In academic affiliation with

Smart EV Charging Management System

A dissertation submitted to the

Faculty of Computing Sciences of Gulf College in academic affiliation with Cardiff Metropolitan University

In partial fulfilment of the requirements of the degree

BSc (Hons) Computer Science Pathway in Computer Science

Submitted By
Name:
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Supervisor:

Date:

Acknowledgment

I would like to express my deepest gratitude to all those who have supported and guided me throughout the development of this project.

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Lastly, I would like to thank my family for their unwavering support and encouragement throughout this endeavor. Without your support, this project would not have been possible.

Thank you all.

Declaration

This dissertation is being submitted in partial fulfilment of the requirements for the degree of Bachelor of Science (Hons) Business Information System and has not previously been accepted in substance for any degree and is not being concurrently submitted in candidature for any degree.

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Candidate signature: ______________________________Date: ______________

Abstract

Global adoption of electric vehicles is crucial for creating a sustainable transport system and reducing the impacts of climate changes. Nevertheless, these challenges include the poor charging infrastructure, limited access and adoption due to low number of EVs, and lack of features that directly address the User Needs of consumers. This thesis describes the design and implementation of a Smart Electric Vehicle Charging Management System based on the IoT to solve these problems. The system used IoT technologies for the purpose of increasing operational efficiency, real time monitoring and overall user satisfaction. These include the charging session management application across web and mobile, the payment gateway with associated secure sockets layer connections, and the energy optimization algorithms. The backend should be implemented using PHP and Node.js, however the frontend must be built with HTML, CSS and JavaScript for better user interface. MySQL is effectively used for managing the databases while XMPP is used for real-time communication between IoT device and server. It is this context that the agile methodology was adopted for its benefits in cyclic, developmental improvements and stakeholder engagements. This thesis also considers the environmental aspect of the proposed system and advocates for efficient energy utilization and integration of renewable energy in the system. It provides solutions to some of the major problems like – grid loading, demand predictions, and security threats through usage of artificial intelligence and machine learning operating algorithms and key authentications. Figures presented in the following sections show that the proposed system successfully offers reliable, efficient and secure electric vehicle charging services. All objectives of the system are achieved, however future improvements proposal include addition of renewable energy sources, increasing compatibility with different types of EVs, usage of blockchain to enhance transaction security. To summarize, this project demonstrates how IoT could revolutionise EV charge, promote green transport and create the future we need.

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CHAPTER 01

1. INTRODUCTION

1.1. Introduction and Project Background

The transition to electric vehicles is imperative and inevitable for achieving a sustainable mobility system worldwide (Cruz, Iribarren and Dufour, 2019). However, there is some evidence that charging infrastructure for EVs is not very efficient at present due to factors of availability, automation, and payment system (Sierzchula et al., 2014). This research focuses on designing a smart electric vehicle charging system implementing HTML, PHP, JavaScript and CSS along with IoT for updating the status and providing the best user experience. At the same time, the objectives include increasing station availability, automating the choice of station, and controlling charging, as well as using secure forms of payment for services, which will be useful not only for users but also for the providers of services (Angeline and Rajkumar, 2023).

Overview of the Project

The main goal of this undertaking is to create an online portal to support the operation of the charging station for its subscribers in addition to informing the location and status of available charging stations. The development standards will include, HTML for site structure, PHP for the platform's backend and JavaScript for the interactivity of the site, with CSS for aesthetic purposes. Combination with databases will let the users get real-time information about the availability of the stations or the current charging state, while IoT solutions will provide the constant updates.

Justification for Choosing the Project

The choice to develop an IoT-enabled smart EV charging management system is driven by several factors:

Growing Demand for EVs: Considering the widespread utilization of electric vehicles and the increasing number of them, a high demand for infrastructures that have convenient charging possibilities is gaining ground. The growing demand for user-driven services such as charging management system that takes innovative steps to make using it enjoyable and welcoming, facilitating the widespread adoption of EVs is addressed.

Advancements in IoT Technology: The wide use of IoT (Internet of Things) based technology is indicating new chances for improvement of EV charging infrastructure. The project that is targeted at using IoT devices, networks, and data analytics will ensure that smart charging management is created which will improve efficiency, reliability, and sustainability.

Environmental Imperatives: It is essential to find options for transportation that need climate change and reduction of GHG to be solved. Supporting the current imperative of the growth electric vehicles market through the use of the IoT-based charging management system could be found in the improved performance of the system, more convenience for the consumers the reduction of reliance on fossil fuels, and furthering the adoption of renewable energy sources.

Policy Support and Market Trends: Government's worldwide as well as regulatory authorities on a worldwide scale are imposing strategies and subsidies to quicken the E-vehicle's adoption and spread charging infrastructure. Implementing IoT-enabled charging management in the project is well-aligned with the objectives both of governmental policies and of existing market trends capable of augmenting the prospect of being used by larger volume customers.

Problem Statement:

Advanced and sustainable features and technology may create significant opportunities to positively transform the EV charging infrastructure currently facing energy inefficiency, limited smart capabilities, environmental impact, and policy compliance challenges. Forms of charging used by old vehicles emit poor electricity, poor accessibility, and management thinking and prohibit worldwide preferences EVs and at the same time limit their environmental benefits. Uneven regulations and unstandardized regulation rules make it more difficult to apply and run EV charging stations. To face these challenges, a smart IoT-based managing system for EV charging infrastructure with optimization features, facilitating access to devices, and promoting environmental sustainability as well as acknowledging regulatory uncertainties, should be developed.

Objectives of the Project:

General Objectives:

- Develop an IoT-based smart EV charging system that will facilitate automated management.
- As an instrumental provision for minimizing charging infrastructure to function and operate effectively.
- To expand the choices of owners, to give an unbeatable service, and to be sustainable by the charging infrastructure.
- To make electric vehicles popular among passengers and shift the emissions to zero, thus, fighting climate change.

Specific Objectives:

- Iteratively creating software elements such as web-based dashboards, mobile apps, and background servers that are in charge of real-time data collection, management systems, and optimization.
- For energy management practices like demand-side management and time shifting to emerge, for better energy use and grid integration, blending and blending them should be adjusted.
- For the implementation of interoperability different standards and protocols are to be integrated into the EV charging infrastructure and existing regulatory standards.
- To advance user experience, it is required to have intuitive interfaces, accept payments smoothly, and integrate with intelligent home systems.
- Apart from the above-mentioned aspects, intensive security procedures like encryption, authentication, and access control shall be incorporated into the system to secure user data being kept private.
- To have a cradle-to-the-grave analysis of the system as well as integration with renewables all in a bid to reduce the environmental effects.

Scope of the Project:

The project includes the designing, programming, and deployment of an IoT-connected management system for smart EV Charging that can be applied in the garage or public. The project will focus on addressing the following aspects within the defined scope:

Software Development: Create software components such as web-based interfaces, android and IOS mobile apps, and backend servers for controlling the processes of real-time monitoring, charging, and optimization.

Energy Management Optimization: Comprising energy management techniques like demand-side management, peak shaving, forecasting system events, and optimizing algorithms will enable efficient utilization of energy carried through by the grid.

User Experience Enhancement: An essential element in achieving user satisfaction involves the making of interfaces that are consistent and simple, the incorporation of digital payment processing systems, user authentication, and links with the smart home systems that are meant for remote monitoring as well as controlling.

Security Implementation: Among other measures like encryption, authentication, access control, and data privacy mechanisms, security procedures should be applied to guarantee the proper preservation of users' data and the integrity of all information.

Environmental Impact Assessment: The environmental impact should be first considered by making the system undergo lifecycle analysis, then, energy efficiency, carbon emissions, and integration with renewable sources should be assessed.

Project Plan:

Project Deliverables and Milestones:

a. Investigation Plan:
- Investigation into existing EV charging infrastructure and usage of the IoT technologies (2 weeks).
- The first phase after partner selection is the stakeholder analysis and requirements elicitation (2 weeks).

