EVIONICS – POWERING THE GROWTH OF

E-BIKES IN PAKISTAN

FINAL YEAR PROJECT UG 2019

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DEDICATION

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Stations

SUSTAINABLE DEVELOPMENT GOALS CONTRIBUTION

The Sustainable Development goals (SDGs) are established by the United Nations in 2015 to address the world's most pressing social economic, and environmental challenges and provide a framework for addressing these challenges and guiding collective efforts towards a more sustainable future. This includes a comprehensive set of 17 global goals.

Our project meets 4 out 17 SDGs set forward by the United Nations.

ABSTRACT

Electric vehicles (EVs) are gaining popularity as a more sustainable substitute for traditional gasoline-powered automobiles. They not only release less pollutants, but they also lessen climate change and air pollution. However, maintaining these cars calls for a sufficient charging infrastructure, which may be extremely difficult for underdeveloped nations like Pakistan. Three objectives were looked after by the study that was done to solve this problem. The initial goal was to find ideal locations for solar energy-based charging stations in Islamabad, Pakistan, using a multi-criteria decision analysis (MCDA) method based on geographic information systems (GIS). This strategy included considering several variables, including solar availability, land use patterns, accessibility, and preexisting infrastructure. A weighted linear overlay was used to create the final suitability map after methodologies like the Analytic Hierarchy Process (AHP) were used to set the weights for these parameters. The best locations for charging stations were found using this map. The second goal was to create a mobile application that would allow customers to search for local charging stations and reserve a spot for charging. React Native, was used to create the application. Real-time information on charging station availability, scheduling a session for charging, paying for the charging service, and leaving comments on the charging experience are all elements of the app. The third goal was to create an Internet of Things-based battery swapping system that enables consumers to switch an empty battery for a charged one. With this method, customers may replace their used batteries with fully charged ones at various sites that have been installed with battery switching stations. The battery swapping mechanism is a useful solution to the problem of lengthy EV charging periods and lowers user range anxiety.

These three goals have been combined to create a complete plan for sustainable EV charging infrastructure in Islamabad. For EV customers, dependable and environmentally friendly charging choices are provided via solar energy-based charging stations and an IoT-based battery swapping system, and a mobile app makes it simple for them to find and reserve charging stations. This remedy can serve as a template for other Pakistani cities and towns in other developing nations that want to encourage sustainable mobility.

CHAPTER 1

INTRODUCTION

The automobile sector has grown to be one of the most significant industries in the world, not just economically, but also in terms of research and development. Electric vehicles (EVs) are rapidly becoming a popular mode of transportation worldwide, as they offer several benefits over traditional gas-powered vehicles. The depletion of fossil fuel supplies and CO2 emissions are forcing governments to look for an alternative option. Cities transitioning from a fossil-fuelled to an eco-friendly automobile fleet might lead the way to a more sustainable future. To reach climate change stabilization targets, it is becoming increasingly obvious that a large-scale transition from the internal combustion of petroleum fuels to electric-drive cars powered by low-carbon energy sources will be required. Keeping in view of the current environmental and economic challenges, electric vehicles seem to be a promising option to overcome these problems. According to the world economic forum, 1 in 7 cars sold globally now is electric while in 2017, just 1 in 70 cars sold was electric. Electric car sales went up by 60% in 2022 globally. As the demand for electric vehicles rises, there is a greater need for a dependable charging infrastructure to support the general population's quick uptake of this mode of transportation. Faced with a slew of cross-sectoral and multifaceted hurdles, Pakistan has lately opted to transition from ICEs to EVs, with a range of policy alternatives for automakers, customers, and global stakeholders. By switching to electricity, a domestic energy source, they lessen their reliance on petroleum goods for energy. However, electric automobiles have infrastructural issues. The issue of range, which is the largest drawback of electric vehicles, needs to be resolved, therefore charging infrastructure must be developed and provided.

1.1. Techniques for Site Selection

1.1.1. Multi-Criteria Decision Methods

MCDA is a collection of systems analysis techniques for handling complex decision-making issues like site selection. Multiple studies used MCDA for the selection of suitable sites for charging stations such as Analytical Hierarchy Process (AHP), Weighted Linear Combination (WLC), Analytical Network Process (ANP), Fuzzy AHP, TOPSIS, and a combination of these. For Ankara, Turkey's capital, a combination of the Fuzzy analytical hierarchy process (FAHP) and TOPSIS was used for the optimal siting of charging stations. The study considered 15 factors depending on environment, economics, and urbanity. GIS and MCDA were employed for finding suitable locations for charging stations and to calculate weights Analytical Hierarchy Process (AHP) and FAHP were applied for the city of Istanbul. Furthermore, TOPSIS is applied to rank alternative locations. Another study combined Geographic Information System (GIS) and MCDA to select sites for installing PVCS (Photovoltaic Charging Stations) in Beijing, China.

1.1.2. Analytical Hierarchy Process

Thomas L. Saaty in the 1970s, developed this method. AHP is extensively applied, studied, and refined ever since. AHP is a system that combines math and psychology to organize and analyze complicated choices. This uses expert's opinion to judge scores by dividing complicated problems into sum problems and forming a hierarchical system. It consists of three parts: the primary objective or issue you're attempting to resolve, all potential answers, or alternatives, and the standards by which you'll evaluate the options. By putting the decision's criteria and potential outcomes into numerical form and connecting them to the main objective, AHP offers a logical framework for making necessary decisions. The importance of criteria is assessed through pairwise comparison, two at a time. Finally, based on these numerical values the most desired solution is selected.

1.1.3. Solar Energy based charging station

Another aim of this study is to locate sites for EVCSs that have maximum solar potential. Two objectives are served by increasing the use of renewable energy sources: first, to reduce carbon dioxide emissions, which will lessen the effects of climate change; second, to increase the security of the energy supply by reducing the use of fossil fuels, which will increase the use of renewable energy sources. The study of this research's findings reveals that research on photovoltaic energy is expanding and may play a significant part in meeting the world's growing energy demand. Due to the strain on local electrical infrastructures, renewable energy sources with natural abundance and low cost, such as wind and solar, are needed. A study indicates that significant penetration levels of photovoltaics and electric cars are required to meet CO_2 emission objectives, which emphasizes the necessity for daytime charging infrastructures, most likely at or close to workplace facilities.

1.2. Mobile Application

The second objective of this study is to build a mobile application to facilitate the users. The mobile application consists of multiple features. Firstly, the application can help the EV driver to locate nearby charging stations, secondly, it can help the user to book a charging slot in advance. Another interesting feature is to compare the cost of fuel and electric charging of the vehicle. React native expo was employed for developing this app. For the database of application firebase was used.

1.3. Battery Swapping System

Due to multiple benefits, battery swapping became popular as it can car recharging duration, manage the load on the power grid and help maintain battery life. In another study battery swapping systems, charging stations, and residential buildings were considered to propose a cooperative operation to minimize the operational cost. Fast charging is a key factor, as swapping the depleted battery with a fully charged battery can be significantly fast. This can improve the productivity of electric vehicles as they spend less time off the road. Now stopping for charging while traveling can highly impact your travel time. The battery-swapping system enables the user to spend less time on charging which eventually shortens the travel time. Studies have also proven that swapping batteries reduces the stress on a single battery which thus improves the life span of a single battery. This can also influence the cost of EV ownership and make them a more attractive option for transportation.

Overall, this can be a huge help to overcome the barriers to the adaptation of electric vehicles by providing time-saving and efficient infrastructure for the maintenance and charging of electric vehicles.

CHAPTER 2

MATERIAL AND METHODS

2.1. Site suitable analysis for the location of solar-based EV charging stations in Islamabad.

2.2. Locating suitable sites for EV charging stations involves numerous parameters and criteria. This process can be a time-consuming and complex process. However, efficient technology and GIS techniques can facilitate this process. In this research, we aim to use GIS to locate suitable sites for the installation of solar energy-based charging stations for EVs in Islamabad. For the selection of a suitable criterion, multiple aspects were considered with respect to its impact on the environment and geographical factors. In the earlier stages of the analysis, several criteria were analyzed and finalized using a literature review prior to further GIS techniques. Criteria taken reflected environmental and geographical factors.

