
Tester Name(s):	Abdul Bhutta, Walid Ayub	**Date:**	02/15/2023
Hardware Version:	V1.0	**Time:**	12:00pm
Setup:			

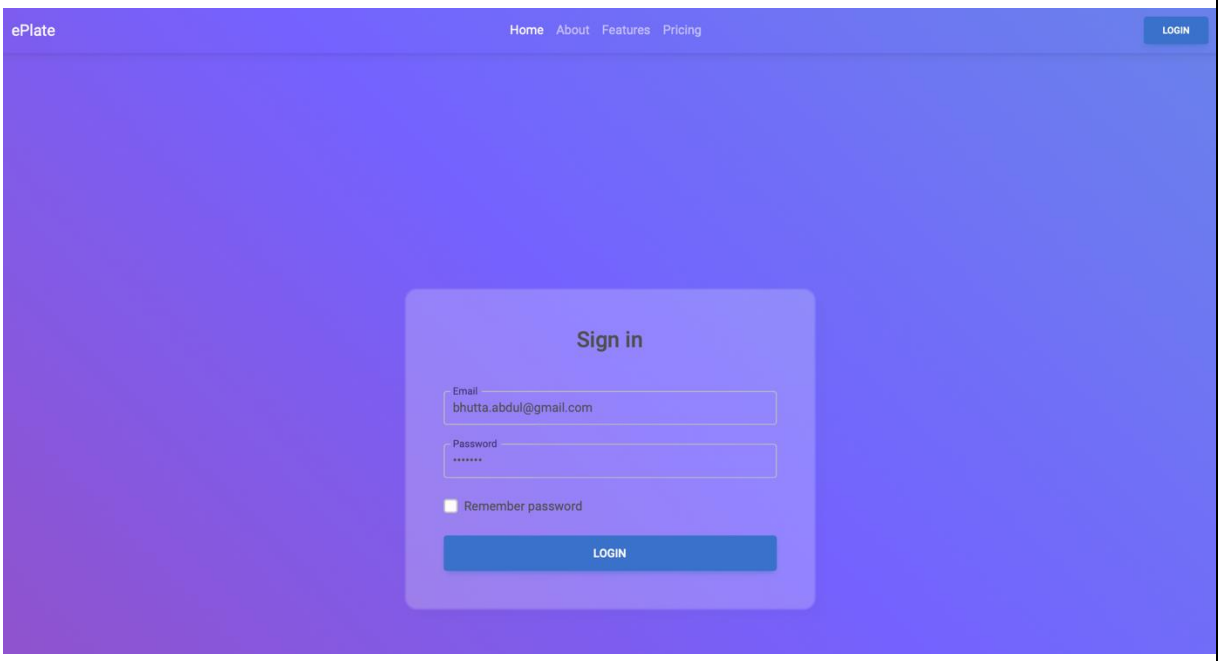
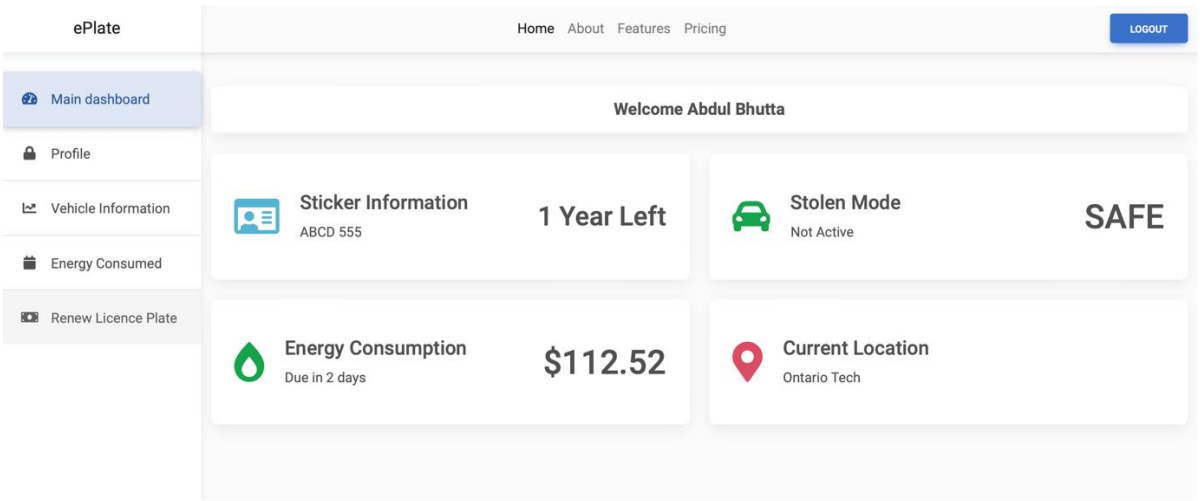
Step	**Action**	**Expected Results**	**Pass**	**Fail**	**N/A**	**Comments**
1	Connect the Raspberry PI to the power bank	The Raspberry Pi should be powered on.	✓			
2	Remove source power	No change on the Raspberry Pi and power bank.	✓			
3	Verify battery usage	The Raspberry Pi should stay powered on for at least 72 hours.	✓			Power bank successfully powered Raspberry Pi for 72 hours.
Test Result:			**Pass**			