- The environmental impact assessment and regulatory analysis would carry on for about three weeks.

b. Development Plan:

- Software development: Design UI for the website, mobile application, and back-end servers (8 weeks),
- Integration and testing: Incorporate hard and soft components, carry on the activation process, check and verify (6 weeks)

c. Evaluation and Test Plan:

- User acceptance testing: Collect feedback from actors, and proceed to the stage of system improvement and iteration (4 weeks).
- Performance testing: Test system performance, scalability, and reliability for a variety of load conditions(s) in (2 weeks).
- Environmental impact evaluation: Conduct lifecycle analysis as well as assess energy efficiency and sustainability metrics (3 Weeks)

Phase	Task	Duration	Start Date	End Date
Investigation Plan	Investigation into existing EV charging infrastructure and IoT usage	2 weeks	April 5, 2024	April 19, 2024
	Stakeholder analysis and requirements elicitation	2 weeks	April 20, 2024	May 3, 2024
	Environmental impact assessment and regulatory analysis	3 weeks	May 4, 2024	May 24, 2024
Development Plan	Software development: Design UI for website, mobile app, and back-end servers	8 weeks	June 22, 2024	August 16, 2024
	Integration and testing: Incorporate hardware and software components, activation process, and verification	6 weeks	August 17, 2024	September 27, 2024

Phase	Task	Duration	Start Date	End Date
Evaluation and Test Plan	User acceptance testing: Collect feedback and iterate system	4 weeks	September 28, 2024	October 25, 2024
	Performance testing: Test system performance, scalability, and reliability under various load conditions	2 weeks	October 26, 2024	November 8, 2024
	Environmental impact evaluation: Conduct lifecycle analysis and assess energy efficiency and sustainability metrics	3 weeks	November 9, 2024	November 29, 2024

Table 01: Project Deliverables and Milestones

Investigation Plan:

a. **Research Objectives:**

- Study the level of EV infrastructures available and the relevance of IoT technologies.
- Draw up a list of stakeholder's needs and wants, where problems arise in EV charging.
- Measure harmful effects brought about by EV charging infrastructure and regulatory standards.

b. **Research Methodology:**

- **Literature review:** Collect reference materials from academic papers, industry reports, and publications by government agencies.
- **Surveys and interviews:** Conduct surveys among the EV users, charging infrastructure operators, distributors, and regulators.
- **Environmental assessment:** Base life cycle analysis on consumption energy emissions and resource utilization assessment and build up life cycle impact assessment around these points.

c. **Timeline:** 7 weeks

Research Objectives	Research Methodology	Timeline
Study the level of EV infrastructures available and the relevance of IoT technologies.	Literature review: Collect reference materials from academic papers, industry reports, and publications by government agencies.	7 weeks
Draw up a list of stakeholder's needs and wants, where problems arise in EV charging.	Surveys and interviews: Conduct surveys among the EV users, charging infrastructure operators, distributors, and regulators.	
Measure harmful effects brought about by EV charging infrastructure and regulatory standards.	Environmental assessment: Base life cycle analysis on consumption energy emissions and resource utilization assessment and build up life cycle impact assessment around these points.	

Table 02: Investigation Plan

Evaluation and Test Plan:

User Acceptance Testing:

- Develop test case based on users' needs (requirements and use cases) (1 week)
- Find an instance to interview representatives keyed to the nucleus of the spiral, and get their opinion or response (2 weeks)
- Cycle design changes by responding to the user’s feedback (1 week).

Performance Testing:

- Set the scene up and also specific objectives and metrics for the test (week one).
- Implement load testing, stress testing, and scalability testing during week one (week 1).
- Analytical test results, locating the constraints, and system performance optimization (1 week).

Environmental Impact Evaluation:

- Collect lifecycle data for, and do an update assessment and evaluation of impact (2 weeks).
- Address the energy consumption, emissions, and resource use then use the energy cost, emission, and resource use basis (1 week).

- Plot the tactics for enhancing energy effectiveness among the enterprises and sustainable practices (1 week).

Timeline: 6 weeks

Phase	Task	Duration	Start Date	End Date
User Acceptance Testing	Develop test cases based on users' needs (requirements and use cases)	1 week	Sep 28, 2024	Oct 4, 2024
	Interview representatives and gather their opinions or responses	2 weeks	Oct 5, 2024	Oct 18, 2024
	Implement design changes based on user feedback	1 week	Oct 19, 2024	Oct 25, 2024
Performance Testing	Set up test environment and define objectives and metrics	1 week	Oct 26, 2024	Nov 1, 2024
	Implement load testing, stress testing, and scalability testing	1 week	Nov 2, 2024	Nov 8, 2024
	Analyze test results, identify constraints, and optimize system performance	1 week	Nov 9, 2024	Nov 15, 2024
Environmental Impact Evaluation	Collect lifecycle data and update assessment of impact	2 weeks	Nov 16, 2024	Nov 29, 2024
	Address energy consumption, emissions, and resource use	1 week	Nov 30, 2024	Dec 6, 2024

Phase	Task	Duration	Start Date	End Date
	Develop strategies for enhancing energy efficiency and sustainable practices among enterprises	1 week	Dec 7, 2024	Dec 13, 2024
	Total	6 weeks		

Table 03:

Gantt chart

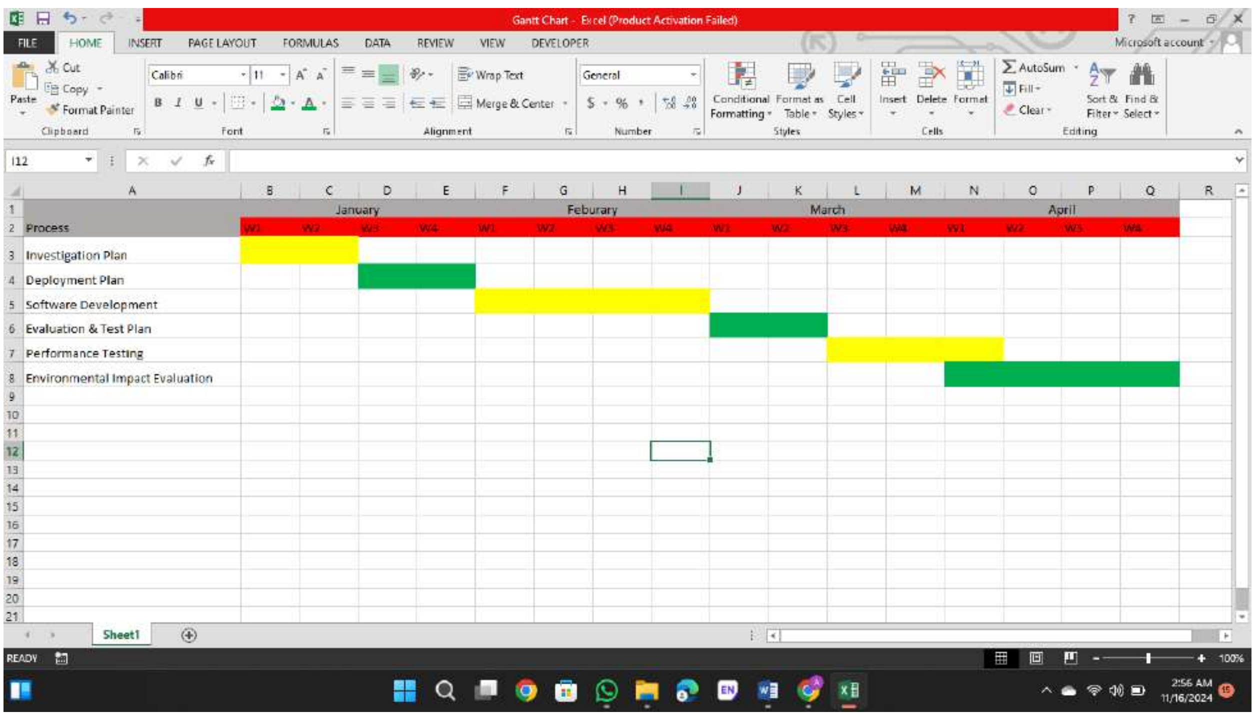


Figure 01: Gantt Chart

CHAPTER 02

1. LITERATURE REVIEW

The smart IOT-powered e-vehicle charging management system is a highly sophisticated network of sensors, smart metering & software to make the process of charging the EVs optimally. Such system entry to the Internet of Things (IoT) technology empowers it with the capability to create dynamic and intelligent charging infrastructure that is capable of controlling, monitoring, and managing EV charging in real-time and remotely (Xue et al., 2021). A basic smart charging management system due to the IoT integration has at its core different components which are charging stations, sensors, controllers, communication modules, and cloud-based platforms. These are the components that gather and distribute the data, analyse current charging habits, harness energy effectively, and make smooth interactions possible between EV users (Chen et al., 2020).