2.2.2. Study Area

Pakistan's capital city, Islamabad, is situated in the nation's northern region. It is a component of the Islamabad-Rawalpindi metropolitan region and is located at the base of the Himalayas. Islamabad is positioned 540 meters above sea level and covers a total area of 906 square km. It's situated at 73.05°E longitude and 33.69°N latitude. The Pakistan Bureau of Statistics estimates that Islamabad has 1.2 million residents. With a population growth rate of 4.91% each year, Islamabad is among the cities in Pakistan that are expanding at a rapid pace. With residents from all around Pakistan and other nations, the city boasts a diversified population. Islamabad has been divided into five zones and regulated by the Islamabad Capital Territory (ICT) government. Several other government agencies, including the Pakistan Supreme Court and the Prime Minister's Secretariat, as well as the National Assembly of Pakistan, are located in Islamabad. The Capital Development Authority (CDA), which oversees planning and development in the city, is one of several development authorities that are in Islamabad in addition to the ICT administration. The city's infrastructure, including the roadways, water supply, and sewage systems, is managed by the CDA. ICT administration and various development authorities work together to oversee Islamabad, a rapidly expanding city with a diverse population.

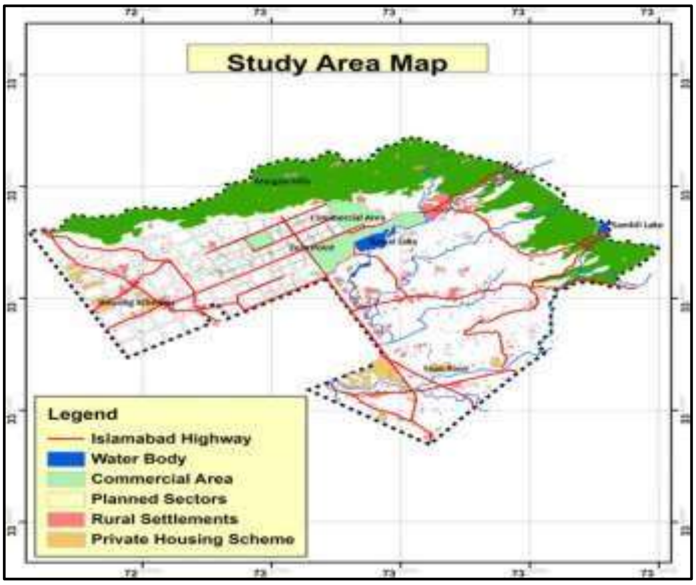

Figure 1 Islamabad

2.2.3. Data Sets and Layers.

2.2.3.1. Solar Potential.

As this study aimed to locate sites for hybrid charging stations an essential aspect of this analysis is the solar potential of Islamabad. The target is to find locations that have the best solar potential. To calculate the solar potential of Islamabad we used ArcGIS. The digital elevation model (DEM) of Islamabad is used for this analysis. Multiple preprocessing steps were involved such as projecting the data, the linear units should be meters, also, create a hill shade to clearly visualize the features like trees and buildings. Solar radiation is calculated using the spatial analyst tool. ArcGIS comes with an area solar radiation tool to calculate. This tool considers the position of the sun and the light-blocking obstacles. The output is a raster that shows the solar radiation in watts per hour per square meter. While using this tool mention the desired year and hour interval. For topographic parameters, one can choose calculation direction, for example, for 32 each cell will be checked from 32 direction for light obstacles. To reduce the reading to a smaller number, divide the raster by 1000. Now the values are in kilowatts per hour per meter square.

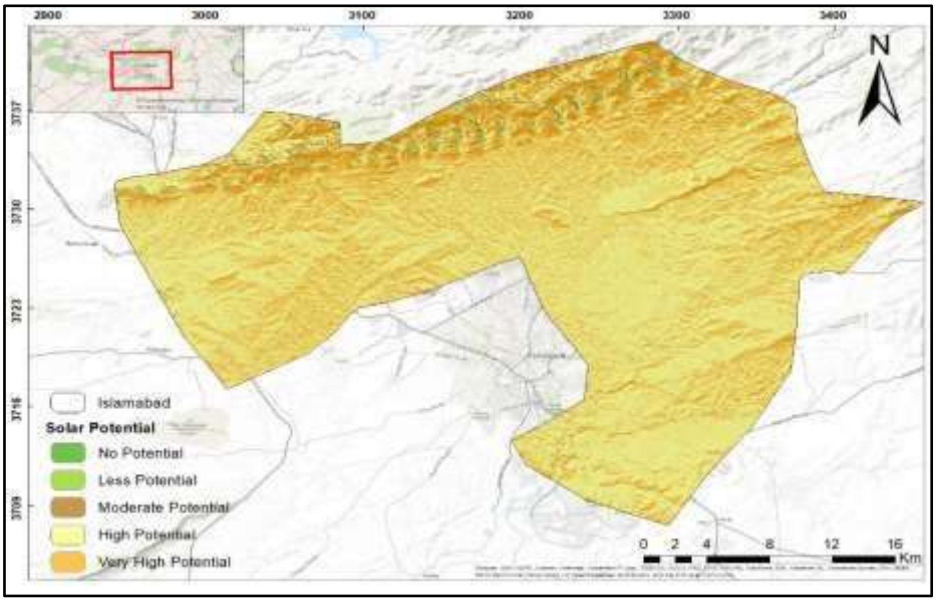

Figure 2 Solar Radiation of Islamabad

2.1.3.2 Flood Prone Area.

To ensure that we get the best possible sites to install the charging stations we considered ruling out the areas that could be prone to flooding. Factors that contribute to flood-prone areas can include natural features such as low-lying terrain, proximity to rivers, lakes, or oceans, as well as human-made structures like dams or levees that can fail and cause flooding. ArcGIS hydrology tool extension is used to perform this analysis. Through expert opinion and literature review, we came up with five factors that should be considered while generating a flood risk map.

Influential Factors:

- Elevation
- Slope
- Land use/landcover
- Precipitation
- Proximity to streams/channels.

We start by loading the data such as DEM, slope, landcover, and precipitation and generate hill shade map. After this performed the hydrological analysis such as fill, flow direction, flow accumulation, and extract streams. Calculate the proximity to streams.

We reclassify all the layers, and rate and score them. Finally, using a weighted sum we generated a flood risk map.

Table 1 Weights for hydrological analysis

FACTORS	INFLUENCES
Elevation	10%
Slope	15%
Land use/ landcover	10%
precipitation	35%
Proximity to streams/channels	30%

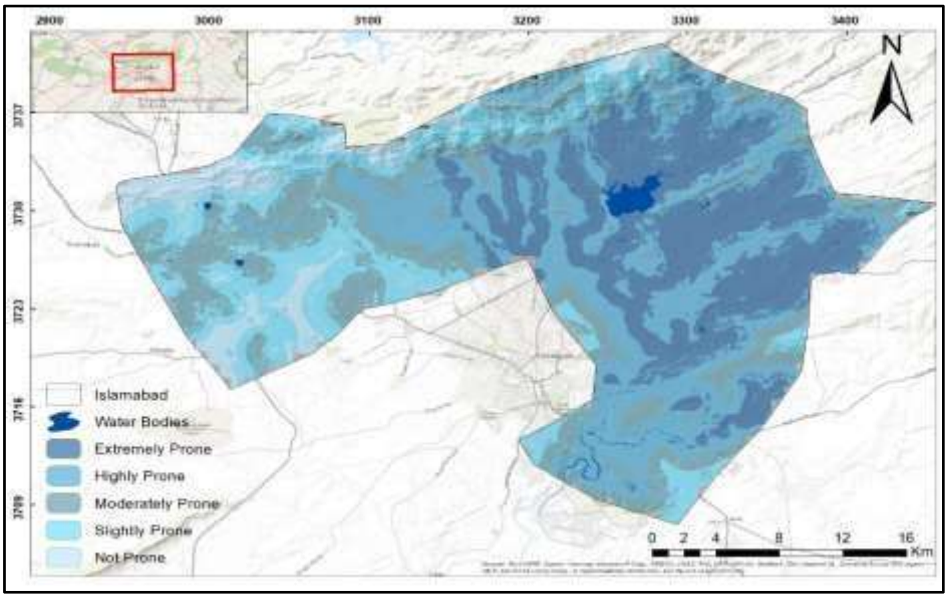

Figure 3 Flood Prone area of Islamabad.

2.1.3.3. Fuel Stations and Parking lots.

Islamabad is a rapidly growing city and land cost is very high in this city thus, it is very important to efficiently utilize the land. This study considered existin g fuel stations and parking around the city. This will make our project cost-efficient as we can use the existing infrastructure. To make a layer of fuel stations and parking we manually digitized the fuel stations and parking of Islamabad from google earth pro. There are multiple benefits to using these existing structures. These locations are easily accessible i.e., near roads and vehicles can approach these locations. It is easy to install the charging station on the existing conventional fuel stations as they have adequate areas for parking. Lastly, fuel station rooftops and parking have a huge solar potential which is a major aspect of this project.