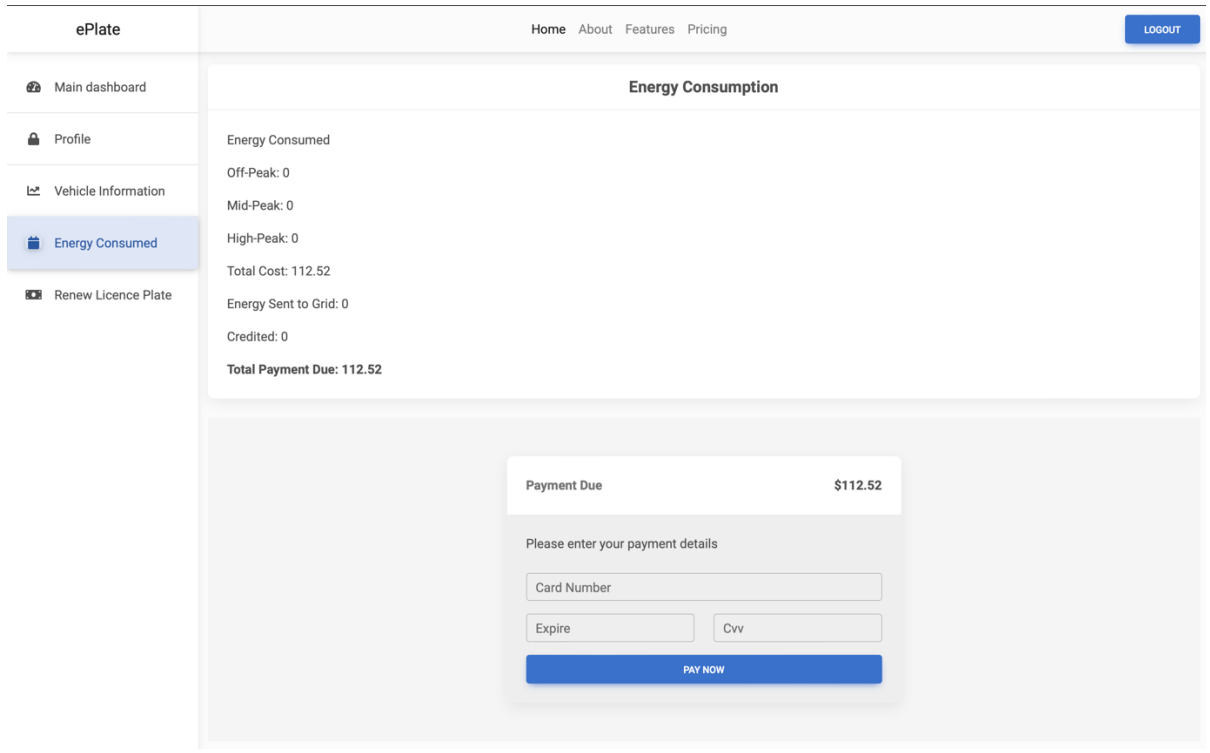
Table 3.6: Completed Integration Test Case #6

Test Writer(s):	Abdul Bhutta, Emran Soltani, Kumail Syed, Walid Ayub, Yussef Elzein		
Test Case Name:	IT #6	**Test ID:**	Plate-IT-06
Description:	Test the interaction between energy consumed and payment module.	**Type:**	Black Box: ✓ White Box: ☐
Tester Information			
Tester Name(s):	Abdul Bhutta, Walid Ayub	**Date:**	02/17/2023
Hardware Version:	V1.0	**Time:**	2:00pm
Setup:	The user must exist within the database and have an outstanding balance.		