1.1. Evolution of Electric Vehicles (EVs) and Charging Infrastructure:

Historical Background of Electric Vehicles:

The electric vehicles era can be linked to the 19th century when inventors began to experiment with the electrical engine as an alternative to the internal combustion engine. In 1835, Thomas Davenport was the first person to build an electric vehicle in the US by driving a small motor powering a model car using electricity. In the 19th and the beginning of the 20th century, electric cars were especially favoured for urban transport as they were virtually noiseless and offered little pollution, which is a major issue for air quality today. There were some major setbacks on the way of EV adoption because of the emergence and widespread adoption of petrol-powered cars first of all due to the discovery of a lot of petroleum and also the development of the improved internal combustion engine that made cars on a gas more effective than electric vehicles. Gasoline-powered cars offered greater efficiency in range, and faster refuelling time thus they were more practical and more widely used than electric cars for long-distance travel (Gupta et al., 2020).

Development of Charging Infrastructure:

Electric vehicles have become more popular to drive on different roads, and having more charging stations is playing a vital role in everybody's life. At the very beginning of the emergence of the trend toward electric cars, charging infrastructure was simply not enough, and in most cases, it was only some basic charging poles installed in public parking spaces and residential areas (Deb et al., 2018). Charging stations hosted by these shops were primarily used for AC charging which was slow compared to the charging speeds that they currently support. Additionally, such locations did not have smart features and connectivity capabilities in place.

Introduction of IoT-enabled Smart Charging Solutions:

To overcome the problems of older charging systems, two-way communication and full control over the charging process were introduced and exposed the customers to a new IoT-based electric vehicle charging system. Becoming an interconnected, intelligent, and real-time optimized component of IoT network technology was made possible by charging infrastructure. (Patil, 2019)

1.2. IoT Technology and its Application in Electric Vehicle Charging:

Integration of IoT in Electric Vehicle Charging Infrastructure:

The integration of IoT technology in electric vehicle charging infrastructure enables the development of smart charging solutions that offer several key functionalities:

Remote Monitoring: IoT-equipped charging stations can be worked out with cloud-based platforms, which would make it possible to keep track of charging sessions, maintain the condition of the stations, and troubleshoot stuff immediately.

Dynamic Pricing: Utilizing the capability of IoT technology, for example, with factors like energy demand, time of day, or grid congestion, pricing models may be differential and vary. High-pricing stations will change pricing dynamically and accordingly between peak and off-peak to create an incentive and the reason for maximum grid usage.

Predictive Maintenance: IoT is a technology that is capable of sensing the condition or the decision-making ability of the equipment and it can make data evaluation in real-time. Predictive maintenance algorithms can be used for the analysis of this type of data and develop plans to replace worn-out parts or schedule maintenance well in advance when the equipment is most likely to be without service, and consequently, increase uptime and reliability. (Asaad et al., 2017)

Energy Management: IoT charging systems which are smart can be tailored to optimize energy consumption by the coordination of charging schedules with regards to what is made available by renewable energy and grid load, and individual user preferences. This infrastructure implements the technology for demand response mechanisms and accommodates the entry of intermittent renewable power sources into the grid. (Asaad et al., 2017)

Benefits and Advantages of IoT-enabled Charging Systems:
The adoption of IoT-enabled charging systems offers several benefits and advantages for electric vehicle owners, charging operators, utilities, and society as a whole:

Enhanced User Experience: IoT-enabled charging systems not only give EV users the simplicity of accessing a charging infrastructure, real-time updates of charging status, and various payment choices but also make it more convenient for them to charge their electric cars which would enhance the entire user experience.

Improved Efficiency: Smart energy management technology through IoT that accounts for peak and off-peak consumption times will result in less energy waste, help manage grid congestion, and maximize charges at the right time for better efficiency. (Savari et al., 2019)

Grid Integration and Stability: Adding the IoT to the charging system yields grid-friendly charges that are adjustable, ancestral, and renewable energy integration-oriented, thus, the grid stability and reorganization can then be enhanced.

Cost Savings: Through prompt power usage intensity, load leveling as well and renewable energy integration, IoT-enabled charging infrastructures can lead to monetary savings over time for both the utility providers and the electric vehicle owners (Asaad et al., 2017).

Environmental Sustainability: Offline-added charging revolutionary systems that advantage the usage of the electric vehicle as a sustainable transport system for pollution reduction and energy independence are the reason for these systems' growth rate. (Savari et al., 2019)

Case Studies Demonstrating Successful Implementation:
Several real-world examples demonstrate the successful implementation of IoT-enabled charging systems in diverse environments:

Enel X JuiceBox: Enel X, a progressive stockholder of energy management solutions, brings to the market JuiceBox, a line of smart charging stations for electric vehicles. This network uses IoT key technology use, including remote monitoring, demand response, and energy optimization features, as a way to provide EV owners with efficient and effortless charging.

ChargePoint: ChargePoint is known to possess the number one backup of the largest networks of EV charging stations worldwide with over 120,000 charging points spread between North America and Europe. ChargePoint IOT-based smart charging infrastructure is designed to manage and balance power with the help of IoT-connected devices and contributes to grid optimization and efficient energy management.

Amsterdam Electric Vehicle Charging Network: Nowadays, a wide net of smart charging stations powered by IoT systems is one of the most widely used tools in Amsterdam to enhance its sustainable electric vehicles fleet. These stations now have sophisticated features allowing the citizens to read the details on the screens in real-time, adjust the prices of electric cars according to energy consumption, and integrate renewable energy into the urban transport system making Amsterdam a pioneer in sustainable urban mobility.

Nissan Leaf Vehicle-to-Grid (V2G) Pilot Project: Nissan had a situation from the UK to prove the operations of Vehicle-to-Grid (V2G) technology which allows the cycle of energy bidirectional between electric vehicles and the grid (Deb et al., 2022). IoT (internet of things)-enabled charging infrastructure turned out to be the core in managing various V2G interactions, leading to optimal energy exchange, and setting up grid stability.

1.3. Key Components and Architecture of IoT-enabled Charging Systems:

Role of Cloud Computing and Edge Computing:

Cloud computing and edge computing play complementary roles in the architecture of IoT-enabled charging systems:

Cloud Computing: Cloud-based platforms come with large-volume data storage, processing, and analytics solutions for computing tasks generated due to sensors-based charging facilities. Platforms that are cloud-based help in the centralized control, monitoring, and updated notifications related to the charging stations and data aggregation and analysis over multiple locations.

Edge Computing: Edge computing is that data processing takes place at that point of the network which is nearest to its source – at the edge of the network instead of being transmitted to centralized cloud servers. To bridge the gap between IoT and cloud computing technologies and thereby achieve lower latency and diminished bandwidth requirements, edge computing devices can be deployed, for instance, as gateways or edge servers, which can process data sets in real-time, as well as perform decision-making and apply control actions locally. Edge computation represents applicable conditions for sensitive data, such as the transmission of urgent charging parameters or the creation of quick-response control algorithms.