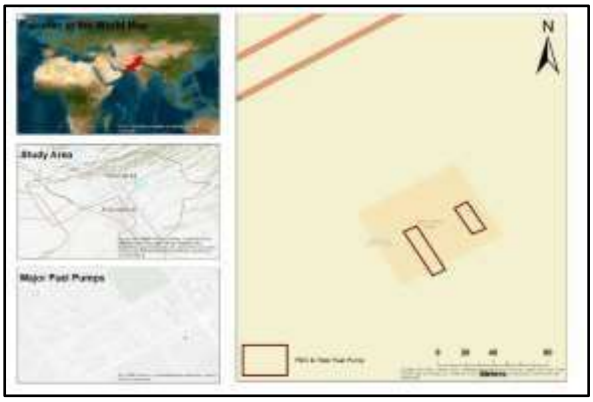

Figure 4 Fuel Stations in Islamabad

Figure 5 Parking lots in Islamabad

2.1.3.4. Land Use and Land Cover.

Land cover and land use provide critical information for determining a site's viability for a certain use or development, and their examination can assist uncover prospective development obstacles or possibilities. Land cover and land use can also have an influence on a site's socioeconomic circumstances, such as access to infrastructure, housing, and services. For example, urban regions often have better access to infrastructure and services than rural locations. In this study, the land use and land cover of Islamabad were divided into five classes: water bodies, shrubs, bare land, buildup area, and forest. These classes help us identify the potential zones for the installation of charging stations.

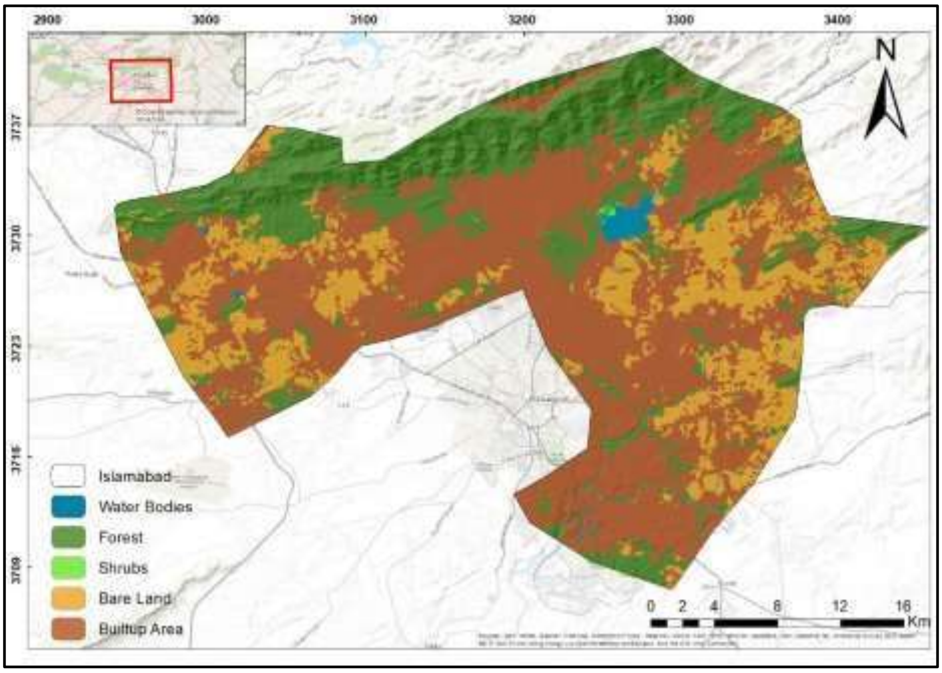

Figure 6 Land use/ landcover

2.1.3.5: Roads

Customers require fuel stations to be conveniently accessible, and highways offer a way for people to get there. Without roads, it would be challenging for consumers to get to charging stations to charge their cars. In this study, we target the primary roa ds of Islamabad. The data set used was from OSM (Open Street Map). The data were filtered in ArcGIS using. OSM provides a very detailed dataset, using the table of the content we selected the road through the “select by attribute” tool. Roads highly influence our end results as they are considered a primary factor.

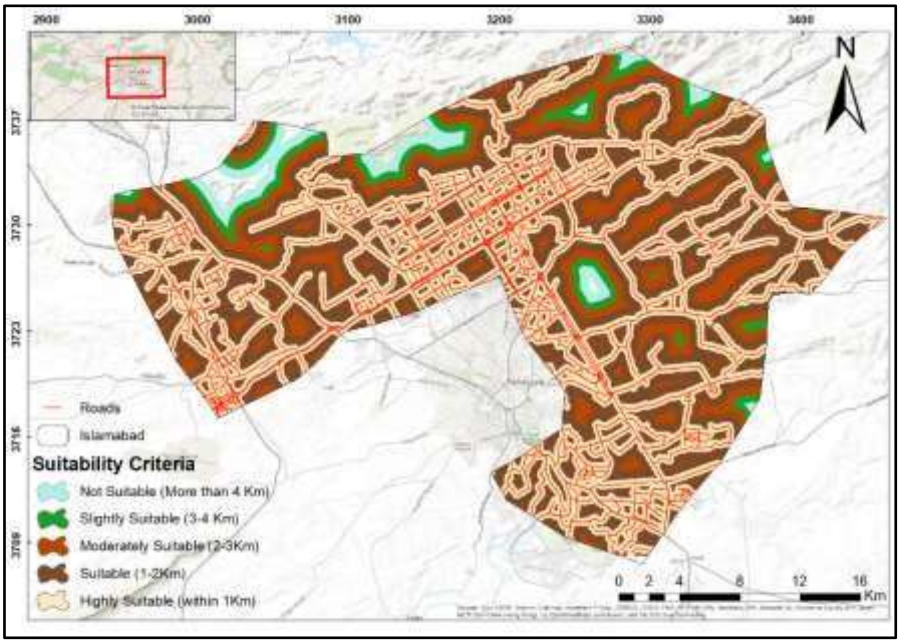

Figure 7 Roads of Islamabad

2.1.3.6. Slope

Slope plays an important part in this analysis. The slope of Islamabad varies from location to location, the central area of the city is comparatively flat while the hilly area of the city has steep slopes. In this study, the slope range of Islamabad slope was divided into five classes ranging from most suitable to least suitable. While finding suitable sites for the EVCSs slope is essential because it can impact drainage, accessibility, construction costs, and environmental impact.

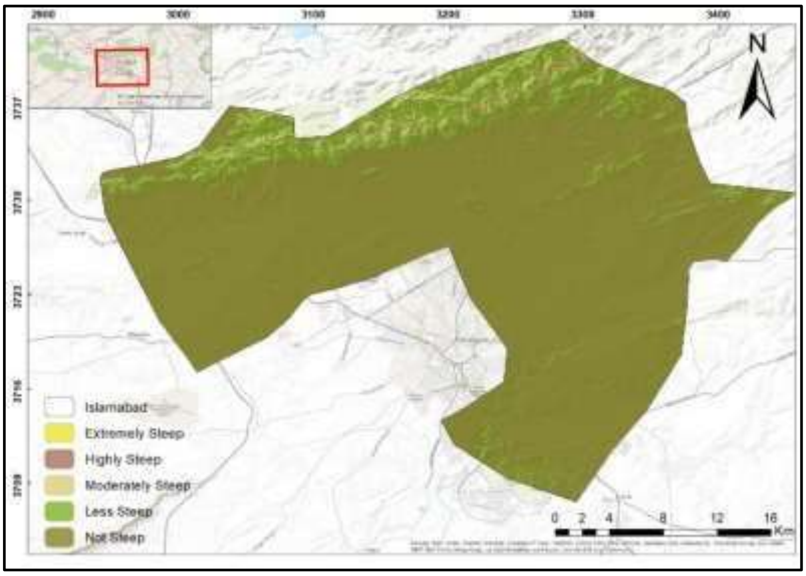

Figure 8 Slope of Islamabad

2.1.3.7. Aspect

Another topographic characteristic considered during the study is aspect. The aspect of the slope determines the amount of sunlight that it receives. As this study aims to locate sites for hybrid charging stations and aims to utilize maximum solar potential this aspect is another essential factor. Slope and aspect are two interrelated topographic characteristics and have a huge impact on the result of the analysis. The aspect of Islamabad was divided into five classes ranging from most suitable to least suitable. The objective was to locate areas that receive maximum sunlight during the daytime.