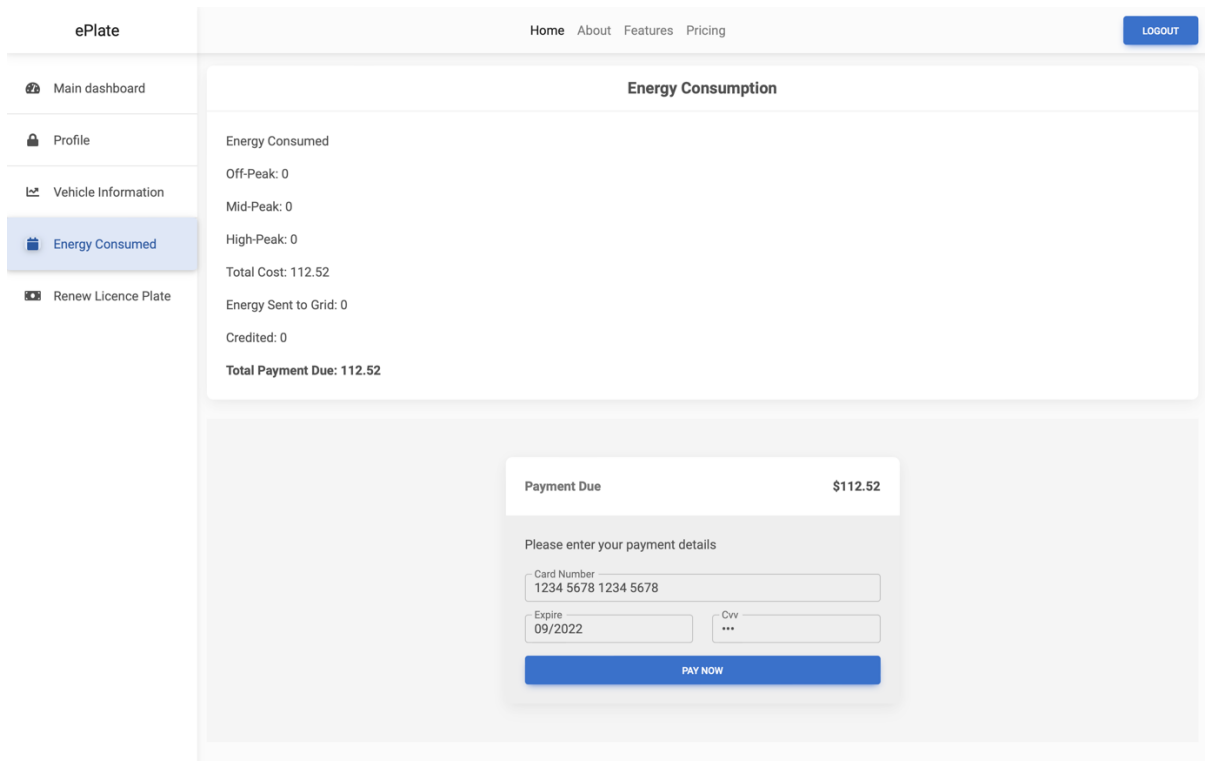
Step	**Action**	**Expected Results**	**Pass**	**Fail**	**N/A**	**Comments**
1	Login as an authorized user	The webpage will display the personal portal.	✓			
2	Access the Energy Consumption page	The webpage will display the outstanding payment.	✓			
3	Enter payment information	The webpage will be redirected to the payment page.	✓			Dummy credit card and no actual payment module
4	Submit Payment Information	Information for payment will be received.	✓			
5	Verify payment	The portal page should display the correct cost.	✓			
Test Result:			**Pass**			

Plate-IT-06 Results

Step 1: Login as an authorized user

Step 2: Access the Energy Consumption page

Step 3: Enter payment information (Dummy credit card and no actual payment module)



Step 4: Submit Payment Information



Step 5: Verify on portal

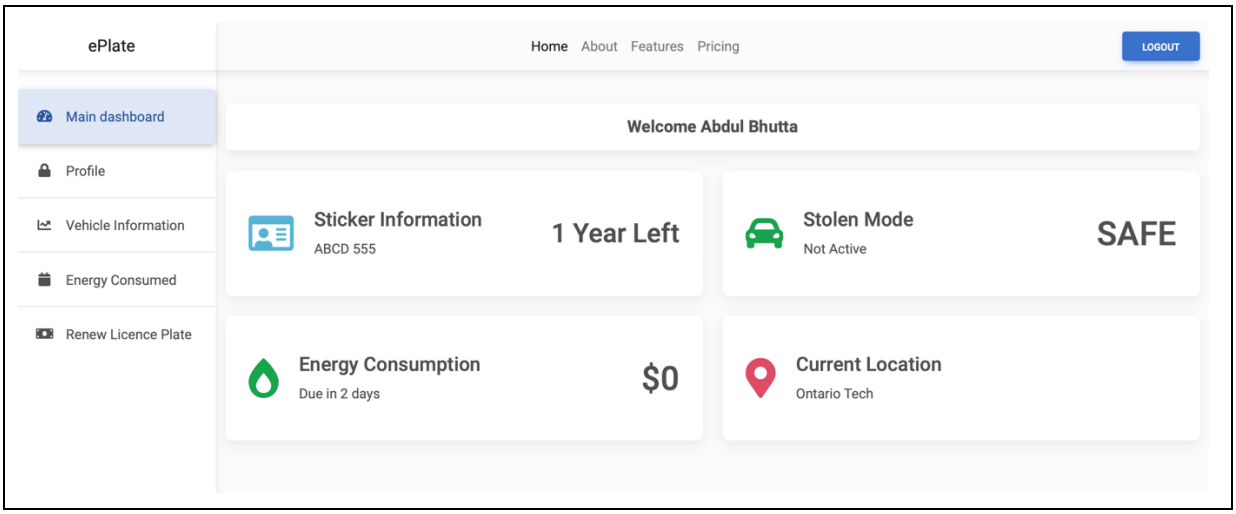

ePlate
Home
About
Features
Pricing
LOGOUT
Main dashboard
Profile
Vehicle Information
Energy Consumed
Renew Licence Plate
Welcome Abdul Bhutta
Sticker Information
ABCD 555
1 Year Left
Stolen Mode
Not Active
SAFE
Energy Consumption
Due in 2 days
$0
Current Location
Ontario Tech