1.4. Energy Management and Optimization Techniques:

The issue of energy management and optimization is central to the proper and continuous operation of IoT-enabled charging systems that are both economically and environmentally sound. Through employing multiple bills and methods, charge infrastructure managers can avoid energy loss, reduce load shedding, and maximize the efficiency of public electric vehicle charging. The following sections outline key energy management and optimization techniques:

Peak Shaving and Load Balancing Techniques:

Shaving peaks and load balancing methods are meant to lower peak demand and distribute electricity loads uniformly throughout the grid. Increasing their effectiveness will help avoid overloading electrical infrastructure and lower energy costs. In the context of IoT-enabled charging systems, peak shaving and load balancing techniques include:

Distributed Energy Storage: Recurring connections, e.g. battery units or V2G vehicle systems as distributed energy storage, can store energy when there is low demand to then discharge it during high demand times to reduce grid stress levels. The grid can be effectively supplied with flexible and resilient power by employing vehicles equipped with V2G technology as mobile energy storage units. (Uddin et al., 2018)

Load Balancing Algorithms: The load balancing algorithms level up charging loads belonging to various charging stations or phases to capture the electrical infrastructure utilization as uniformly as possible to prevent the individual circuits and transformers from overloading. These algorithms certainly take into account the issues of charging station availability, grid capacity, and demand of users who will be the service beneficiaries for better coordination of the load distribution and elimination of the bottlenecks. (Uddin et al., 2018)

Predictive Analytics for Energy Consumption:

Predictive analytics techniques utilize historical data, machine learning algorithms, and statistical models to presume future energy consumption patterns and thus improve workload optimizations. In the context of IoT-enabled charging systems, predictive analytics can:

Forecast Charging Demand: Predictive analytics algorithms analyse several data factors that include past charging data, climate conditions, and user behaviour to predict future charging demand and change the infrastructure accordingly. Through the application of predictive analytics that detects the peak demand periods and decreases the charging rates subsequently, the efficient use of energy and grid integration takes place. (Shin, Woo and Rachuri, 2014)

Predictive Maintenance: Utilizing predictive analytics, equipment failures or maintenance due to the sensor data and performance metrics can be avoided before it happens by dealing with the problem in real time. The algorithms of predictive maintenance can detect any anomaly and predict the chance of failure, they provide scheduling proactive maintenance, which is the reason for the reduced downtime and greater reliability.

1.5. Environmental Impact and Sustainability:

These decisions have to be made carefully by the designers of the IoT-based charging systems for electric vehicles and sustainability and environmental impact must be considered. Low carbon emissions, energy mix diversification, life cycle analysis, and policy support, therefore, are the crucial steps to the transformation of the transportation system and charging system design into a more sustainable, eco-friendly system. The following sections discuss these aspects in detail:

Reduction of Carbon Footprint through EV Adoption:

One of the main positive environmental impacts of EV driven adoption process is that the motor vehicle journey becomes less environmentally unfriendly. As opposed to conventional gasoline vehicles, EVs emit lower amounts of greenhouse gases since they do not utilize fossil fuels as a propulsive source. An IoT-based charging system that not only shifts to the EV category but also supports EV adoption is the perfect framework for lowering the emission level in the transportation sector and of course, mitigating the problematic condition of climate change. (Indra Teja Vadium et al., 2019)

Integration with Renewable Energy Sources:

Integration with renewable energy sources, which is a key factor for the sustainability of IoT-connected charging systems, must be included as a strategy for enhancing the sustainability of the system. Renewable energy sources including solar, wind, and geothermic power could help infrastructure operators increase the environmental sustainability of their power supplies and ameliorate reliance on fossil fuels. (Big Data Mining of Energy Time Series for Behavioural Analytics and Energy Consumption Forecasting, 2018).

Life Cycle Analysis of IoT-enabled Charging Systems:

Life cycle assessment (LCA) for IoT-based charging systems covers the environmental impacts that occur at every transition phase of the charging system starting with its manufacturing, installation, and operations, and at the final stage, this is either through disposal or recycling. LCAs are such methods that provide the operators with an idea about the areas of improvements and sustainability performance of charging infrastructure for their charging systems throughout the life cycle of charging infrastructure.

CHAPTER 03

2. ANALYSIS AND METHODOLOGY

2.1. Analysis and Problem-Solving Method:

A holistic analytical and problem-solving approach, which involves undertaking a detailed analysis of the relevant literature and research on IoT-based EV charging system management systems, has been used in this literature review. By adopting a reflective and integrative assessment, the location of the most prominent contentions, difficulties, and directions toward the objectives are defined adequately. The method involves:

Reviewing Existing Literature: Finding and collecting all the papers, journal articles, trade reports as well as scholarly works related to IoT-enabled charging systems, EV technologies, energy management methods, user experience design, policy implications, and emerging trends consists of conducting a thorough review.

Analysing Key Findings: Evaluating the gathered literature to portray important details such as findings, streaming patterns, challenges, and best practices that the field of EV charging management entails. This review includes integrating data and formatting them into patterns and trends to advice on research objectives and the final recommendation.

Problem Identification: It is important to ascertain the obstacles and barriers that restrain the wide implementation and the success of IoT-enabled Charging systems, such as interconnectivity problems, scalability challenges, and the desire for uniform standards. Through developing solutions and strategies, these problems could be found and solved sustainably.

Problem-Solving Approach: Through the use of problem problem-solving approach that targets the identified challenges and issues, working with stakeholders, formulation of standards and protocols, use of modern technologies, innovation, and policy formulation, this issue can be addressed.

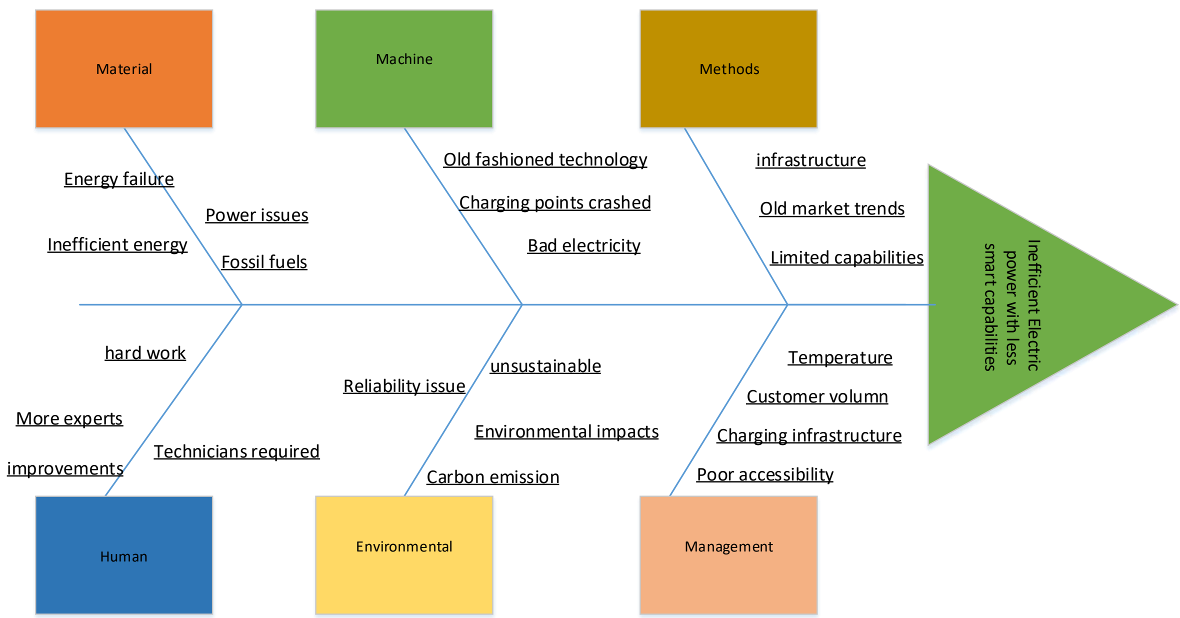


Figure 02: Fishbone Diagram of the problem solving Approach

2.2. Research Methodology and Data Collection Procedure:

The research approach applied in this literature review is supportive of qualitative analysis, involving analytical and synthetically processing of previous research. The data collection procedure involves the following steps:

Literature Review: Implementing a systematic lit review on STEM-based academic databases, research repositories, publications from industry, and governmental reports to gain an understanding of this type of system's use in IoT for smart EV charging management.