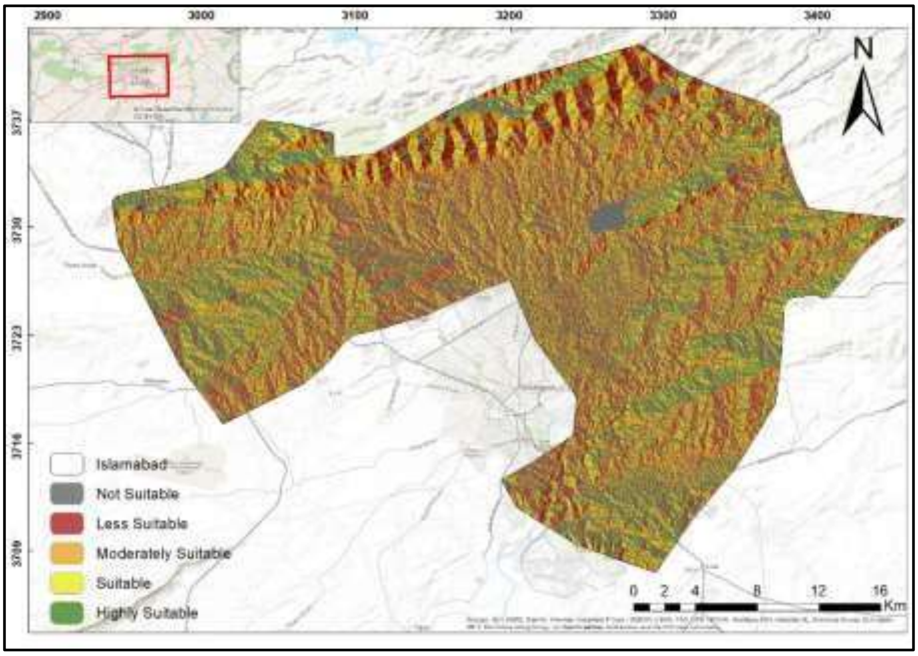

Figure 9 Aspect of Islamabad

2.1.3.8. Elevation

Islamabad's height varies from around 450 meters (1,476 feet) to 1,600 meters (5,249 feet) above sea level, with the city's average elevation being around 540 meters (1,770 feet). The elevation is important for the construction, and accessibility of the charging stations apart from that it also plays a crucial role in the construction of the charging station and the design of the infrastructure. The elevation of Islamabad was divided into five reasonable classes ranging from most suitable to least suitable.

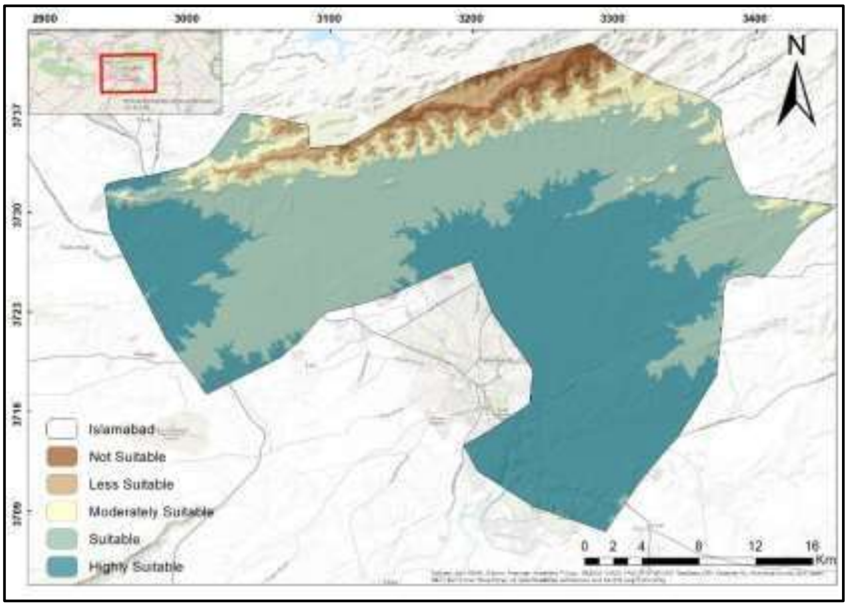

Figure 10 Elevation of Islamabad

2.2.4. Analytical Hierarchy Process

After acquiring all the layers and the required dataset AHP is used to compute the weights of each criterion. AHP is a well-structured technique that analyzes complex decisions based on mathematics and psychology. Once the problem is clearly defined and the criteria are identified, create a decision hierarchy that breaks the problem into further smaller and more manageable segments. The topmost represents the goal while the lower represents the alternative options and decision criteria. Furthermore, a pairwise comparison is carried out which involves the comparison of each component to every other component relatively. In AHP, Saaty's prescribed scale ranges from 1-9, where 1 represents equal importance and 9 represents extreme importance. After each component is compared and a matrix is formed relative weights are computed which is simply normalizing the pairwise comparison values and then summing them up for each component. A consistency check is performed to check the consistency of the pairwise comparison and does not contain any discrepancies or errors. After the determination of relative weights and consistency checks, each alternative is evaluated based on the criteria. This is done by multiplying the weights of each criterion by the performance of each alternative on that criterion. The final decision is made by selecting the alternative with the highest overall score. In this study, seven factors were involved to determine the weights through AHP.

2.2.5. Weighted Overlay

The weighted overlay is an extensively used GIS analysis technique that takes in multiple input spatial datasets into a single output layer based on their relative importance and interactions. The method uses a series of weights and functions to combine the input datasets in a weighted and nonlinear manner. After weights were assigned to each layer based on their relative importance in the decision-making process. The dataset can have different units and ranges thus it is important to normalize the data to a common range. In this analysis, for each layer, a range from 1 to 5 was defined. 1 being the most suitable and 5 being the least suitable. After normalization and weight assignment, all the layers are combined using a weighted overlay function. This tool creates a new output layer that shows the overall suitability or risk of the decision-making process created by applying the weights to each layer in this function. This process gave reasonable results for the analysis.

Table 2 Weights of criteria

LAYERS	WEIGHTS
LULC	37.4
Radiation	14
Roads	22.6
Flood	3.8
Slope	10.2
Elevation	7.3
Aspect	4.7