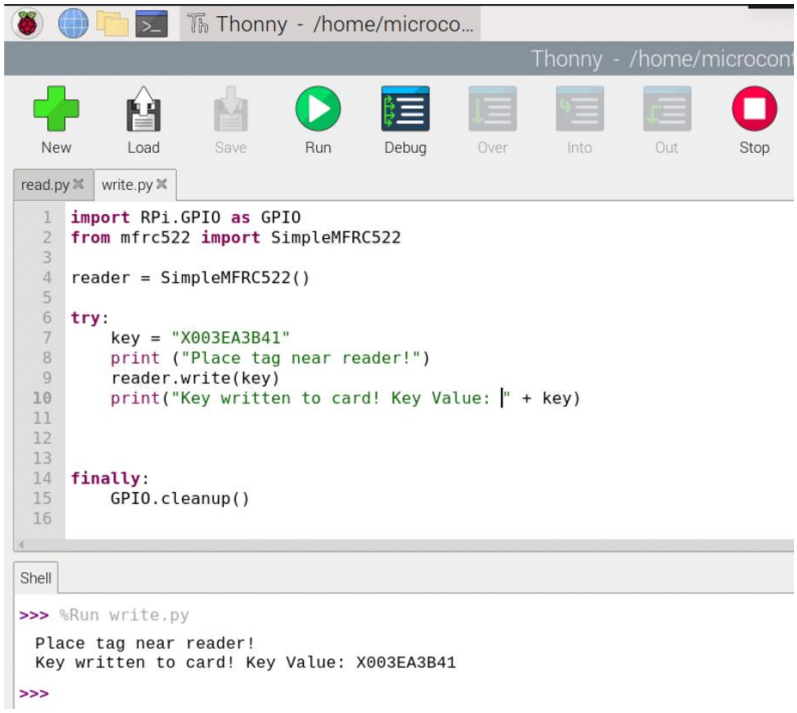
Table 3.7: Completed Integration Test Case #7

Test Writer(s):	Abdul Bhutta, Emran Soltani, Kumail Syed, Walid Ayub, Yussef Elzein		
Test Case Name:	IT #7	**Test ID:**	Plate-IT-07
Description:	Test the writing module with the Raspberry PI serial to the RFID tag and verify output	**Type:**	Black Box: ✓ White Box: ☐
Tester Information			
Tester Name(s):	Abdul Bhutta, Walid Ayub	**Date:**	02/16/2023
Hardware Version:	V1.0	**Time:**	4:30 PM
Setup:	The user must have one tag to program the current key		

Step	Action	Expected Results	Pass	Fail	N/A	Comments
1	Place a tag near the RFID reader	The RFID reader should read the key value from the tag.	✓			
2	Verify the output key	The serial number and the key should match	✓			
3			✓			
4			✓			
5			✓			
Test Result:			**Pass**			

Plate-IT-07 Result

Step 1: Place tag near the reader



Step 2: Verify card has been programmed

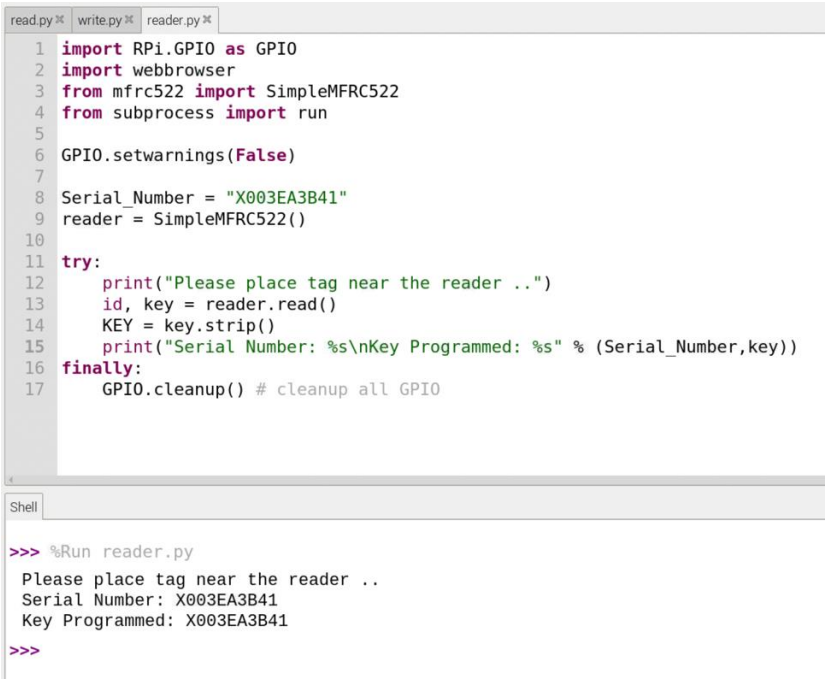


Table 3.8: Completed Integration Test Case #8

Test Writer(s):	Abdul Bhutta, Emran Soltani, Kumail Syed, Walid Ayub, Yussef Elzein		
Test Case Name:	IT #8	**Test ID:**	Plate-IT-08
Description:	Test the interaction between the RFID reader and unauthorized LCD	**Type:**	Black Box: ✓ White Box: ☐
Tester Information			
Tester Name(s):	Abdul Bhutta, Walid Ayub	**Date:**	01/25/2023
Hardware Version:	V1.0	**Time:**	1:30 PM
Setup:	The user must have one authorized and unauthorized RFID tag		

Step	**Action**	**Expected Results**	**Pass**	**Fail**	**N/A**	**Comments**
1	Verify the LCD is turned off	The LCD should display no content	✓			Display_power = 1 should be displayed as it does not allow any hdmi output
2	Use an unauthorized RFID tag with the reader	The display should not be turned on and the user should be alerted	✓			
3	Use an authorized user tag with the reader	The display will turn on and licence plate should appear	✓			
4						
5						
Test Result:			**Pass**			

