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FACULTY OF ENGINEERING AND INFORMATION TECHNOLOGY

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HARDWARE GRADUATION PROJECT

# Smart Bus System

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# 1 Acknowledgments

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## Disclaimer

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# 2 Abstract

The world is developing rapidly in many areas nowadays. Especially in the technology field. One of those areas where technology is developed and used is ”Transportation and Buses Systems”. Safety, Payment, Monitoring, and Management Systems are examples of the field of Busses and transportation field is developing. Across the world, many bus companies use technology to keep track, organize their buses, and manage them. On the other hand, that is not the case locally. Al Taneeb, Al Waleed, and Al Tamimi are some of the local companies that run the majority of the buses across the country, they use their systems, unfortunately, those systems are old and not that practical. So, to keep pace with this development, local bus companies should use more techno- logy. Facilitating the management of buses for the companies, ensuring safety for passengers, and making their life a little bit easier.

Smart Bus System is a system for a company to track its buses' routes and monitor their movement. Easing the supervision of the whole system by providing subsystems to monitor the buses by using a GPS to locate the bus and track it alongside the path. Safety is important as well! A CO2 detector saves passengers' lives by opening windows if there is a lack of oxygen , In addition, if a fire occurs on the bus, the water pump will start working to extinguish the fire and send a message to the admin that there is a fire . regarding the communication between buses and stations, there will be independent communication to keep the system working in case the server goes down showing a bus is arriving at a station or willing to leave one. Finally, in the payment system, RFID cards will be used to pay for bus rides.

Note that there is no internal controller in the demo meaning that an external controller will be implemented to simulate the steering wheel by using an application on the phone, and some but- tons to communicate with the station.

Other systems can be found but they are not covering all implemented features. Most of the already existing systems rely on servers and cannot work without them. More security and safety measures are added. No system is perfect but constant development and adapting to cover weak spots is the way to improve the system.

# 3 Introduction

Although the use of traditional buses is common locally. it still wastes a lot of time for passengers, for example, passengers waste their time standing to buy tickets to ride buses, and they may waste another time riding on the bus while paying cash, in addition to the fact that the driver will waste time when receiving their money and returning change, which may causes more late passengers who pay to be on time for their appointments.

The Oxygen levels may decrease in the bus without any notice from the driver nor passengers, causing harm to them, especially since the windows of modern buses are closed and cannot be opened.

For buses' companies, buses are not tracked and monitored. This may cause a problem contacting the buses reaching them in case of emergency or even providing some luxury apps for the clients to locate the buses and approximate the time to move toward them.

Smart Bus system aims to provide safety and security in the bus for passengers. In additionto facilitate charge the cards. This system has multiple features that achieve safety and security like:

1. There is a CO2 detector in the bus, so when the CO2 is higher than the safe percentage. The windows will open automatically if there is a lack of oxygen in the air.
2. Gas and heat detector sensor , if a fire occurs, the water pump will start working to put out the fire .
3. The bus driver can choose the trip he would like to take using the keypad, so that each trip has its specific price sadly in the database.
4. Every RFID card has a unique ID, so every customer can charge his/her card on the station or any other certified sale point.
5. GPS tracking the bus path all the time.
6. Sending a text message to the passenger that he has entered the bus and the discount amount.

The research will be demonstrating the problem and how it could be solved. Then providing a methodology and some devices and equipment that used to partially solve the problem. and then suggesting some extra steps that can be taken to improve the solution and make it closer to what a perfect system should be.

# 4 Constraints Limitations and Earlier Coursework

## 5.1 Constraints Limitations

### 5.1.1 Lack of Resources

It's not easy to find all the components needed in the local electronics stores. How to deal with these components is another story. Some problems with their functionality or misusing them may be caused by the lack of experience.

### 5.1.2 Time Limit

To finish the project with the desired details and features, it takes big time because the project will pass through many stages, including the learning interval, planning and designing interval, building and debugging interval. In addition, there will be enhancements to improve project's performance. and finally, the testing interval. Furthermore, the semester is limited for three months.

### 5.1.3 The Power

Dealing with the power is a big deal because there are multiple modules in the project. Each component varies than the others. In the bus, there will be some 12 Volts, 6 Volts batteries and power-bank to get the needed power to run it. Other modules are less challenging and can be powered by a USB with low current needed.

### 5.1.4 The Cost

The project has multiple components, each will cost money, But the point of such project is to find an economic system with lower cost as possible to meet the financial level. as well as make it attractive to anyone who is willing to use it.

## 5.2 Earlier Coursework

The knowledge of the participants in Hardware was gained in the Computer Engineering Department from all the courses that we have taken such as: Microprocessor, Micro-controller, Electrical Circuits, Digital Design, Critical Thinking Research and Computer Networks. Other knowledge was gained by participating in some courses and sessions online.for example:

1. Arduino course
2. ESP8266 & ESP32 course
3. Django Framework
4. Flutter Framework
5. Firebase
6. Aws Lambda Service

## 5.3 Standards and Protocols

### 5.3.1 HTTP

Hypertext Transfer Protocol (HTTP) is an application-layer protocol for transmitting hypermedia documents, such as HTML. The HTTP protocol was designed to communicate between web browsers and web servers, but it can also be used for other purposes. HTTP is a stateless protocol, this means that the server does not keep any data (state) between two requests.[5]

### 5.3.2 I2C

The I2C communication bus is very popular and broadly used by many electronic devices. It can be easily implemented in electronic devices which require communication between a master and multiple slaves or even multiple master devices. The easy implementations is because the it requires only 2 pins for communication (SDA and SCK) between up to almost 128 (112) devices when using 7 bits addressing and up to almost 1024 (1008) devices when using 10 bits addressing.[4]

### 5.3.3 SPI

Serial Peripheral Interface (SPI) is an interface bus commonly used to send data between micro-controllers and small peripherals, sensors and SD cards are common. It uses separate clock (sck) and data lines(MISO,MOSI), along with a select line (cs) to choose the device willing to contactto.[7]

# 5 Literature Review

Cities growth is one of the challenging trends among the world. Providing services in a certain quality might be hard these days but for sure it is getting harder by time. Water, electricity, buildings, healthcare, and transportation systems are some of the aspects and surly there is more.