Selection Criteria: Polishing the selection criteria by identifying relevant literature, particularly through the keywords and using legit and the newest sources as well as the high academic level.

Data Extraction: Identifying main ideas, findings, and important details from the selected literature for which I will then backward the process of analysis and integration. This refers to building the capacity to differentiate between the fundamental principles, techniques, findings, and consequences of the study that are aligned with the stated objectives.

Synthesis and Analysis: The essential activity is either to evaluate and put together the extracted information to point out the flow, trends, issues, and opportunities of the electric vehicle charging management business. It is this discrimination that leads to organizing data, comparing output findings, and thus, the practice of making conclusions which helps researchers in achieving their research objectives.

2.3. System Development Methodology:

As for the technological support of smart IoT-enabled electric vehicle chargers, the approach of Agile would be preferable. There is a type of development methodology called Agile and it uses a flexible and iterative way by following principles like collaboration, adaptability, and customer feedback throughout the development process. Sprint is a lean and incremental development cycle comprising interdisciplinary and collaborative teams that work together to deliver products or enhancements at the end of each iteration. Agile methodology enables to execution of prototyping quickly, and ongoing improvements, and adapts on a dime to changing requirements which makes it suitable for projects that are complex and dynamic like IoT-enabled charging systems.

2.4. System Requirements:

Stakeholder Interviews: Interviews with the primary audience such as electric vehicle (EV) owners, electric vehicle infrastructure service providers, utility companies, and regulating bodies are conducted to determine EV users' requirements, choices, and constraints while charging their cars.

Surveys and Questionnaires: Disperse surveys and questionnaires by highlighting the engaging questions to anyone from the wide spectrum of user groups that may include different stakeholders who are expected to offer their solutions to the key questions.

Use Case Analysis: Highlight case uses of IoT application systems, one example being the registration and payment process, the system management and monitoring, and different controlling scenarios.