Plate-IT-08 Result

Step 1: Verify the LCD is turned off

```
Serial_Number = "X003EA3B41"
reader = SimpleMFRC522()
licenceplate = "https://licenceplatetemplate.azurewebsites.net"
alertUser = 0

try:
    print ("Started ..")
    while True:
        authorization = 0
        if (authorization == 0):
            print("LCD Removed")
            run('vcgencmd display_power 0', shell=True)
        id, key = reader.read()
        KEY = key.strip()
        print("Serial Number: %s\nKey: %s" % (Serial_Number,key))
        if (Serial_Number == KEY):
            authorization = 1
            print("Correct LCD")
            webbrowser.open(licenceplate, new=0, autoraise=True)
        elif (Serial_Number != KEY):
            authorization = 0
            alertUser = 1
            print("Serial Number do not match! User has been alerted")

finallv:
```

Shell

```
>>> %Run read.py
  Started ..
  LCD Removed
  display_power=1
```

Step 2: Use an unauthorized RFID tag with the reader

read.py | write.py

```
try:
    print ("Started ..")
    while True:
        authorization = 0
        if (authorization == 0):
            print("LCD Removed")
            run('vcgencmd display_power 0', shell=True)
        id, key = reader.read()
        KEY = key.strip()
        print("Serial Number: %s\nKey: %s" % (Serial_Number,key))
        if (Serial_Number == KEY):
            authorization = 1
            print("Correct LCD")
            webbrowser.open(licenceplate, new=0, autoraise=True)
        elif (Serial_Number != KEY):
            authorization = 0
            alertUser = 1
            print("Serial Number do not match! User has been alerted")

finally:
```

Shell

```
Serial Number do not match! User has been alerted
LCD Removed
display_power=1
Serial Number: X003EA3B41
Key: fakeKey
Serial Number do not match! User has been alerted
LCD Removed
display_power=1
```

Step 3: Use an authorized user tag with the reader

read.py write.py

```
13 try:
14     print ("Started ..")
15     while True:
16         authorization = 0
17         if (authorization == 0):
18             print("LCD Removed")
19             run('vcgencmd display_power 0', shell=True)
20         id, key = reader.read()
21         KEY = key.strip()
22         print("Serial Number: %s\nKey: %s" % (Serial_Number,key))
23         if (Serial_Number == KEY):
24             authorization = 1
25             print("Correct LCD")
26             webbrowser.open(licenceplate, new=0, autoraise=True)
27         elif (Serial_Number != KEY):
28             authorization = 0
29             alertUser = 1
30             print("Serial Number do not match! User has been alerted")
31
32 finally:
```

Shell

```
display_power=1
Serial Number: X003EA3B41
Key: fakeKey
Serial Number do not match! User has been alerted
LCD Removed
display_power=1
Serial Number: X003EA3B41
Key: X003EA3B41
Correct LCD
```

4 Project Plan

4.1 Updated Winter Semester Deliverable Breakdown

Below is the updated deliverable breakdown for the Winter semester.

Table 4.0: Winter Semester Deliverable Breakdown

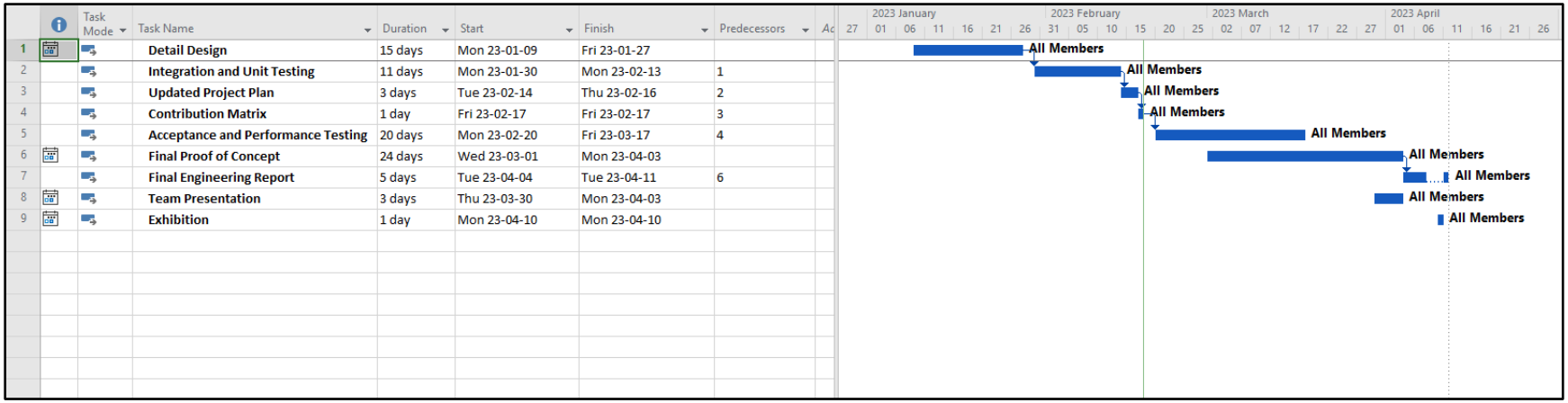
Deliverable	Report Section Name	Section Deliverables	Assigned Team Member(s)	Duration (Days)
Detail Design & Integration Testing Report	**Report Introduction**	Abstract, Dedication, Acknowledgements, Report Introduction	All Members	2
Detail Design & Integration Testing Report	**Detail Design**	Diagram Creation Design Analysis Detailed Schematics	All Members	15
Detail Design & Integration Testing Report	**Integration Testing / Unit Testing**	Refine Integration Tests Complete Integration Tests	All Members	10
Detail Design & Integration Testing Report	**Project Plan**	Updated Task Breakdown Update Gantt Chart	Abdul Yussef	2
Detail Design & Integration Testing Report	**Contribution Matrix**	Matrix Creation and Completion	Yussef	1
Detail Design & Integration Testing Report	**Report Corrections**	Proofreading Consistency Check General Flow Check	Emran Kumail	2
Detail Design & Integration Testing Report	**Report Formatting**	Format Report Organizing Tables & Figures Table of Contents	Yussef	1
Detail Design & Integration Testing Report	**Report Submission**	Submission to Capstone Advisor	Yussef	>1
Acceptance Test Demonstration Report	**Acceptance Testing**	Complete Acceptance /Performance Testing Refine Acceptance Tests	All Members	3
Acceptance Test Demonstration Report	**Demonstration Rehearsals**	Assign Sections for Presentation Practice Presenting	All Members	2
Acceptance Test Demonstration Report	**Acceptance Test Demonstration**	Present to Capstone Advisor	All Members	>1