One of the challenges among large cities is the transportation system. There are multiple models of transportation including Air travelling, Sea travelling and Land transportation. Those 3 models are applicable in most countries across the world. Air travelling is applicable across travelling across countries. Some counties actually use airlines to connect cities or states inside the same country. Sea travelling or Maritime traveling is one of the most efficient way to move a large number of passengers and payloads. It is cheap, cost effective and amazing way to see the world. Last way of travelling is land travelling. Trains, buses, cars and trucks are some of the vehiclesused to travel by land[8].

Returning back to Block cements called cities, cars Buses and Subways metro are the most systems used to travel by land. Subways requires a huge budget to be applied and ofcourse the most important a suitable and supportive infrastructure. Subways require a large wide streets and a very organized infrastructure and a strong built buildings to endure the constructions work around them.

Cars and buses are more suitable for remote places and poor countries but they face a lot of problems due to traffic, narrow streets and old systems they are using. Security and safety systems are another story, payment systems are varying between company to other.

Palestine is one of the countries that are considered a poor one. It is occupied and has no sovereignty over it's land. This and more making a subway system looks like a dream for those people. What about cars and buses? well, cars and buses are the most used in this country. Though,it is still challenging to manage these buses into more efficient way due to traffic, and the bad infrastructure in most cities as well as the traditional system of a bus is moving from point A to point B among cities but not inside the same city. There are some exceptions ofcourse but still itis not the case in most places.

To run a bus system ( or any other transportation system ) it should be a convenient easy to use and ease the life of the passengers. Safety and emergency precautions are needed too. Making the system more time efficient and less time consuming would make it better. Monitoring and safety are important too. Monitoring can help running some Machine Learning models to improve the system efficiency and to pass the peak times with less effort. It also helps improving the whole system by noticing where are the problems and who to be improved which means providing a better service and a more reliable one. Tracking is a good point too! but how? well, if the buses were tracked all the time this will provide data on how where and why the paths can be changed into depending on the behavior of the passengers. This feature can be also used to provide an application that shows the buses in real time and estimate how much time it would take a bus to reach a certain point. Stations are another way to improve the service.

# 6 Methodology

## 7.1 Equipment and Components

### 7.1.1 Arduino Mega

Arduino Mega is a powerful microcontroller board that offers an extensive range of features and capabilities. It is an upgraded version of the standard Arduino board, providing more input/output pins and memory capacity. With its 54 digital input/output pins and 16 analog inputs, the Arduino Mega offers ample connectivity options for various components and sensors. In the context of our application, we connect the Arduino Mega to the water pump, MQ2 sensor, and window motor. The water pump, controlled by the Arduino Mega, allows for efficient fire suppression by delivering water when needed. The MQ2 sensor, connected to the Arduino Mega, enables the detection of gases such as smoke, ensuring timely fire detection and safety measures. Additionally, the window motor, also connected to the Arduino Mega, enables automated control of window operations. By utilizing the Arduino Mega's capabilities and its compatibility with a wide range of components, we can create a comprehensive and efficient system that integrates these devices seamlessly, enhancing fire safety and automation in our environment.

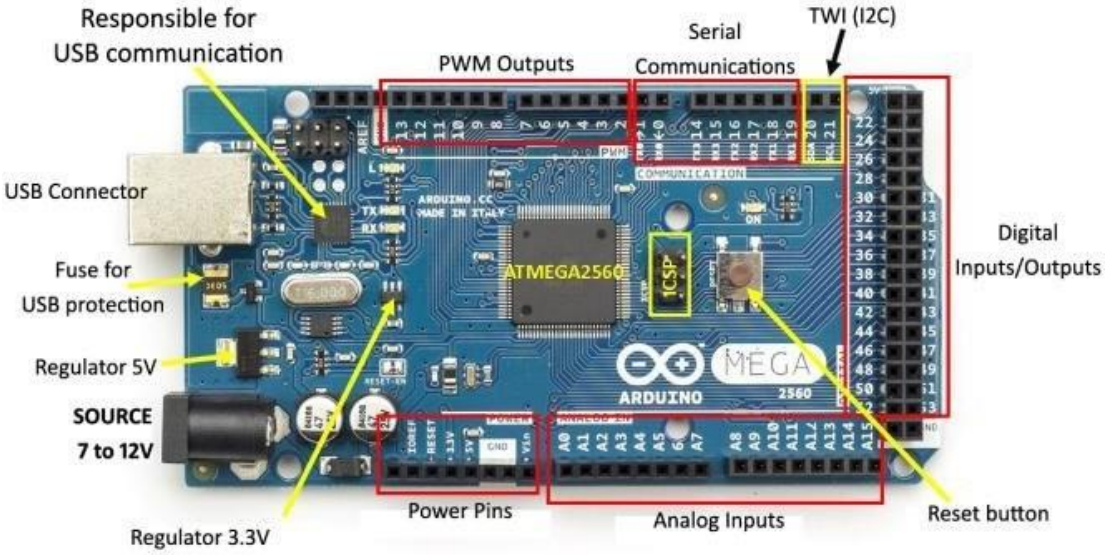



Figure 1: Arduino Mega 2560

### 7.1.2 Arduino Uno

It is a microcontroller board developed by Arduino .c. It has 6 analog inputs, 14 digital outputs/inputs pins. A 16 MHz ceramic resonator (CSTCE16M0V53-R0) [3].
The Arduino Uno has been used to read the keypad to select the trip id by Captain and send this value serially to the ESP8266.