Survey: https://forms.gle/3ZED6eyfEtVkM5sX6

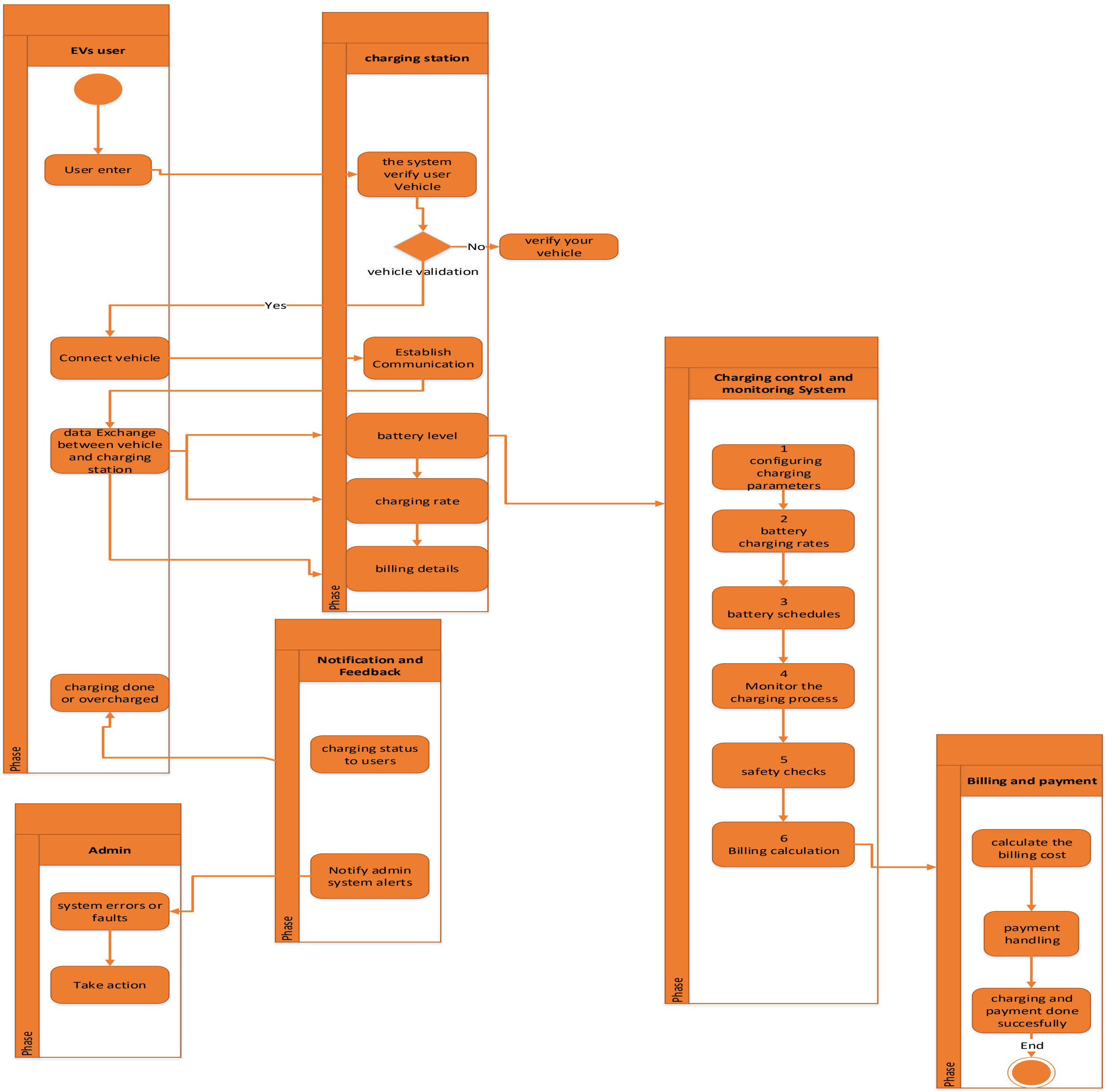


Figure 03: Activity diagram of IOT

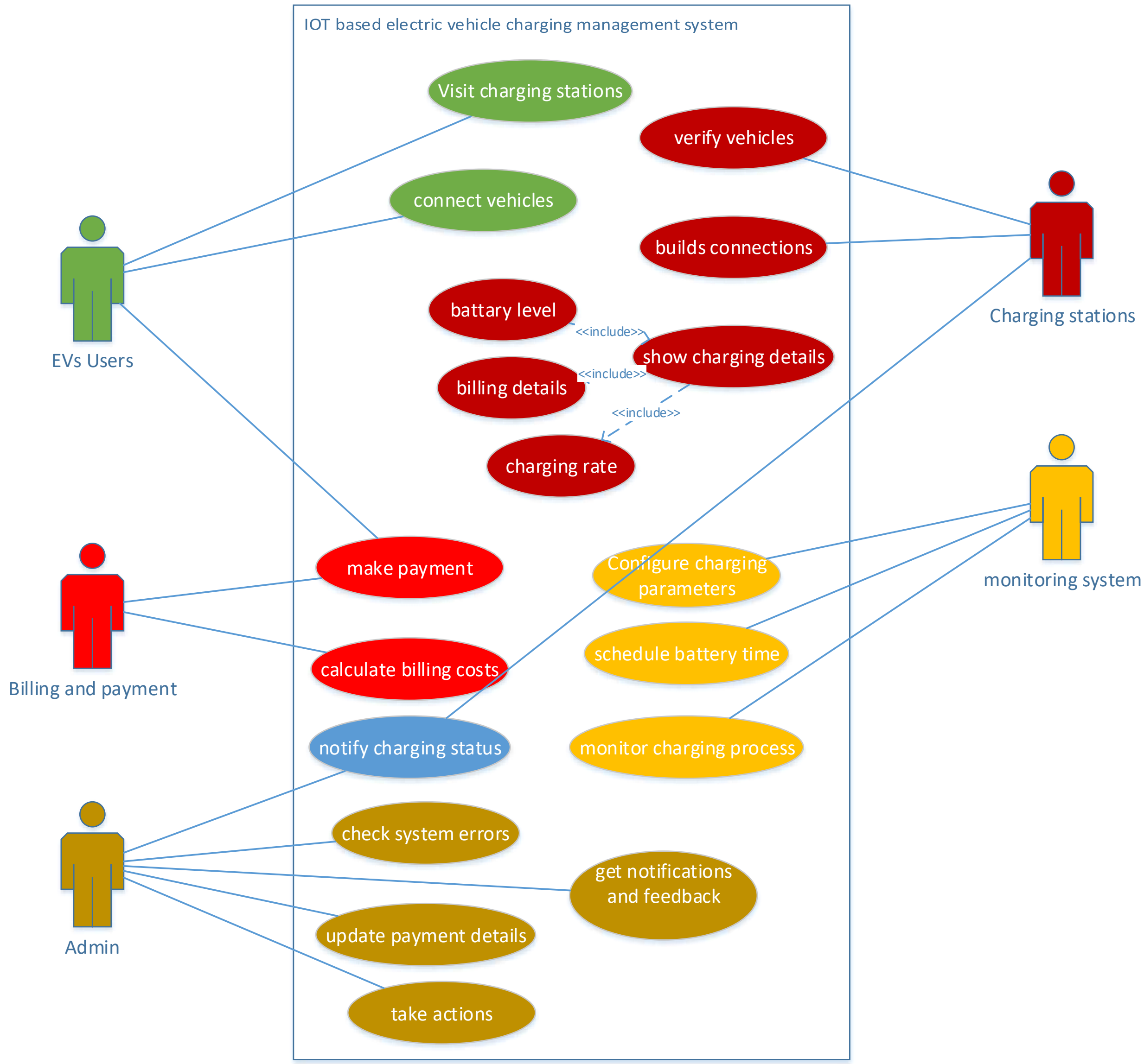


Figure 04: Use case diagram of IOT

2.5. System Development Tools:

Smart Electric Vehicle (EV) Charging Management System which is built on the IoT incorporated several tools and tech to guarantee high efficiency, effectiveness, and easy integration. For project management during the agile process, both Trello and Jira were used to help with the management of tasks, scheduling of sprints and general collaboration in completing a project. Within version control, Git and GitHub were used to facilitate control of code changes as well as to display and coordinate endeavour amongst developers. Writing tests and debugging was also made easier by Visual Studio Code, where in the unit and code testing was made easier. The back end development for the web app was done using PHP for server side scripting and for controlling the logic while Node.js was used to add efficiency to event based operations. On the frontend, HTML and CSS frameworks to create responsive interfaces to the websites by fulfilling the modes of operation and JavaScript was used in the development of the content and interactive functionalities. In mobile application development, frameworks, such as React Native or Flutter, made the application compatible for both Android and iOS. Moreover, real time data communication between IoT devices and server were achieved by XMPP protocol while developing and testing PHP and MySQL applications were eased by use of XAMPP server environment. MySQL was chosen as the database management system for safe and high level data activities inclusive of storage and retrieval services. These tools and technologies proved useful in the completion of the project with a guaranteed strong and user-friendly system.

2.6. Narrative Analysis Method:

When using the narrative analysis, the following issues may emerge; the study might be bias; the relationship between variables may be ambiguous; incorporating numerical data in the study might be a challenge. Research bias and subjectivity can be controlled through the use of a triangulation technique of analysing works by one or more analysts or comparing the works to increase the reliability of the study. Problems of high degrees of ambiguity can be managed by employing member check whereby participant’s samples information to check its accuracy. A research study that combines qualitative and quantitative information is more insightful in explaining the research phenomenon. To overcome the indicated challenges, the researchers should operate in transparent and very rigorous manner during the analysis, making coding and interpretation more consistent. Thus, reflexivity, peer assessments, as well as feedback from advisory committees ensure the credibility of the research and enhance the process.

CHAPTER 04

3. PROJECT DESIGN

3.1. System Overview and Design Constraints

The proposed IoT-based smart electric vehicle charging management system concept aims at controlling and managing the charging process of EVs with the help of real time monitoring, intelligent control and analytics. It brings together EV owners, charging stations and utility companies through a single interface run by IoT. HTML, CSS, and JavaScript based front end applications give the users an easy to use interface for services such as the management of charging session and getting real time information. The back-end part of the application is implemented with PHP and MySQL to address data operations and management needs. The integration with cloud computing allows data storage and analysis, while edge computing optimizes local decision making decreasing latency and bandwidth demand (Asaad, 2017). The design is subjected to several constraints. There is a requirement for cross-platform compatibility with installed applications and web applications addressing the same devices. Scalability is an important factor because the system must perform efficiently when there are more or few users. Security is also a limitation; the system must be required to employ strict encryption and authorization for the use of secured user data. Further, external conditions must be taken into account, and the quality of the Internet connection in different regions, for instance, might be different. Lastly, legal compliance of the charging infrastructure of EVs and IoT integration and reference models are considered important to meet legal requirements and to achieve compatibility and standardization (Deb et al., 2018).

3.2. System Architecture:

Package Diagram

The package diagram organizes the system into distinct functional components:

- **User Interface Package:** It involves social interfaces on the web and mobile application utilized by owners of EV’s.
- **IoT Device Package:** Coordinates with charging stations and sensors.
- **Backend Services Package:** Responsible for database work, computing, or handling of contracts on the fly, and optimizers.

- **Integration Services Package:** Enables the organisation to interact with external utilities such as energy companies and payment processor services.

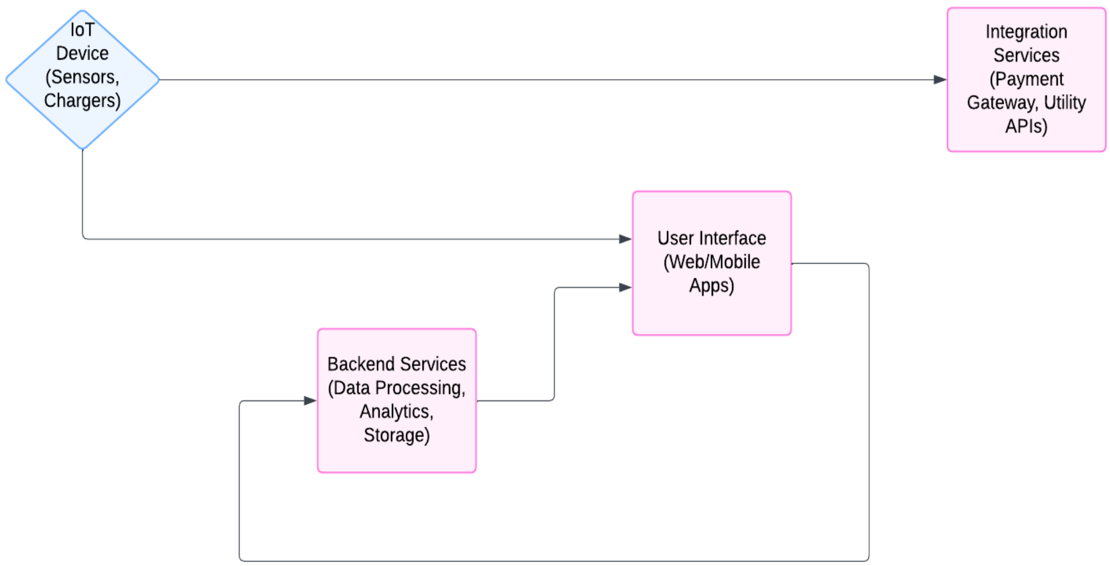


Figure 05: Package Diagram

Deployment Diagram

The deployment diagram outlines the physical distribution of the system:

- **Client Devices:** Smart apps for owners for starting & monitoring sessions through mobile/ web based applications.
- **IoT Devices:** Stations with different charging interfaces, which include the use of sensors and controllers.
- **Cloud Server:** Supports the hosting of backend services to handle production of analytics, storage and updates of the system.
- **Edge Devices:** Executive facilities used for data upload and real-time processing in the local domains.