Acceptance Test Demonstration Report	**Report Introduction**	Abstract, Dedication, Acknowledgements, Report Introduction	All Members	2
Acceptance Test Demonstration Report	**Report Corrections**	Proofreading Consistency Check General Flow Check	Emran Kumail	2
Acceptance Test Demonstration Report	**Report Formatting**	Format Report Organizing Tables & Figures Table of Contents	Yussef	1
Acceptance Test Demonstration Report	**Report Submission**	Submission to Capstone Advisor	Yussef	>1
Final Engineering Report	**Report Introduction**	Title Page, Abstract, Dedication, Acknowledgements, Report Introduction Executive Summary	All Members	3
Final Engineering Report	**Addition of Previous Reports**	Add Report #1 Add Report #2	Yussef	1
Final Engineering Report	**Revised Design Report**	Revise Designs	All Members	4
Final Engineering Report	**Ethical Considerations**	Comments of Ethical Considerations of Project	All Members	3
Final Engineering Report	**Safety Considerations**	Comments of Safety Considerations of Project	All Members	3
Final Engineering Report	**Report Conclusion**	Write Project's Closing Remarks	All Members	1
Final Engineering Report	**Report Corrections**	Proofreading Consistency Check General Flow Check	Emran Kumail	2
Final Engineering Report	**Report Formatting**	Format Report Organizing Tables & Figures Table of Contents	Yussef	1
Final Engineering Report	**Report Submission**	Submission to Capstone Advisor	Yussef	>1
Team Presentation & Video Clip	**Presentation Assembly**	Construction of Presentation	All Members	5

Team Presentation & Video Clip	**Presentation Rehearsals**	Assign Sections for Presentation Practice Presenting	All Members	2
Team Presentation & Video Clip	**In-Class Final Presentation**	Present to Class / Faculty Advisors	All Members	>1
Team Presentation & Video Clip	**Video Clip Planning**	Writing of Script Review of Script Overall Plan of Video	All Members	4
Team Presentation & Video Clip	**Video Clip Filming**	Filming of Prototype Clips	Yussef	2
Team Presentation & Video Clip	**Video Clip Editing**	Assemble Clips Overall Video Editing	Yussef	4
Team Presentation & Video Clip	**Video Compilation & Review**	Finalize Video Review Final Video	Yussef	2
Capstone Design Annual Exhibition	**Presentation Assembly**	Construction of Presentation	All Members	5
Capstone Design Annual Exhibition	**Presentation Rehearsals**	Assign Sections for Presentation Practice Presenting	All Members	3
Capstone Design Annual Exhibition	**Poster Creation**	Design of Poster Assembly of Poster	All Members	5
Capstone Design Annual Exhibition	**Preparation of Final Prototype**	Test Final Prototype Ensure All Parts Assembled	Yussef	2
Team Retrospective Report	**Report Preparation**	Write Team Report	All Members	10
Team Retrospective Report	**Report Corrections**	Proofreading Consistency Check General Flow Check	Emran Kumail	2
Team Retrospective Report	**Report Formatting**	Format Report Naming/Organizing Tables Table of Contents	Yussef	1
Team Retrospective Report	**Report Submission**	Submission to Capstone Coordinator	Yussef	>1
END OF WINTER SEMESTER				

4.2 Winter Semester Gantt Chart

Figure 28 below shows a Gantt chart demonstrating the project plan deliverables throughout to the end of the project and a timeframe for their completion.



	Task Mode	Task Name	Duration	Start	Finish	Predecessors
1		Detail Design	15 days	Mon 23-01-09	Fri 23-01-27	
2		Integration and Unit Testing	11 days	Mon 23-01-30	Mon 23-02-13	1
3		Updated Project Plan	3 days	Tue 23-02-14	Thu 23-02-16	2
4		Contribution Matrix	1 day	Fri 23-02-17	Fri 23-02-17	3
5		Acceptance and Performance Testing	20 days	Mon 23-02-20	Fri 23-03-17	4
6		Final Proof of Concept	24 days	Wed 23-03-01	Mon 23-04-03	
7		Final Engineering Report	5 days	Tue 23-04-04	Tue 23-04-11	6
8		Team Presentation	3 days	Thu 23-03-30	Mon 23-04-03	
9		Exhibition	1 day	Mon 23-04-10	Mon 23-04-10	

Figure 28: Smart Grid Integrated Digital Licence Plate Project Gantt Chart

5 Contribution Matrix

The contribution matrix in the table below displays how the work this report was divided.