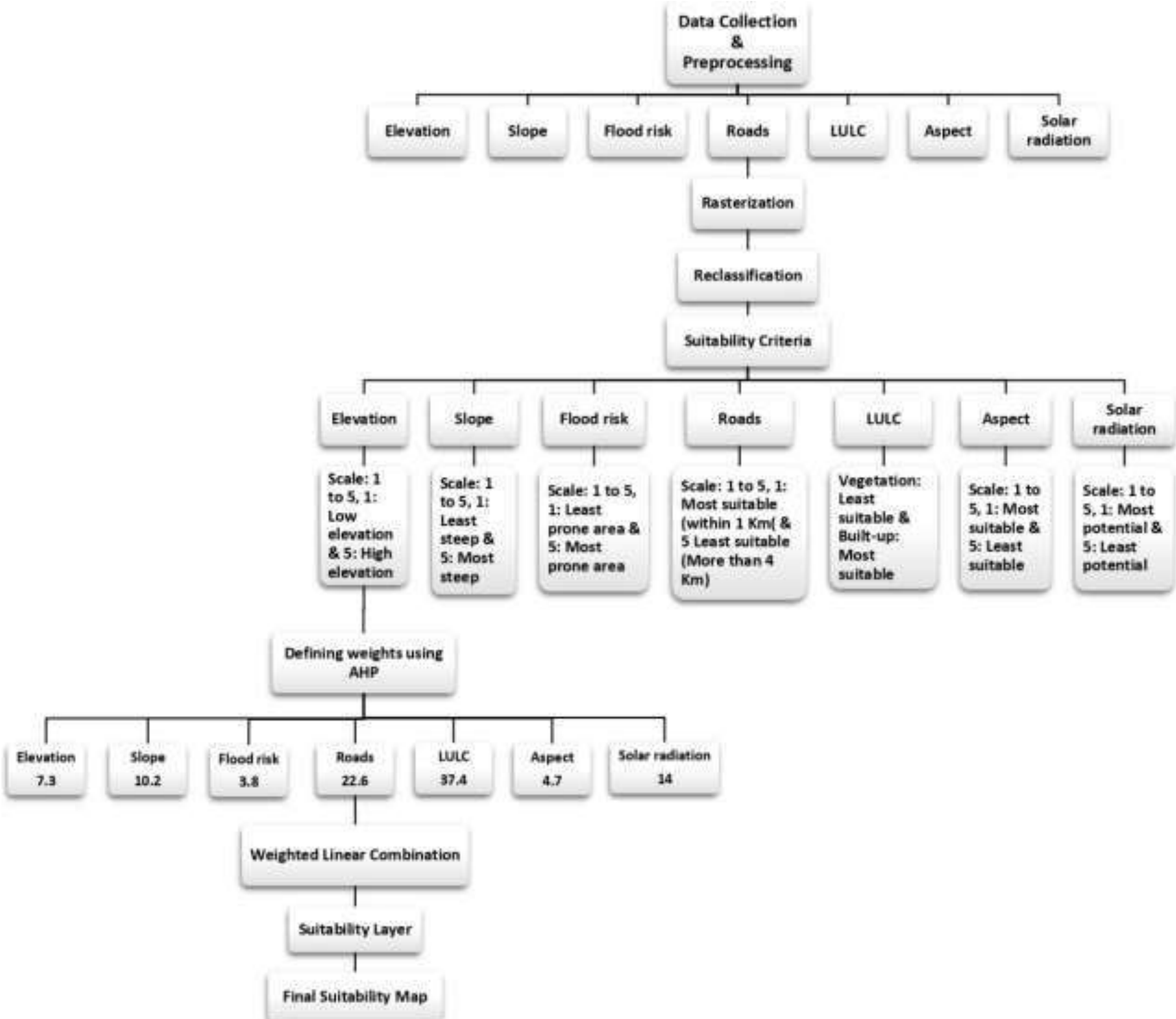

Figure 11 Site Suitability Analysis Flowchart

2.2 MOBILE APPLICATION

The second objective of this study was to develop a mobile application for users to facilitate multiple features. We developed an Android and IOS-compatible application. Following are the features of the application,

- The application displays a map that locates all the nearby charging stations for the user.
- The application enables the user to book a charging slot in advance to save the user time.
- The application provides a brief comparison between the fuel and electricity consumption of the vehicle depending upon the mileage of the vehicle.
- This application is also used for the battery swapping system. It shows the availability of batteries and their charging.
- This application is also compatible with the RFID system installed in the battery-swapping setup. Through this application, the user can open the setup.

2.2.1. Development Environment

Our project follows an open-source development approach, where all technologies, including servers, databases, internal/external apps, application engines, and operating environments, are governed by an Open-Source Community License. For developing this application, we used React Native Expo. This is considered both a library and a framework. React Native is used to create native mobile apps for iOS and Android. Expo is a collection of React Native-based tools and services that streamline the creation, testing, and deployment of React Native apps.

Expo offers a set of tools that make it easier and faster to create React Native apps, including a development server, a simulator, and a collection of libraries and components. Over-the-Air (OTA) updates, which let you distribute changes to your software without going via the software Store or Google Play, are another feature included in Expo.

Expo reduces a lot of the complexity of setting up a React Native project, which is one of its main advantages. Without having to bother about setting up a development environment or configuring Xcode or Android Studio, you can start constructing your app straight away using Expo.

In general, Expo and React Native are potent tools for creating cross-platform mobile apps. These frameworks enable developers to produce native-quality apps that function on both iOS and Android devices while reducing the amount of platform-specific code that must be written by utilizing the power of JavaScript.

2.2.2. Windows

Throughout the development of this project, the operating system of choice was Windows. However, the outcome can be accessed through any platform. Windows was selected due to its widespread usage, user-friendly interface, and compatibility with a wide range of software and tools.

2.2.3. Web Architecture

Our project utilizes a three-tier web architecture, with certain modifications implemented in the logical tier. The following are the tiers of the web architecture:

1. Presentation Tier

2. Logical Tier

3. Data Tier

2.2.3.1. Presentation Tier

The presentation tier is responsible for the user interface and interaction with the system. In this case, the mobile application developed using React Native serves as the presentation tier. It provides the user interface for accessing and controlling the electric vehicle charging system. The mobile application communicates with the logical tier to request and receive data.

2.2.3.2 Logical Tier

The logical tier encompasses the microcontroller boards, which handle data processing and control functions, and the backend developed using Node.js, which manages the communication with the microcontroller boards, exposes APIs, handles data processing, and interacts with the data tier (Firebase) for data storage and retrieval.

1. Microcontroller Boards (Arduino Uno and ESP32): The microcontroller boards, such as Arduino Uno and ESP32, play a crucial role in the logical tier. They act as embedded systems that receive data from various sensors and perform necessary calculations and control functions. Specifically, in the context of the electric vehicle charging system, the microcontroller boards handle tasks such as monitoring battery voltage using the voltage sensors, managing battery charging using TP4056 BMS modules, monitoring temperature using the DHT11 sensor, and detecting flames using the flame sensor. The microcontroller boards process sensor data and communicate with the backend to update the database and retrieve relevant information.

2. Backend (Implemented using Node.js): The backend serves as the bridge between the microcontroller boards and the data tier. It is implemented using Node.js, a JavaScript runtime environment. The backend handles the communication with the microcontroller boards and provides the necessary APIs (Application Programming Interfaces) for data exchange with the mobile application. Here are the key functionalities of the backend:

3. Data Processing: The backend receives data from the microcontroller boards, performs necessary processing and validation, and ensures data integrity before storing it in the database. It also retrieves data from the database and prepares it for the mobile application to consume.

4. API Development: The backend exposes APIs that allow the mobile application to send requests for various operations, such as checking battery status, initiating a charging session, retrieving charging history, and authentication using the RFID module. These APIs handle the logic behind these operations, interact with the database, and return the appropriate responses to the mobile application.

5. Authentication and Authorization: The backend manages user authentication and authorization using the RFID module. It verifies the user's RFID credentials and grants access to the appropriate functionalities and data based on user roles and permissions.
6. Integration with Firebase: The backend establishes a connection with Firebase, the data tier, to store and retrieve data. It utilizes Firebase APIs or libraries to perform operations like data insertion, retrieval, and real-time synchronization with the mobile application.

2.2.3.3. Data Tier

The data tier is responsible for storing and managing the system's data. In this architecture, Firebase is used as the data tier. It serves as the database were information related to charging stations, user authentication, battery status, and other relevant data is stored. Firebase allows for real-time data synchronization between the mobile application and the backend, ensuring that all connected components have access to the latest data.

Overall, this 3-tier web architecture separates the concerns of presentation, application logic, and data management, providing a modular and scalable structure for the electric vehicle charging system. The presentation tier handles the user interface, the logical tier handles the business logic and data processing, and the data tier manages the storage and retrieval of system data.

2.2.4. Software Development Kit

SDK refers to "Software Development Kit". It is a set of resources that programmers apply when building software applications for a particular platform or operating system, comprising tools, libraries, documentation, and other materials. Compilers, debuggers, emulators, and other tools that aid in the development, testing, and deployment of software are frequently included in SDKs. A set of libraries, APIs (Application Programming Interfaces), and documentation that offer instructions on how to utilize the tools to create apps for a particular platform are also frequently included in SDKs. This application is built with SDK 45, SDK 46, and SDK 47, these are different versions of SDK provided by Google for Android application development.

2.2.5. Server-side JavaScript

For this application Node is employed. Node.js is an open-source, cross-platform server-side runtime environment enabling JavaScript code execution outside of a web browser (sometimes shortened to "Node").

The V8 JavaScript engine in Chrome, which converts JavaScript into machine code for quicker execution, serves as the foundation for Node. It offers an event-driven, non-blocking I/O paradigm that makes it portable and effective and enables it to manage a lot of connections with little overhead.

Node is frequently used to create scalable network applications, web servers, execute command-line tools and scripts, and more. Additionally, it has a sizable and vibrant developer community that actively contributes to the platform and builds libraries and modules that are simple to include in Node applications.

2.2.6. Packages and Libraries

Numerous packages and libraries are used for the development of the app. Following is the list of all the libraries and packages the application relies on to run.

- Expo: the expo environment provides multiple tools and services for developing React Native apps.
- Expo-status-bar: A component that provides a consistent status bar across different platforms, such as IOS and Android. It allows developers to customize the status bar’s color, background color, and visibility.
- React: the react library is used for building interfaces. React allows developers to create reusable UI components that can be easily integrated into a React Native application.