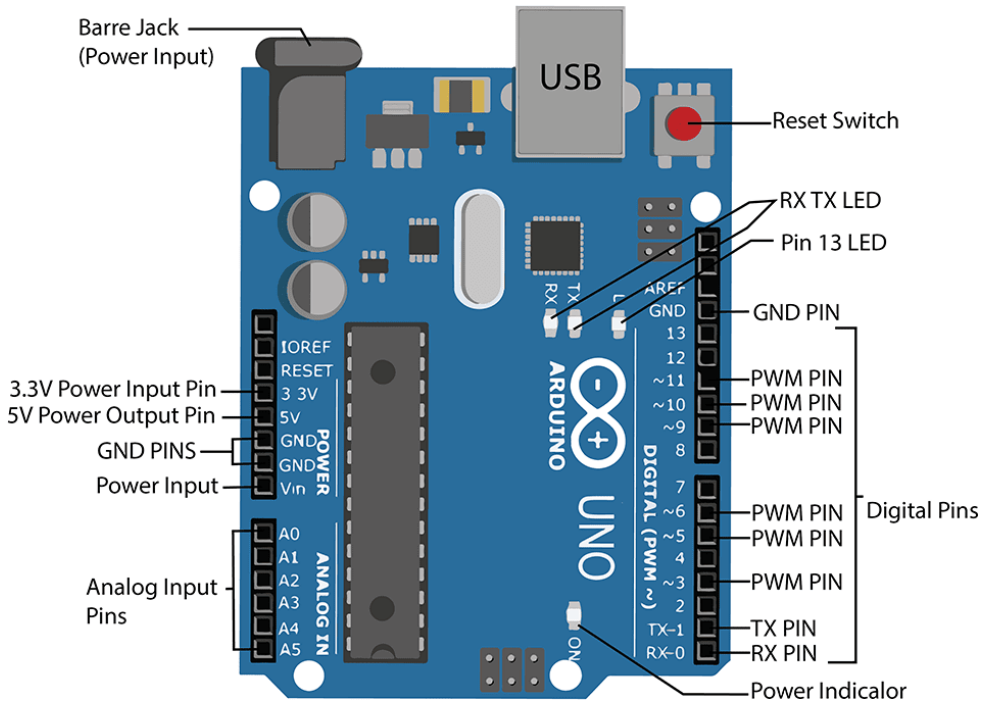



Figure 2: Arduino Uno

### 7.1.3 NodeMCU ESP8266

NodeMCU ESP8266 is an open source platform based on ESP8266 that can connect objects using Wi-Fi to send and receive data [1].
NodeMCU ESP8266 used to connect RFID to scan the cards, read the ID and send it to the server, then the server will deduct the exact amount of the trip and return the remaining amount in the card.
It was also used with the keypad to send the travel number to the server to associate the captain with the travel he selected.
Additionally, we used the nodemcu with a tensioner driver to move the wheels wirelessly using the app.
And also send the GPS reading to the server.

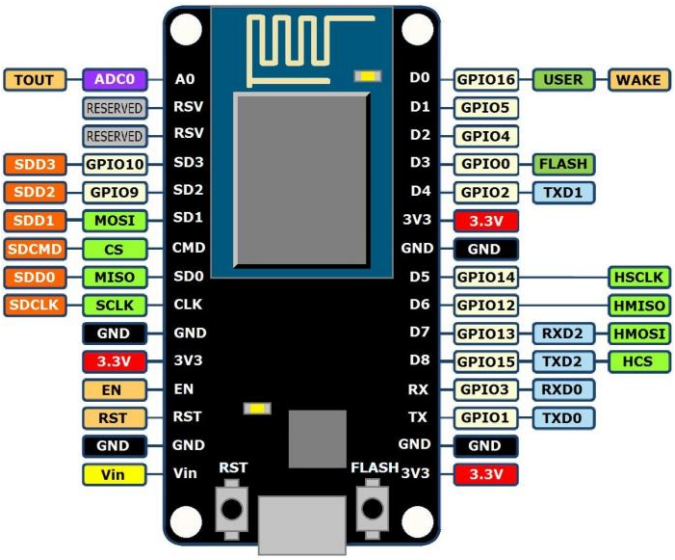



Figure 3: MCUNode ESP8266

### 7.1.4 A6 GPRS/GSM

The A6 module has a serial port for GPRS communication. Using a (TX,RX) serial connection, Arduino (or any other controller) can communicate with the module. The module works well with Wi-Fi-independent applications, primarily SMS and voice calls.

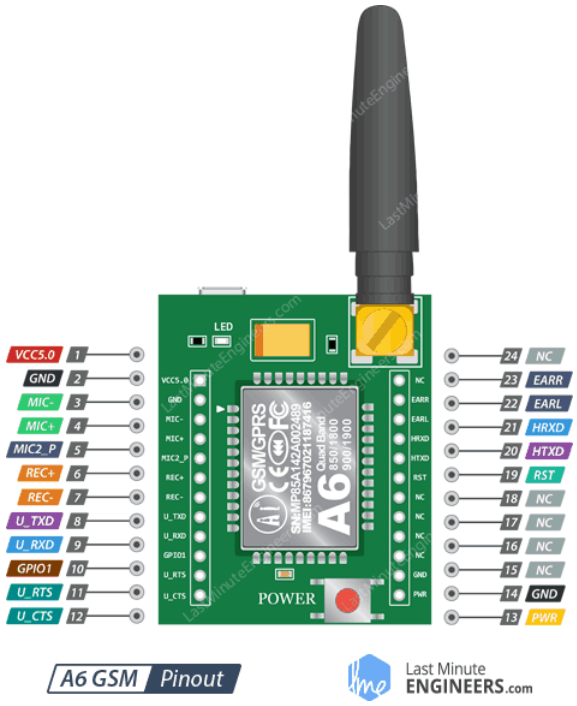



Figure 7: A6 GPRS/GSM module

### 7.1.5 RC522 RFID

An RFID, or radio frequency identification system, is made up of two major components: a card or tag connected to the item to be recognized, and a reader that scans the card (or tag).
The reader is made up of an antenna that produces a high frequency and a radio frequency module.

electromagnetic field (13.56 MHz). The Card (or tag) is a passive device without a battery. It is made up of an antenna for receiving and sending signals as well as a microprocessor for processing and storing information.
The module includes 8 pins for powering: VCC and GND (notice that VCC is 3.3 volts; introducing 5 volts will break the module). Communication using IRQ, Reset, and SPI (SS, MISO, MOSI, and SCK).