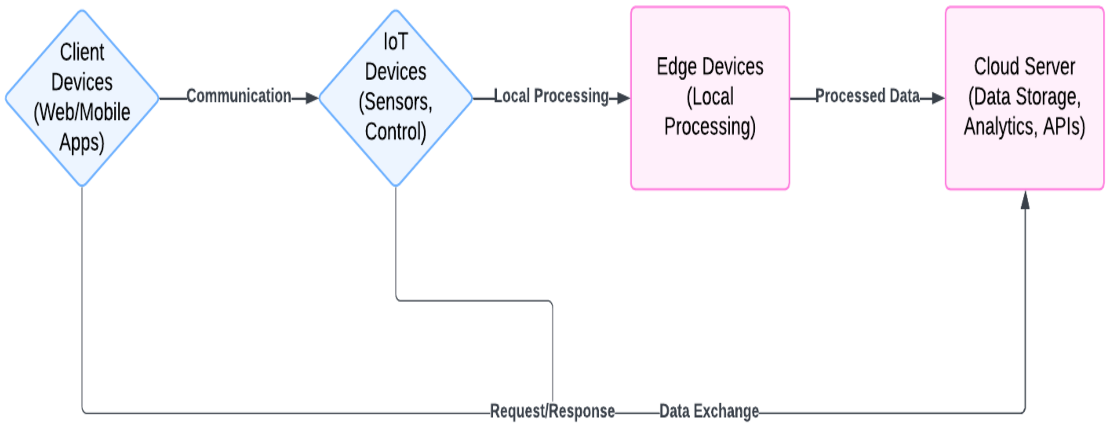


Figure 06: Deployment Diagram

Network Diagram

The network diagram represents communication pathways:

- **WAN Connectivity:** Responsible for the transmission of data between cloud servers and the client's application programs.
- **IoT Network:** A local network of charging points interacts with edge apparatus.
- **Internet Backbone:** Connects cloud servers with utility companies and payment gateways.
- **Data Encryption Channels:** Integrate well with all component to ensure that the communications are secure.

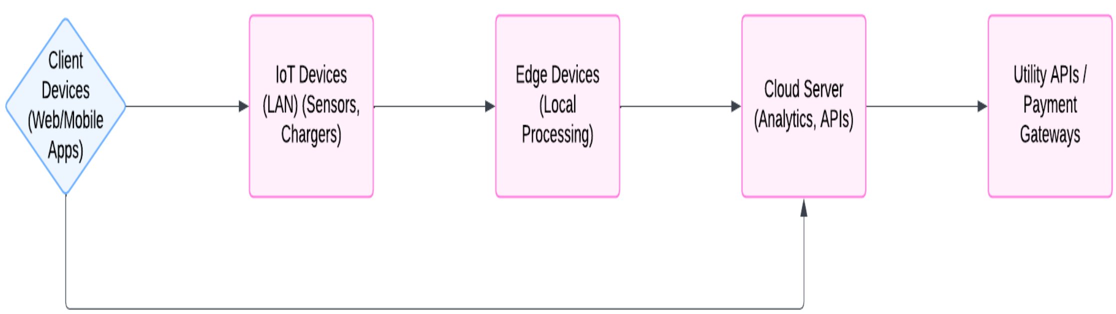


Figure 07: Network Diagram

3.3. Process Model

The above model as drawn clearly illustrate the Data Flow Diagram (DFD) perspective of a process model. It shows the various input and output, and their flow within a system involving the management of relevant vehicle and user processes. Some of the key processes include; Vehicle Registration, Charging Session Management and User Feedback & Support all interlinked by data flows. In the system, while the user who is an external entity registers and pays, the system produces alert messages and gains data for analysis. The DFD offers a clear structure to how inputs are processed through the systems, as well as how the outputs are returned, which makes it perfect for visual representation of the entire system.

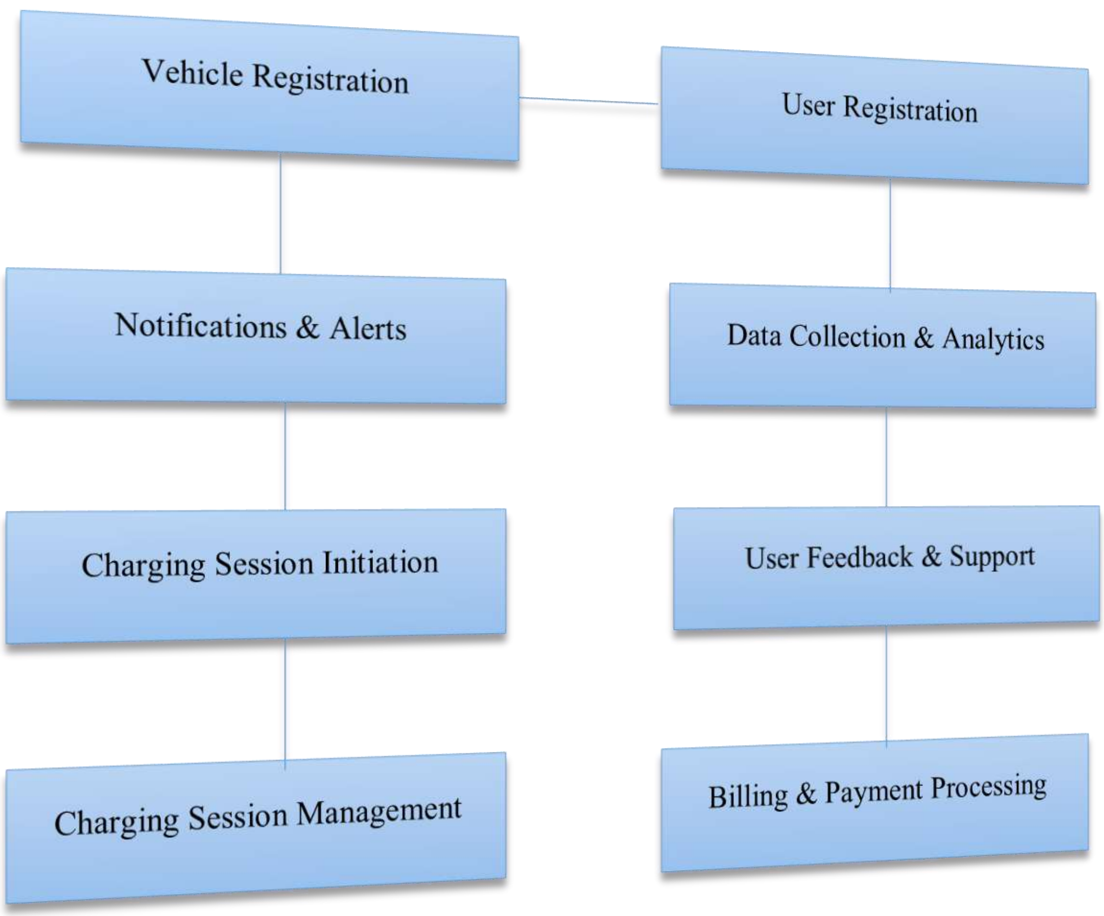


Figure 08: Data Flow Diagram

3.4. Data Model

The entity-relationship data model for this project categorizes and defines the system's data in terms of entities, attributes and relationships. It provides protection of the data, helps in optimizing the usage of the data and enables the functionality of the system like user registration, vehicle details managing, and payment gateway. This section describes the different parts of the data structure in order to improve the understanding of how the database is constructed.