- React Native: the react native library, which is used for building native mobile apps. React Native provides a set of components and APIs that allows developers to create mobile apps that can run on both IOS and Android.
- Firebase: The Firebase SDK, which provides tools for building mobile and web applications with real-time data updates. Firebase includes various services such as authentication, real-time database, storage, and hosting.
- Prop-types: A runtime type checking library for React props. Prop-type allows developers to define the expected types of props passed to a component and display a warning message if the prop type does not match the expected type.
- Expo-random: A package that provides a set of functions for generating random values, such as random byte arrays or UUIDs.
- Expo-linking: A library for handling deep links in a React Native app. Deep links allow users to open a specific screen within an app directly from an external source, such as a link from a website or email.
- @firebase/app: A Firebase package that provides the core Firebase functionality, such as initializing the app, managing configurations, and providing access to Firebase services.
- Expo-app-auth: A package that provides a set of functions for implementing OAuth2 authentication flow in a React Native app. This package includes support for Google, Facebook, and other popular authentication providers.
- Expo-location: A package that provides a set of functions for working with the device's location, such as getting the current location, monitoring location changes, and calculating distances.
- @firebase/auth: A Firebase package that provides authentication services, such as email and password authentication, social authentication, and custom authentication.
- Expo-constants: A package that provides access to various device-specific information, such as device ID, operating system, and platform version.

- Expo-web-browser: A package that provides a set of functions for opening URLs in the system's default browser. This package includes support for handling deep links and opening in-app browser windows.
- Expo-auth-session: A package that provides a set of functions for implementing OAuth2 authentication flow in a React Native app. This package includes support for handling redirects, refreshing tokens, and revoking access.
- React-native-map: library for integrating maps and location services into a React Native app. This library provides a set of components for displaying maps, markers, and overlays, as well as handling user interactions with the map.
- "@expo/vector-icons": This is a package that provides a library of customizable icons for use in React Native applications.

For using the Expo development environment to create a React Native app, you must have these dependencies and libraries. Developers may easily manage and install the necessary packages for their project by including a list of these dependencies in the "package.json" file.

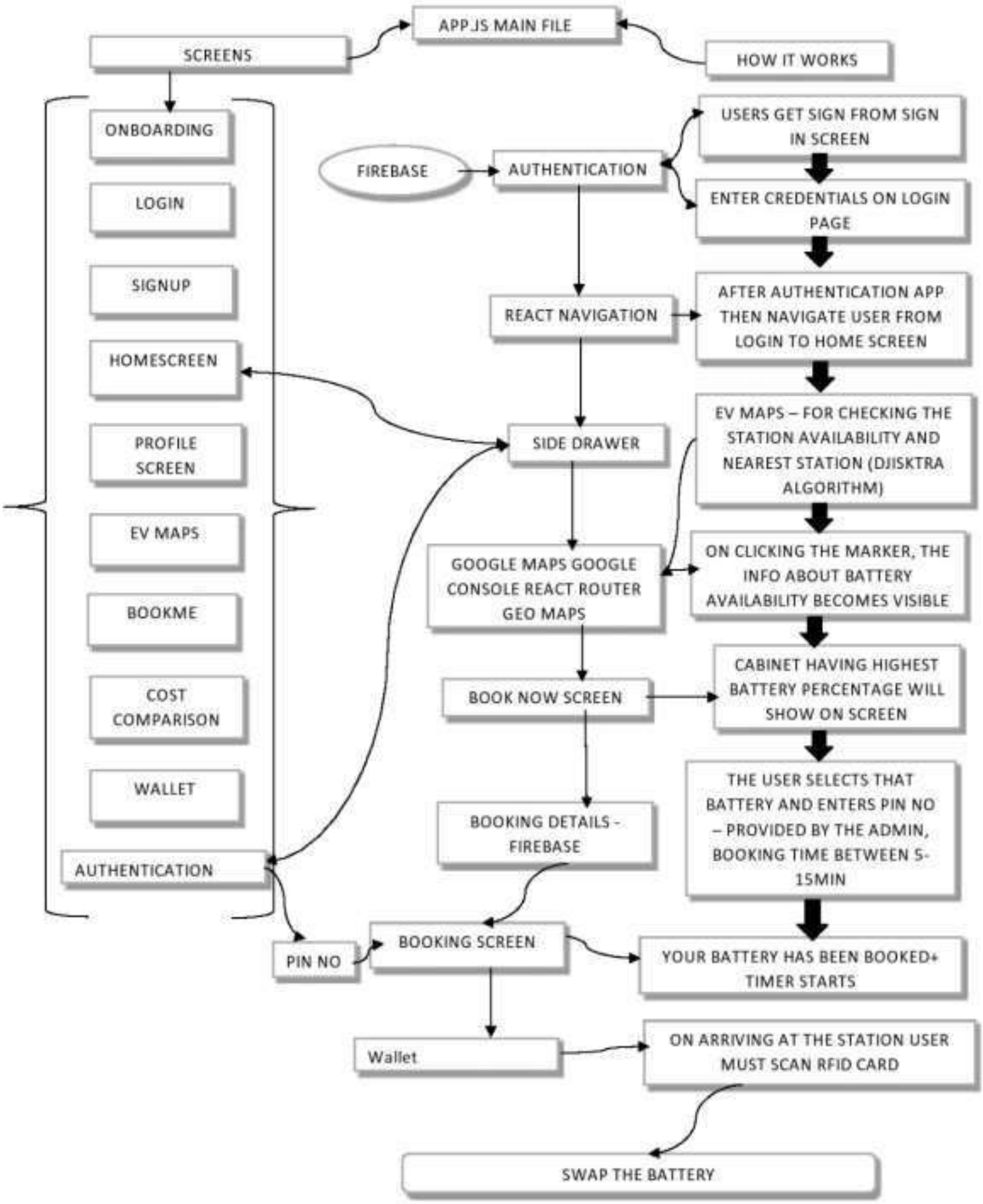

Figure 13 Mobile Application working flowchart.

2.2.7. Application User Interface

An important part of this project was to build an application with a user-friendly, sophisticated, and eye-catching user interface. The idea was to design a front end that can represent the idea of this whole project which is to reduce CO_2 emissions and improve the air quality of the environment.