Figure 8: RFID reader


### 7.1.6 Servo Motor

When there are elevated CO2 levels, the CO2-Activated Window Opening System uses an Arduino microcontroller, a servo motor, and a CO2 sensor to automatically open a window. When the threshold is reached, the Arduino analyzes data from the CO2 sensor and sends the servo motor to open the window, encouraging fresh air circulation and enhancing indoor air quality. Compact and simple to install, this system improves comfort by effectively reducing stuffiness in the bus .


Figure 9: Servo motor

### 7.1.7 MG811 CO2 Module

MG811 is a sensor that is sensitive to CO2 and less sensitive to other gases providing lower current if the CO2 level is high and Higher current when the CO2 level drops down. The interaction can be done by reading the sensor as digital but the easier way is to read analog signal directly using VCC GND for power and Aout for analog.

Figure 10: MG811 CO2 module

### 7.1.8 L298N Motor Driver Module

This module provides an H-Bridge to control the directions of the DC motors. It takes 5 - 35 volts as an input voltage and reflects it as output. Other inputs used to control the direction and speed using pulse width modulation.

### 7.1.9 LCD with IC2 module

16*2 LCD has been used with I2C to indicate the messages , its display the ip , and the card no and the message gets from server , additionally its display the keypad input using wireless communication with another NodeMcu .

Figure 11: 16*2 LCD with IC2

### 7.1.10 37mm 24DC Low Speed Geared Motor

4 Dc motors used to mock the bus movement and being controlled by a mobile application.


Figure 12: DC low speed geared motor

### 7.1.11 Keypad

A keyboard matrix of 4 * 3 is used to send the number of the trip that the captain wishes to start with, and the trip is associated with him in the database.


Figure 13: Keypad

### 7.1.12 MQ2 (Smoke Sensor)

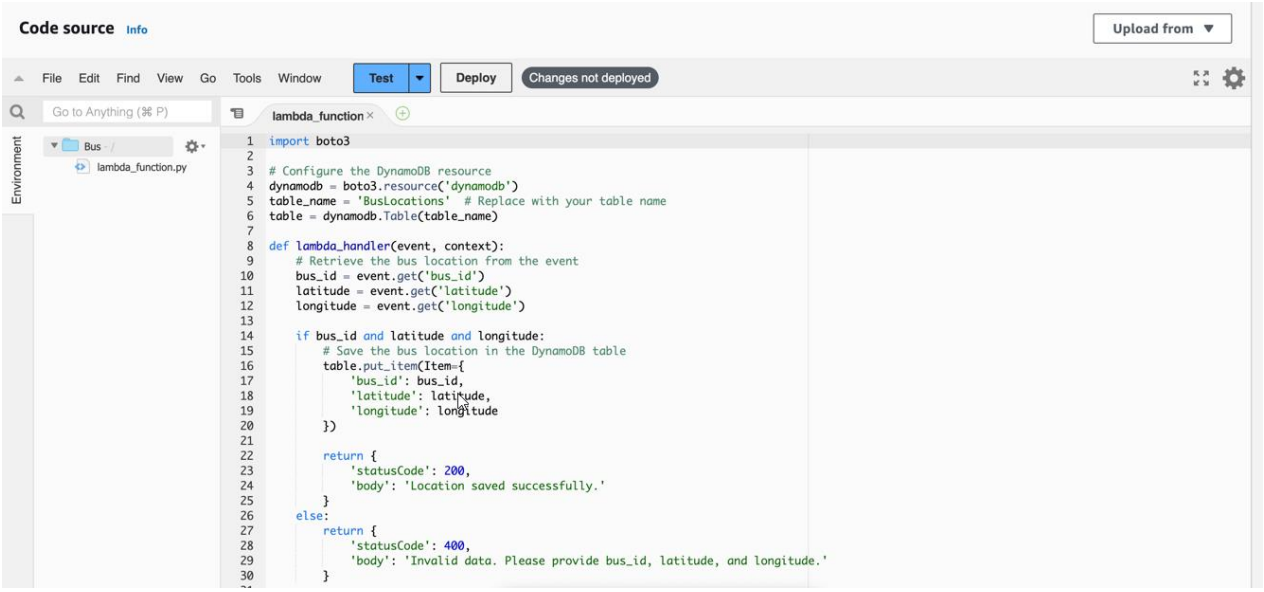
The MQ2 sensor is a versatile gas sensor module widely utilized for detecting gases like methane, carbon monoxide, alcohol, propane, and smoke. This sensor module operates by employing a small heater and a sensing element to measure changes in gas concentration. In particular, when the MQ2 sensor detects the presence of smoke, it triggers the activation of a flame sensor. This additional sensor is designed to sense the presence of fire. Once the flame sensor confirms the presence of a fire, it initiates the turning on of a water pump. The water pump plays a critical role in fire suppression by delivering a stream of water to extinguish the fire effectively. By incorporating the MQ2 sensor along with a flame sensor and water pump, a comprehensive fire detection and suppression system can be created to enhance safety and mitigate the potential damages caused by fire incidents.