Table 5.0: Detail Design & Integration Testing Report Contribution Matrix

	Group Members				
Report #2 Sections	**Abdul Bhutta**	**Yussef Elzein**	**Emran Soltani**	**Kumail Syed**	**Walid Ayub**
Section 1: Introduction					
	✓	✓	✓	✓	✓
Section 2: Concept Generation & Analysis					
Final Software Design	✓	✓	✓	✓	✓
Final Electrical Design	✓	✓	✓	✓	
Casing Design – Front Housing		✓	✓		
Casing Design – Rear Housing		✓	✓		
Section 3: Integration Tests					
List of Integration Tests	✓				✓
Completion of Integration Test Cases	✓	✓			✓
Section 4: Project Plan					
Updated Winter Deliverable Breakdown		✓			
Gantt Chart				✓	
Section 5: Contribution Matrix					
Contribution Matrix		✓			
Other:					
Report Formatting	✓	✓			
Report Corrections		✓	✓	✓	✓

References

3. J. Wood, “Despite Ford promises, failed Ontario licence plates increased costs by 26 per cent,” Newsroom, 16-Jun-2021. [Online]. Available: https://www.taxpayer.com/newsroom/despite-ford-promises,-failed-ontario-licence-plates-increased-costs-by-26-per-ent#:~:text=Throughout%20the%20entirety%20of%20the,have%20added%20up%20to%20%24913%2C867. [Accessed: 10-Oct-2022].

2. Gus, “How to setup a raspberry pi RFID RC522 chip,” Pi My Life Up, 28-Oct-2022. [Online]. Available: https://pimylifeup.com/raspberry-pi-rfid-rc522/. [Accessed: 04-Jan-2023].

3. “Introduction to the raspberry pi GPIO and physical computing,” Introduction to the Raspberry Pi GPIO andPhysicalComputing-SparkFunLearn.[Online]. Available: https://learn.sparkfun.com/tutorials/introduction-to-the-raspberry-pi-gpio-and-physical-computing/gpio-pins-overview. [Accessed: 02-Jan-2023].

4. “GPS module interfacing with Raspberry Pi: Raspberry Pi,” ElectronicWings. [Online]. Available: https://www.electronicwings.com/raspberry-pi/gps-module-interfacing-with-raspberry-pi. [Accessed: 18-Dec-2022].

--------- END OF PREVIOUS REPORTS ---------

Ethical Considerations

An important ethical consideration that we can't overlook in our product is the environmental impact it can cost. When an increasing amount of digital licence plates are connected to the grid, there could be negative environmental impact depending on the source of energy. There is also the potential for a large number of harmful emissions to be released when manufacturing our product on a large scale. It is crucial that we try to manufacture our product using environmentally friendly materials. We must also continuously try to improve ePLATE's energy efficiency. Another ethical consideration is our product's relatively high cost could make the product less accessible for individuals in lower-income households.

Finally, we must take into consideration our users' right to privacy and ensure that we do our best to protect people's personal information and data under any circumstances. We should also remember that user privacy is a top priority so that users always feel that they can use our product without it causing them any problems.

Safety Considerations

Integrating the ePLATE may cause several safety concerns that need to be further examined, such as data privacy. Insufficient security measures to protect the privacy of a vehicle owner's data can potentially allow many unauthorized third parties to access and exploit user information. This poses a danger to users, as obtaining a licence plate already requires the provision of a significant amount of personal information. With a design like the ePLATE, even more information is provided, such as real-time location, which can be concerning for people due to its tracking and surveillance capabilities. Transmitting data about the location and usage of the vehicle breaches privacy rights and requires tough security measures to prevent unauthorized access, as well as constant maintenance and updates. The plate's design is also a key consideration, as drivers wouldn't want their plates damaged due to environmental effects like weather; thus, it should be durable enough to withstand all conditions. It is crucial to consider user safety when developing and implementing a digital licence plate so that it doesn't pose any risks.

Conclusions

The advent of the ePLATE marks a significant advancement in automotive industry. With real-time updates and enhanced tracking capabilities, this technology has the potential to completely transform how we manage our cars. The digital licence plate is a logical development of the current licence plate system given the emergence of linked automobiles and cloud database. Our product has many advantages, however there are issues relating to security and privacy that we must consider. It will be crucial to have the right safeguards in place in order to protect our users' personal data and prevent illegal access to the system. The price of deploying this technology might also prevent its broad adoption, especially in underdeveloped nations.

In conclusion, our digital plate is a great product and has a promising concept that has the ability to revolutionize the automotive industry. It's important that automakers, government organizations, and technology companies work together in order to continue to implement and develop this technology. The digital licence plate could provide a large number of advantages to car owners, law enforcement officials, and governmental organizations if the correct measures are set in place.

Acknowledgments

We would like to express our gratitude to our supervisor Dr. Tarlochan Sidhu who made this project possible. With his guidance, we were able to get a thorough understanding of the project and how to execute our ideas. His continuous support fed our ambition to take this project above and beyond.