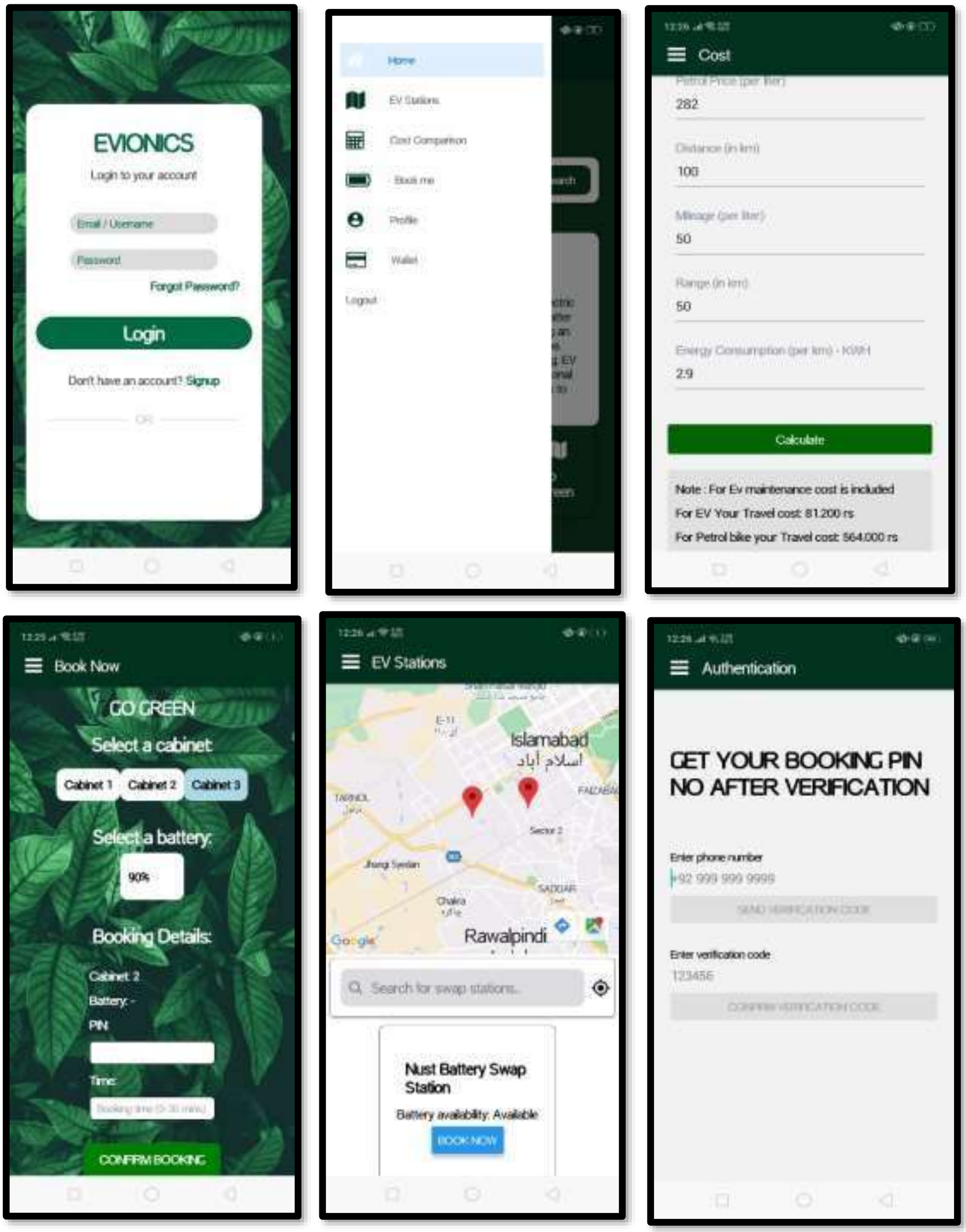

Figure 14 User Interface of Mobile Application

2.3. Battery Swapping System

Finally, the third objective of this project was to design an IOT-based battery-swapping system. Batteries used in this system are equipped with IoT-enabled features, such as sensors, communication modules, and unique identifiers. These features allow the batteries to interact with the battery-swapping stations and other connected devices. The IoT-enabled batteries continuously monitor their own status, including factors like charge level, health, and usage patterns. This data is transmitted to the central system for analysis and management. When a device or vehicle with a depleted battery arrives at a battery swapping station, it sends a request to the central system to initiate a battery swap. The central system verifies the request and authorizes the swapping process. Once the authorization is granted, the IoT-enabled battery in the device/vehicle is disconnected, and a fully charged battery is provided as a replacement. The entire battery swapping system is integrated with an IoT platform that manages the operations, data analytics, and communication between various components. This integration enables real-time monitoring, remote management, and data-driven optimizations.

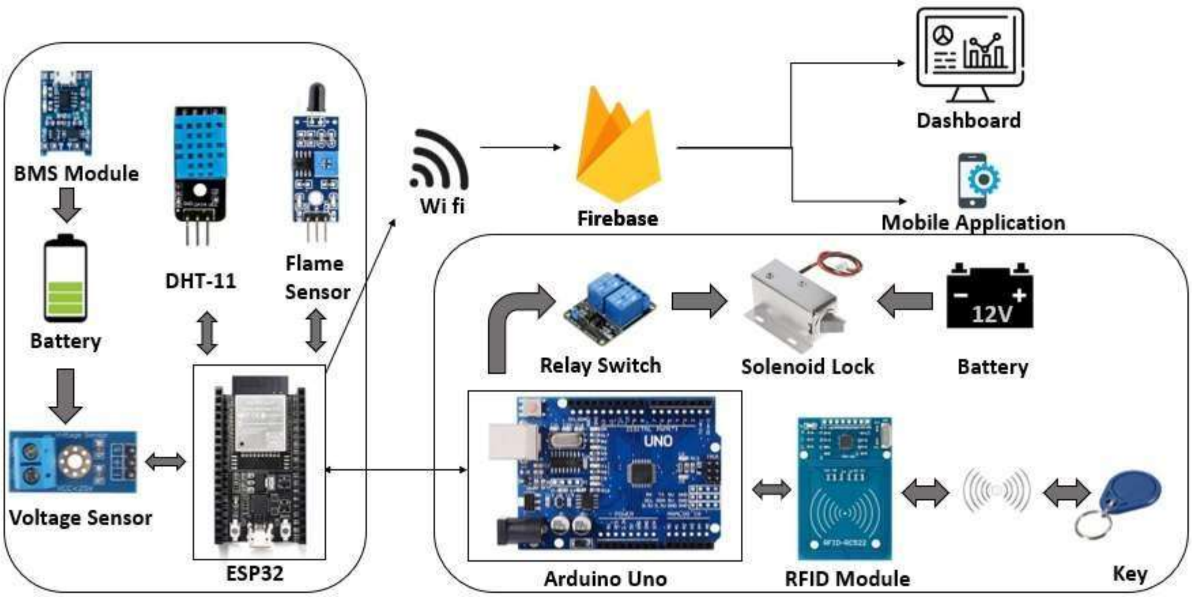

Figure 15 Battery-Swapping process flowchart

2.3.1. System Architecture Voltage sensor:

- A voltage sensor is used to measure the voltage of each battery in the EV charging system.
- It is used to ensure that each battery is charged properly and to detect any voltage irregularities that may occur during charging.
- The voltage sensor used in this system is connected to each battery to measure the voltage of the battery.

TP4056 BMS module:

- A TP4056 BMS (Battery Management System) module is used to protect the battery from overcharging and over-discharging.
- It is also used to balance the voltage of each battery in the EV charging system.
- The TP4056 BMS module used in this system is connected to each battery to manage and balance the charging process.

Temperature sensor DHT11:

- A temperature sensor is used to measure the temperature of the EV charging system and the batteries.
- It is used to ensure that the batteries are not overheated during charging, which can damage the battery.
- The temperature sensor used in this system is the DHT11, which is connected to the microcontroller to measure the temperature of the system and the batteries.

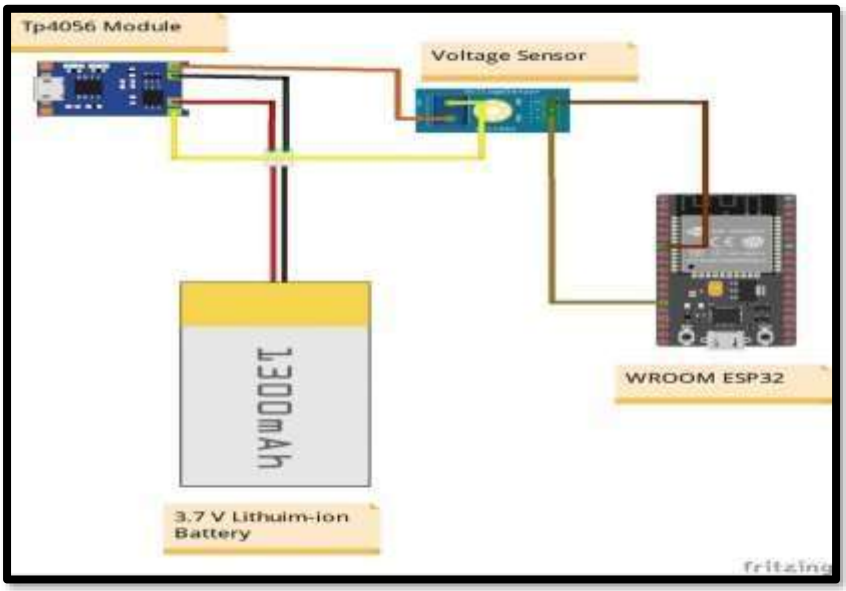

Figure 16 Circuit Diagrams of sensors

Flame sensor:

- A flame sensor is used to detect any fire or flames that may occur in the EV charging system.
- It is used as a safety measure to prevent any damage or injury due to a fire.
- The flame sensor used in this system is connected to the microcontroller to detect any flames or fire and trigger the safety mechanism.

RFID module for authentication:

- An RFID module is used for authentication purposes in the EV charging system.
- It is used to ensure that only authorized users can use the charging system.
- The RFID module used in this system is connected to the microcontroller to authenticate the user and allow access to the charging system.