### 7.1.13 Water Pump

**A water pump is a mechanical device that is utilized to move water from one place to another. It serves a crucial role in a wide range of applications, including fire suppression in various settings. In the context of our bus, we employ a water pump as part of our fire safety system. In the event of a fire onboard the bus, the water pump is activated to deliver a steady stream of water to extinguish the flames. This helps to quickly suppress the fire and minimize potential damage or harm. The water pump is connected to a reliable water source, such as a tank or an external water supply, ensuring a continuous and sufficient water flow. By integrating a water pump into our bus's fire suppression system, we prioritize the safety of our passengers and take proactive measures to combat fire emergencies effectively.**

### 7.1.14 Neo 6m gps module

The bus system incorporates a Neo 6M GPS module that automatically calls an AWS Lambda service function when the bus starts. This function saves the bus's latitude and longitude every minute while the bus is running in database, ensuring continuous location tracking. The GPS module provides accurate location data, while the AWS Lambda function securely stores the information in real-time, enabling efficient bus fleet management and facilitating data-driven decision-making.


### 7.1.15 Power Source

Many power sources used in this project including batteries power banks and a USB cables that are connected to a computer or a suitable power adapter

### 7.1.16 Serial Cable

A serial cable is a vital component used to connect devices like ESP boards or Arduino microcontrollers to a computer for programming and communication purposes. These cables utilize the serial communication protocol to establish a connection between the devices. Typically, a serial cable consists of multiple wires bundled together within a protective outer covering. The most commonly used serial cable for programming ESP and Arduino boards is the USB-to-Serial cable. One end of the cable features a USB connector that can be plugged into a computer's USB port, while the other end has a serial connector, such as an RS-232 or TTL connector, that connects to the respective programming interface on the board. The serial cable allows bidirectional communication between the computer and the device, enabling programming code to be uploaded, data to be exchanged, and debugging information to be transmitted. It provides a reliable and efficient means of programming and configuring ESP and Arduino boards, enabling developers to unleash the full potential of these powerful microcontrollers.

Figure 14: Serial wire

Figure 15: Micro Serial wire

### 7.1.17 wires

Wires used to connect the components.

### 7.1.18 Breadboard

Breadboard used to ease wiring some parts and to supply power for multiple parts using 1 wire from the source.

### 7.1.19 Wooden Model

Bus wooden model to mock a real bus shape.

Figure 16: Wooden Bus Model

### 7.1.20 Python (Django Backend)

Django is a high-level Python web framework known for its versatility and efficiency in building robust web applications. With Django, developers can create complex websites and applications quickly and easily, thanks to its built-in features and elegant design patterns. It follows the Model-View-Controller (MVC) architectural pattern, which promotes separation of concerns and modularity. Django provides a powerful Object-Relational Mapping (ORM) system, enabling developers to interact with the database using Python code instead of SQL queries. It also offers a templating engine that allows for easy rendering of dynamic web content. Django's batteries-included philosophy means that it comes with a wide range of pre-built functionalities, such as authentication, form handling, and administration interfaces, saving developers time and effort. Moreover, Django promotes security best practices, including protection against common web vulnerabilities. Overall, Django empowers developers to build scalable and secure web applications, making it a popular choice for developers worldwide.

**GitHub : https://github.com/motaha1/bus_api**

### 7.1.21 Flutter

Flutter is a powerful open-source UI software development kit (SDK) created by Google that allows developers to build high-performance, cross-platform applications for mobile, web, and desktop. Using a single codebase, developers can create visually stunning and responsive user interfaces that run seamlessly on multiple platforms. Flutter's key strength lies in its reactive framework, which enables fast rendering and hot-reloading, allowing developers to see instant changes in real-time during the

development process. With Flutter, developers can leverage a rich set of customizable widgets, enabling them to create beautiful and consistent user experiences across different platforms. The framework also offers a wealth of pre-built components and libraries, saving developers time and effort in implementing common functionalities. Additionally, Flutter provides native performance by compiling the Dart code directly to native machine code, resulting in fast and smooth applications. Its extensive documentation, active community, and continuous updates make Flutter a popular choice for developers seeking to build visually appealing and performant cross-platform applications.

***Github : https://github.com/motaha1/smart_bus_flutter***

### 7.1.22 PythonAnyWhere

PythonAnywhere is a cloud-based platform that provides developers with a fully-featured Python environment accessible from anywhere with an internet connection. It allows users to write, run, and deploy Python applications without the need for local installations or configurations. PythonAnywhere supports Python 2 and Python 3, and it offers a web-based code editor with syntax highlighting and code completion. Users can easily create and manage virtual environments, install third-party libraries, and run Python scripts or web applications. The platform also provides a console where users can execute commands and interact with their Python environment. PythonAnywhere supports scheduled tasks, allowing users to automate certain processes or run scripts at specific times. Moreover, PythonAnywhere supports popular web frameworks like Django and Flask, enabling users to deploy their web applications directly from the platform. Overall, PythonAnywhere is a convenient and accessible solution for developers to work with Python projects from any device, making it ideal for learning, prototyping, and deploying Python applications.

url : https://motaha2001.pythonanywhere.com/admin/

AWS Lambda :

AWS Lambda is a serverless compute service provided by Amazon Web Services. It allows you to run your code without provisioning or managing servers. With AWS Lambda, you can upload your code, define triggers, and let the service handle the rest. When a trigger event occurs, such as changes in a database or incoming messages, AWS Lambda automatically scales and runs your code. You are only billed for the actual compute time consumed by your functions, making it a cost-effective solution. AWS Lambda is widely used for various use cases, including real-time file processing, web and mobile backends, data transformations, and building serverless applications. Its event-driven architecture and seamless integration with other AWS services make it a powerful tool for developers, enabling them to focus on writing code rather than managing infrastructure.