We would also like to acknowledge our capstone coordinator Dr. Vijay Sood. He was able to give us a strong detailed understanding of producing reports and how to have a complete presentation on our project.

Our sincere appreciation to Dr. Sheldon Williamson for offering his knowledge and guidance with this project. In our first meeting, he provided us with many ideas on smart grid technology and possible recommendations on how to implement them.

A special thank you to Mr. Peter Kahr for helping us with the 3D printing for our casing and creating badges for our prototype as well.

Lastly, we would like to thank our friends and family for their continued support and encouragement throughout our final year.

We will be forever grateful for this capstone project as it has not only challenged us but helped us understand the process of designing, testing, building, and implementing a product from start to finish.

References

N/A

Appendices

Appendix A – Capstone Exhibition Poster

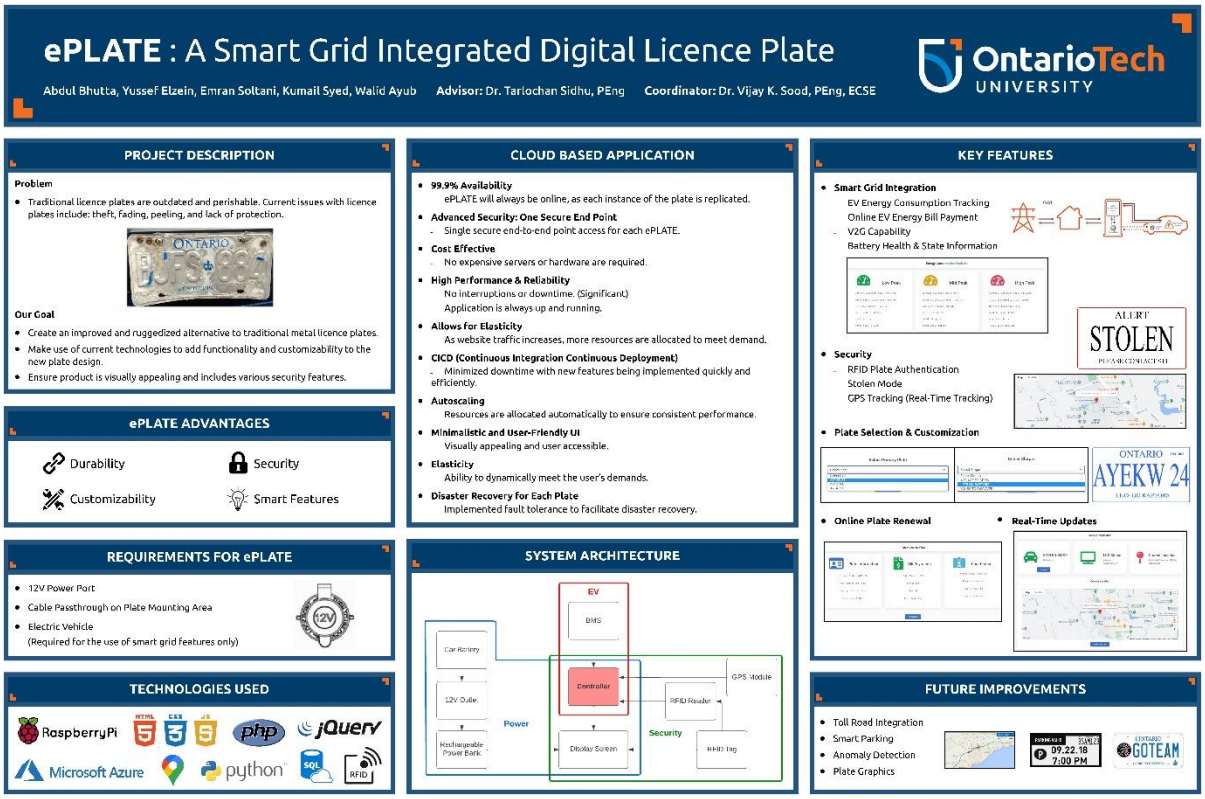


Figure 1: Smart Grid Integrated Digital Licence Plate Capstone Exhibition Poster

Contribution Matrix

The contribution matrix below shows how the sections for this Final Engineering Report were divided.

Table 1: Final Engineering Report Contribution Matrix

	Group Members				
Final Engineering Report Sections	**Abdul Bhutta**	**Yussef Elzein**	**Emran Soltani**	**Kumail Syed**	**Walid Ayub**
Section 1: Title Page					
		✓			
Section 2: Executive Summary					
			✓		
Section 3: Table of Contents/Tables/Figures					
Table of Contents		✓			
List of Tables		✓			
List of Figures		✓			
Section 4: Report 1					
	✓	✓	✓	✓	✓
Section 5: Report 2					
	✓	✓	✓	✓	✓
Section 6: Revised Design Report					
	✓	✓	✓	✓	✓
Section 7: Ethical Considerations					
	✓				
Section 8: Safety Considerations					
					✓
Section 9: Conclusions					
				✓	
Section 10: Acknowledgements					
		✓	✓	✓	
Section 11: References					
		✓			
Section 12: Appendices					
			✓		
Section 13: Contribution Matrix					
		✓			
Other:					
Report Formatting		✓			
Report Corrections		✓			