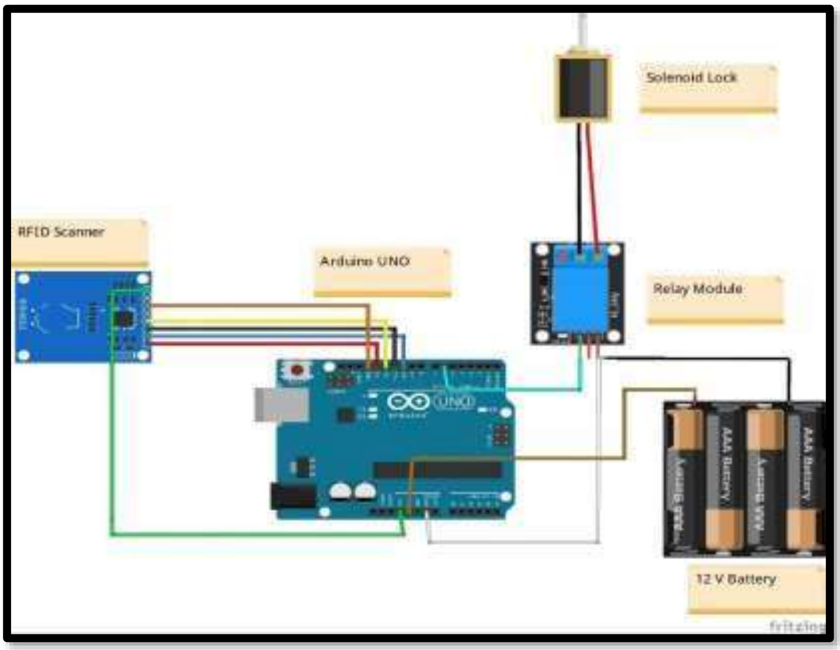

Figure 17 RFID module for authentication

LCD screen 16x2 for display:

- An LCD screen is used to display the status of the EV charging system.
- It is used to show the battery level, charging status, and any error messages that may occur during charging.
- The LCD screen used in this system is connected to the microcontroller to display the status of the charging system.

Microcontroller Boards: Arduino Uno and ESP32:

- A microcontroller board is used to control the EV charging system.
- It is used to collect data from the sensors, manage the charging process, and control the output to the batteries.
- The microcontroller boards used in this system are the Arduino Uno and ESP32, which are programmed to control and manage the charging process.

CHAPTER 3

Results and Discussion

3.1. Results

The AHP technique has been used to evaluate each criterion, the process starts by creating hierarchy of goal. For this analysis 9 factors were included to locate most suitable location for charging stations in Islamabad. Data set from multiple inline sources were used and multiple GIS preprocessing, tools and techniques were employed to identify these sites. By combining AHP, MCDA, and GIS tools, the site suitability analysis for EVs in Islamabad will offer a comprehensive and spatially explicit assessment, enabling stakeholders to identify the most suitable locations for EV infrastructure deployment in the city. Once the factors and weights are carefully assessed and assigned each layer was reclassified to define a range from most suitable to least suitable. As Islamabad has a hilly terrain has varied topography. The central area is situated at a lower elevation and as you move toward the northern and northeastern part of the city, the elevation gradually increases due to Margalla hill. This factor shows that the most suitable area for the charging station is in the central part of the city. Other factor and literature review also suggest that the central and part of the city is most suitable.

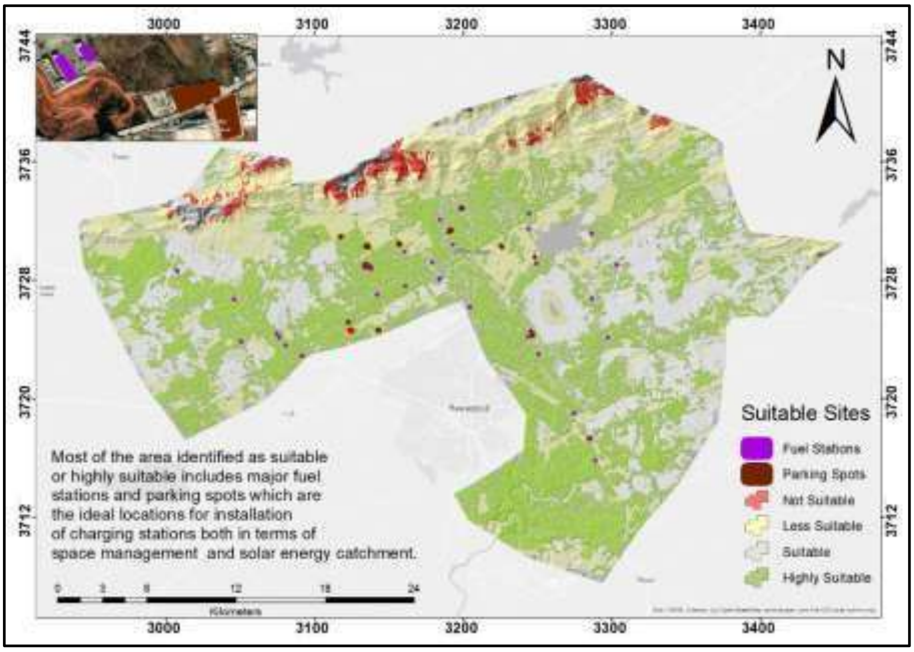

Figure 18 Suitable Sites for EVCGs in Islamabad

Most of the areas identified as suitable or highly suitable includes major fuel stations and parking spots which are the ideal location for the installation of charging stations both in terms of space management and solar energy radiation.

3.2. Discussion

The study on charging infrastructure and the development of an app for electric vehicles is a significant step toward promoting sustainable transportation solutions. The use of GIS-based multi-criteria decision analysis to identify suitable sites for charging stations is an innovative approach that considers multiple factors such as accessibility, availability of sunlight, and proximity to major highways or city centers. This approach ensures that the identified sites are the most appropriate and can meet the needs of the users.

The use of renewable energy sources like solar power for charging stations is also an excellent step towards reducing carbon emissions and promoting sustainable development. This approach is crucial for the long-term sustainability of electric vehicles.

The development of an app for users to locate nearby charging stations and book a charging slot is also a useful feature. This can help reduce range anxiety, which is a common concern for electric vehicle owners, by providing them with real-time information on available charging stations. The ability to book a charging slot in advance can also help users plan their journeys more efficiently.

Throughout the project, we went through the following stages:

- Identify the need for proper charging infrastructure and IoT-based battery-swapping system for electric vehicles.
- Conduct GIS-based multi-criteria decision analysis to identify suitable sites for charging stations in Islamabad, Pakistan.
- Develop an app for users to locate nearby charging stations and book a charging slot.
- Use sensors such as voltage sensor, temperature sensor, flame sensor, and RFID module for authentication to monitor and control the charging process.
- Use microcontroller boards like Arduino Uno and ESP32 to control the sensors and communicate with the app.
- Use mobile application technologies like React Native, Firebase for the database, Expo for coding, and Node for the backend.

There were some limitations and bottlenecks that we faced during the project:

- The availability of suitable sites for charging stations may have been limited, particularly in densely populated urban areas.
- The compatibility of different electric vehicle models with the charging stations has been a challenge, as some vehicles may require different charging protocols.
- Faced challenges in obtaining accurate data on factors like traffic volume, availability of sunlight, and proximity to major highways.
- Difficulty in integrating different sensors and technologies into a cohesive system, leading to technical challenges during the development process.
- Funding limitations, as sustainable transportation solutions, may require significant investments in charging infrastructure and renewable energy sources.

For now, these problems are solvable in one way or another.

CHAPTER 4

CONCLUSION

Conclusion

In conclusion, the EV charging solution presented in this study offers a sustainable and user-friendly approach to address the challenges of electric vehicle adoption. The development of a user-friendly app for locating and booking charging stations, by integrating GIS analysis and renewable energy sources addresses a key concern of electric vehicle owners: range anxiety. By providing real-time information on available charging stations and allowing users to reserve charging slots in advance, the app empowers individuals to plan their journeys efficiently and alleviates concerns about finding charging infrastructure. With the use of sensors and RFID authentication, the charging process is safe and secure. Overall, this EV charging solution serves as a blueprint for establishing efficient and environmentally friendly charging infrastructure. It has the potential to drive the widespread adoption of electric vehicles and contribute to a greener future.

Recommendations

Based on the findings of your study, we would recommend that policymakers and stakeholders in Islamabad, Pakistan consider implementing the proposed charging infrastructure and battery-swapping system. The use of renewable energy sources like solar power for charging stations is an excellent initiative to reduce carbon emissions and promote sustainable development.

Additionally, we suggest that the app for users to locate nearby charging stations charging slots should be user-friendly and regularly updated to provide real-time information on available charging stations. This will help reduce range anxiety and encourage more people to switch to electric vehicles.

Finally, I recommend that the IOT-based battery-swapping system should be piloted in a few locations first to ensure its feasibility before expanding it to other areas. It is also important to ensure that the battery-swapping process is secure, reliable, and does not compromise the safety of users. Overall, the study provides valuable insights into promoting sustainable transportation solutions and should be considered by policymakers and stakeholders in Islamabad, Pakistan.

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