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## A GUI for the web and mobile application

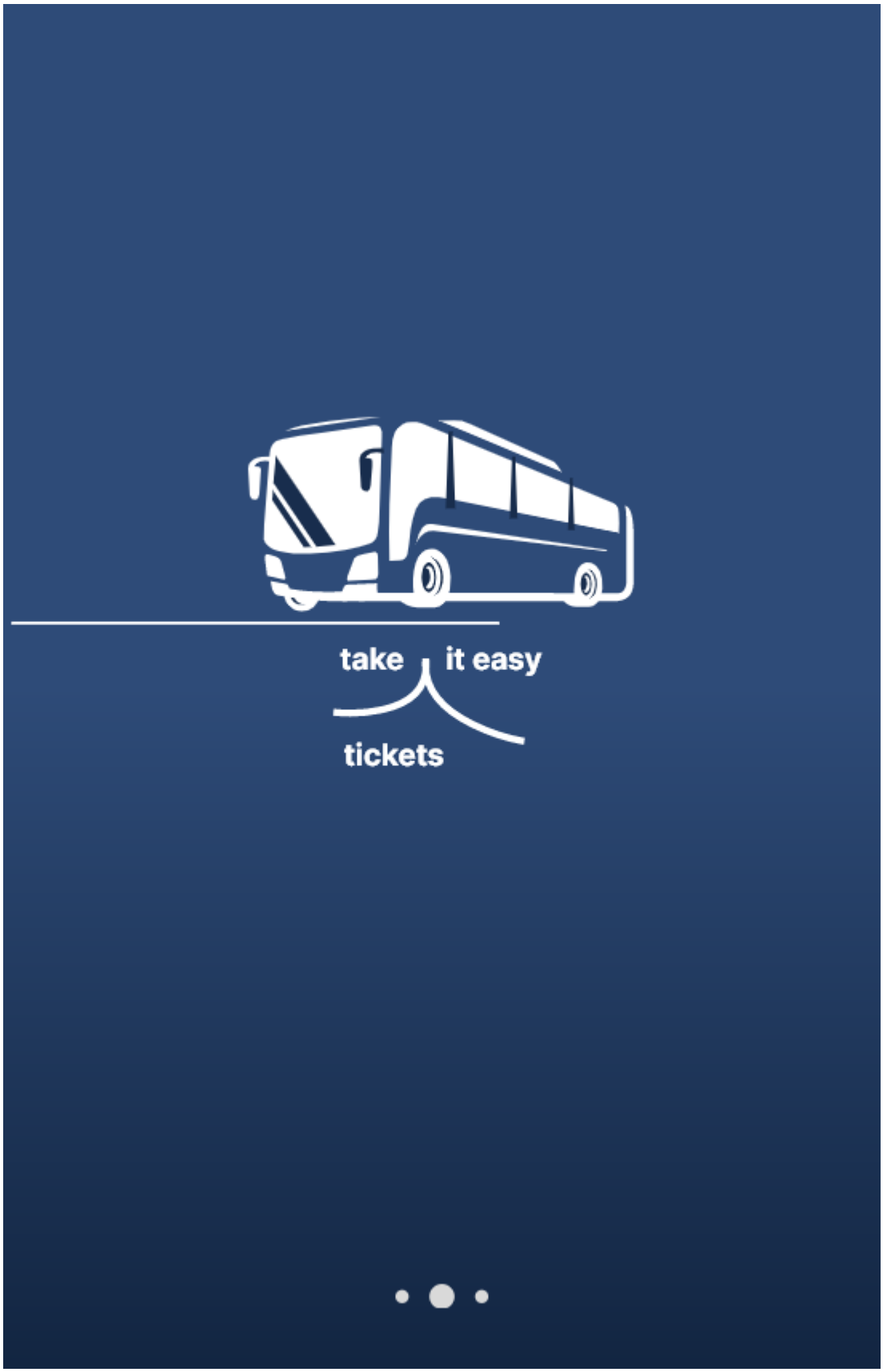


Figure 18: Home Page

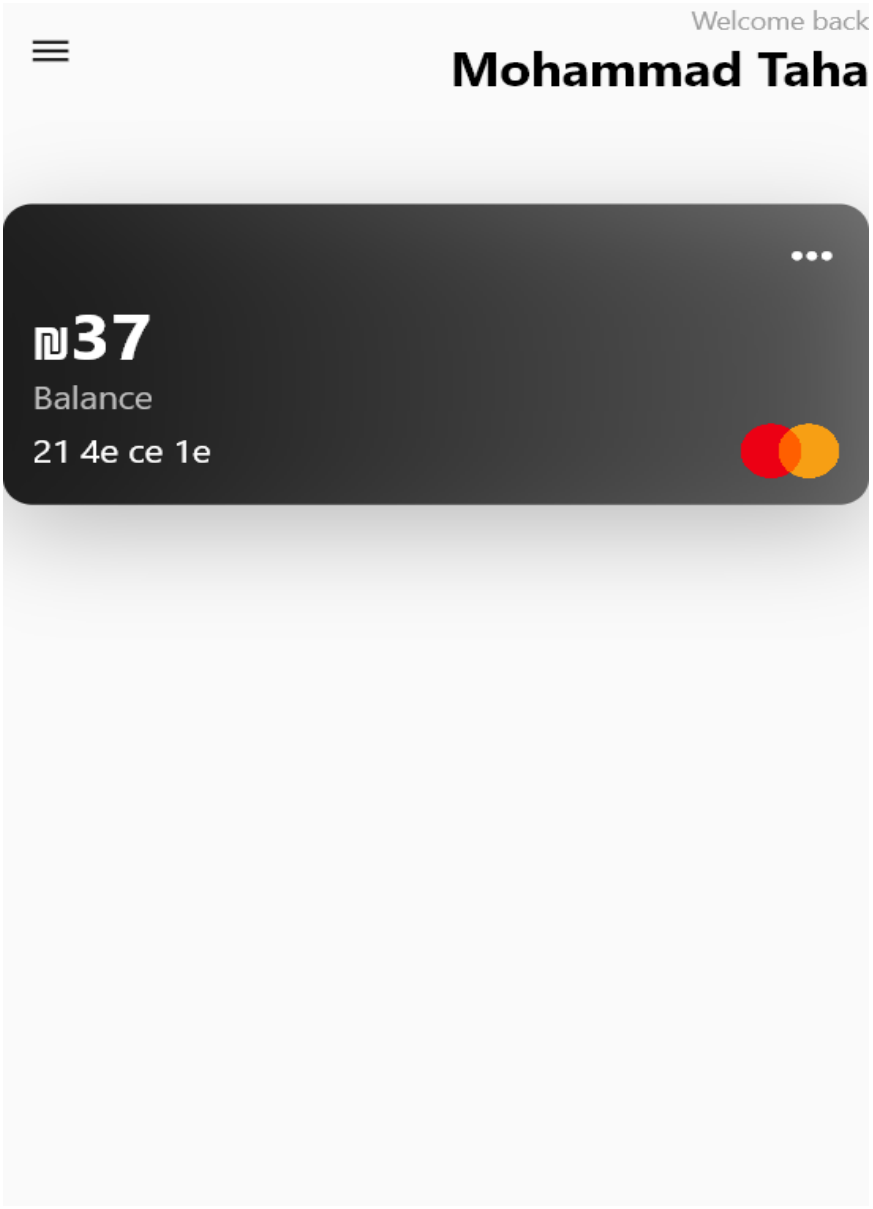


Figure 20: Buses Locations Page

Figure 22: Gps Page

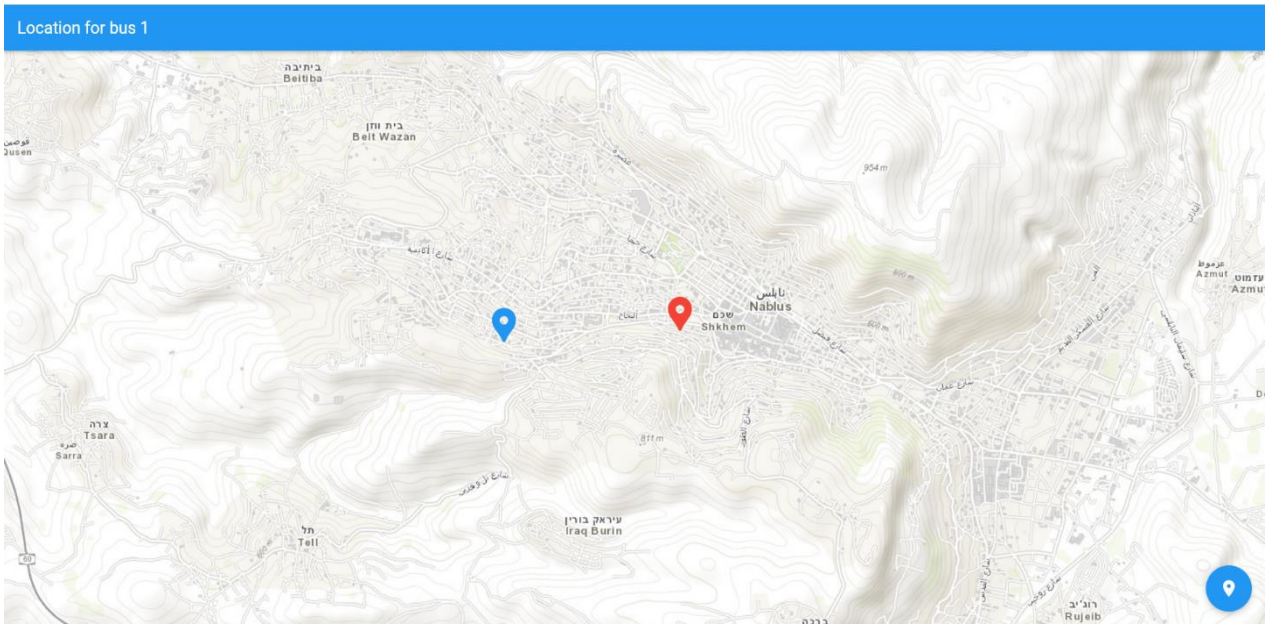


Figure 23: Adding New Card Page

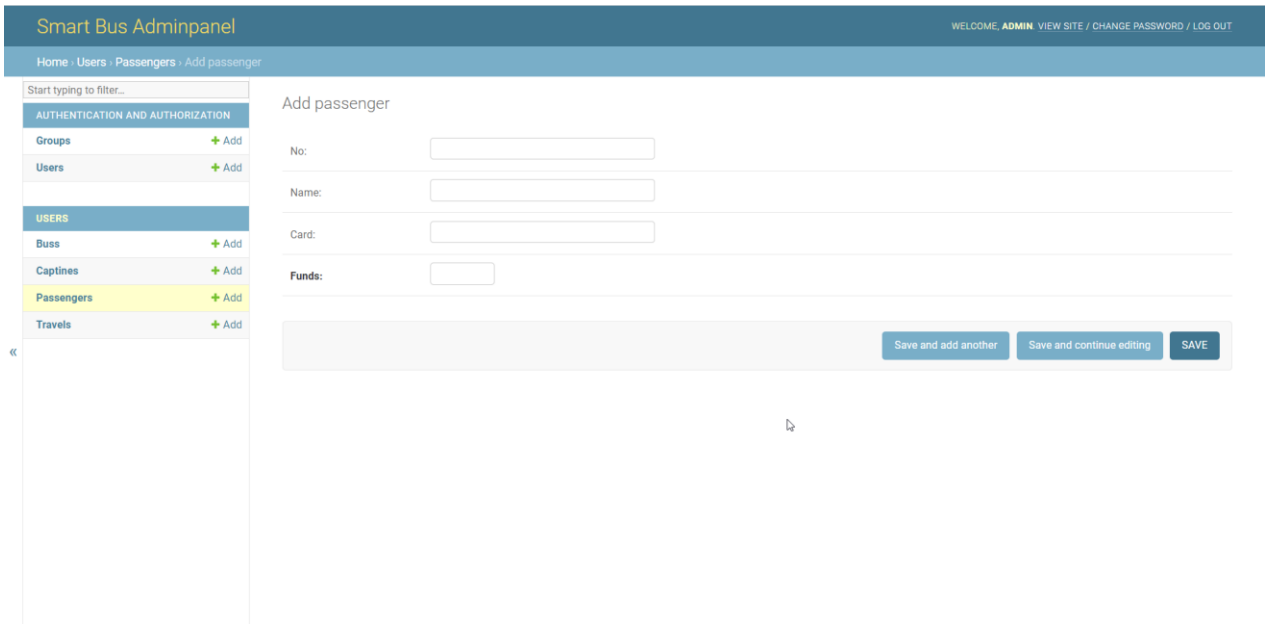
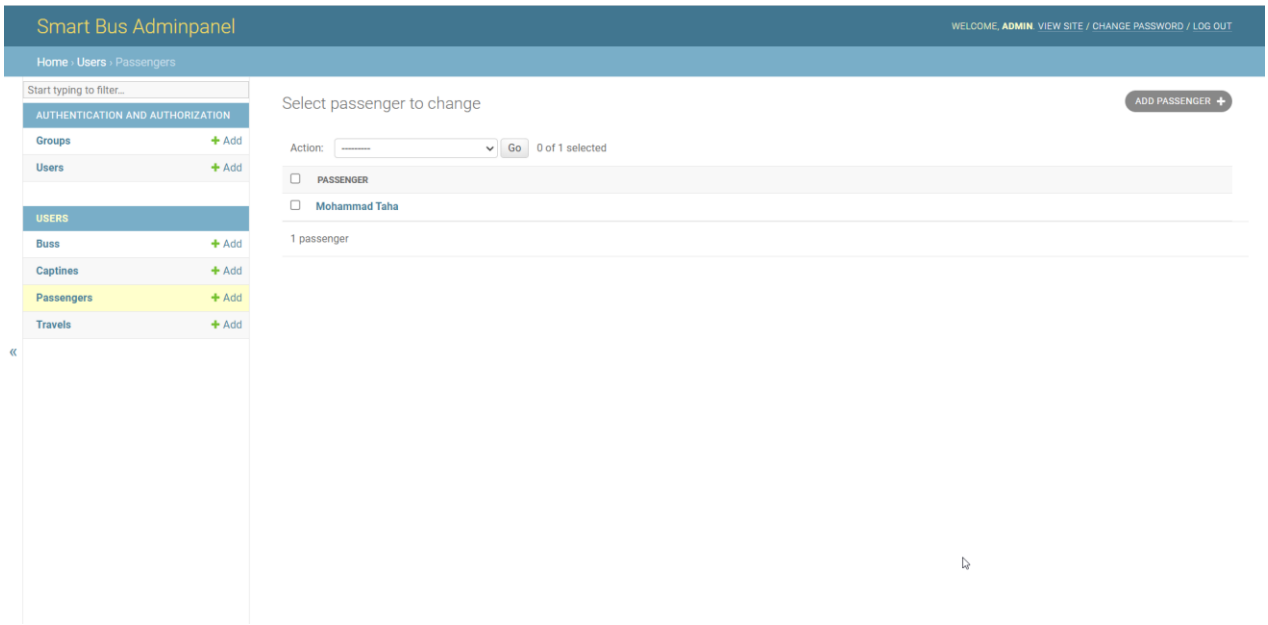



Figure 24: All Cards Page



# 8 Discussion

The primary objective of this project is to enhance the user experience of the local bus system in economically challenged regions like Palestine, where the construction of subways or train rails is not feasible. Several improvements have been implemented to achieve this goal, including the integration of safety features, enhancements to user experience, the implementation of an independent payment system, the separation of certain functionalities from the server to improve communication, and the overall reliability of the system.

During testing with Arduino, it was observed that while the CO2 sensorare effective, they may have limitations. For instance, they may not be able to differentiate between CO2 rise due to a fire or normal overcrowding on the bus. Additionally, the current bus door system utilizing RFID technology needs to be replaced with a tripod turnstile and emergency cards to address situations where passengers need to retrieve their forgotten belongings. To ensure a more reliable connection, Bluetooth should be replaced with an ESP or another Wi-Fi module for seamless communication between the bus and the station.

Expanding the functionality of Firebase beyond simple ID-value pairs could provide additional features such as gifts or client classes, along with gathering more data about trips to offer targeted promotions and increase sales. Furthermore, incorporating specific functionalities or encoding into the bus cards would enable their usage even in the absence of internet connectivity or server downtime, eliminating the dependency on the server for a certain number of trips. These improvements aim to streamline and simplify the system, making it more efficient and user-friendly.

# 9 Conclusion

There is no perfect system and as the technology improves the more the systems improved. It is just a big circle aims to provide the best way with the available technologies.

Improvement is a journey that never ends. and here is some points this system can be passing through to be mature enough.

1. ML... ML ... ML, Machine learning is the best way to study the data that collected from the users and this makes it possible to notice how to improve the service.
2. Independency, the system is dependent on the server in way too many cases but providing some ways to save the state and sync it when possible will provide more reliable system and still can work with down servers and last for maybe some days providing enough time to save the user data.
3. security and safety is a big problem that can never be done from. Safety of the passengers and how to protect them in case of accidents and fire is a way from being done and this could be a very good topic to dive into.
4. Some problems were mentioned in the discussion so another look would be great to get a bigger idea.

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