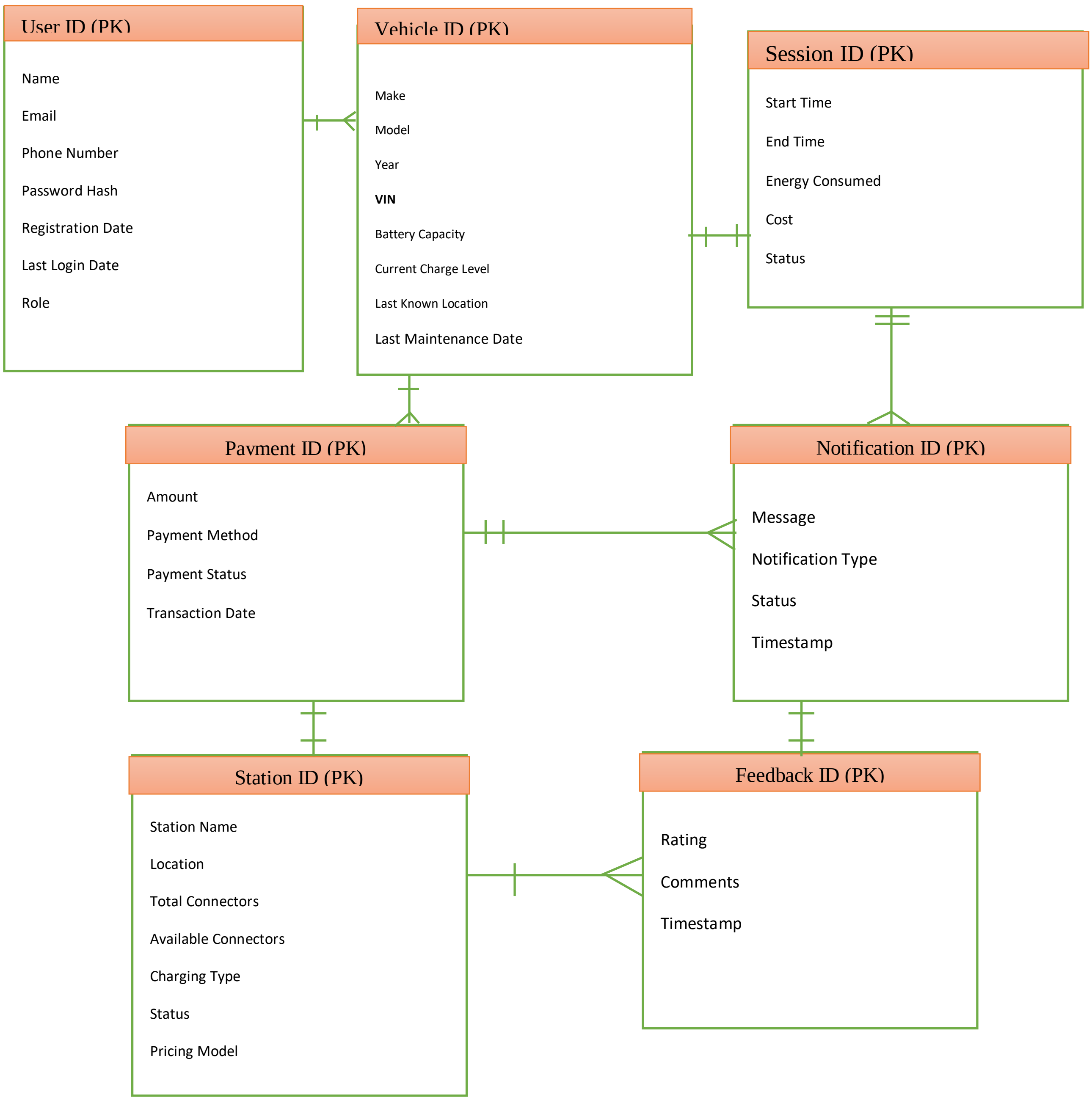


Figure 09: Entity Relationship diagram

Data Schema:

Field Name	Data Type	Description	Constraints
User ID	Integer	Unique identifier for users	Primary Key, Not Null
Vehicle ID	Integer	Unique identifier for vehicles	Primary Key, Not Null
Session ID	Integer	Unique identifier for sessions	Primary Key, Not Null
Payment ID	Integer	Unique identifier for payments	Primary Key, Not Null
Start Time	Timestamp	Start time of a charging session	Not Null
Amount	Decimal	Payment amount for a session	Not Null, Positive Value

Table 04: Data Schema

The data model is central in the system since it helps in storage, retrieval and management of the data. It defines entities and mutual connections and thus contributes to avoiding inconsistent data, streamlines the interaction of various system processes, including user registration, session management, and payment services.

CHAPTER 05

4. PROJECT IMPLEMENTATION, TESTING & EVALUATION

4.1. Project Implementation

Software Deployment

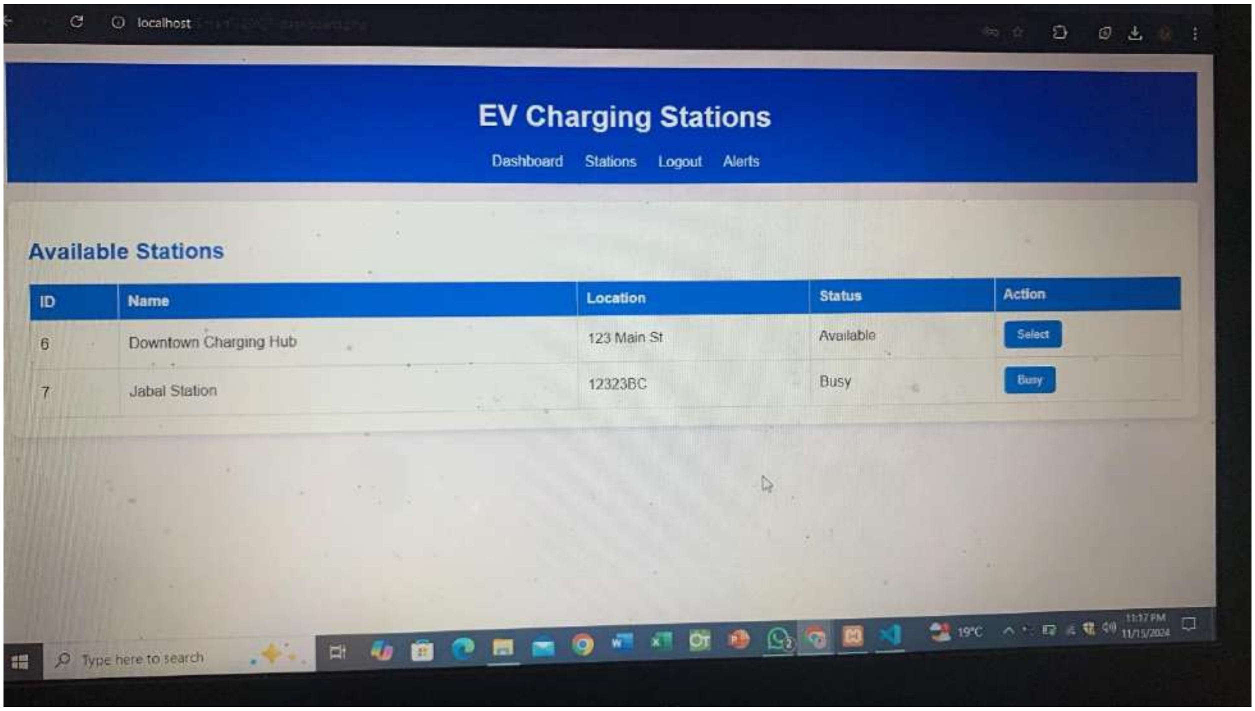
The implementation phase brings the developed Internet of Things (IoT)-based smart electric vehicle (EV) charging management system design to 'live,' with the possibility of real-world application. Real-time processing and storage of data demand a strong server environment; hence, the system uses an independent server with 16 GB RAM and four cores processors, SSD, Apache web server with the PHP support, and MySQL database facilities. Minimum hardware requirements are 64-bit Windows Linux or Linux server with 8GB Ram and 500 GB storage 64-Bit Processing PHP 7.4+ and Intel based IoT integration libraries MySQL 5.7+ hardware requirements. After installation, Apache with PHP have to be configured, a MySQL database has to be created for the project and necessary files have to be uploaded, and IoT devices should connect through a secure MQTT broker in order to be able to communicate. Applications are developed and run on Android and IOS whereas the web application is run on web browsers of today's generation. After installation, cross-browser compatibility and Android and IOS compatibility tests were carried out to ensure all the modules of the system worked as expected and that they were communicating as required.

Screenshots and Discussion of Implemented Functions

The system under development encompasses several modules for the end users as well as the administrator. The main interfaces are personal user interfaces such as the dashboard and administrative interfaces and IoT device interfaces.

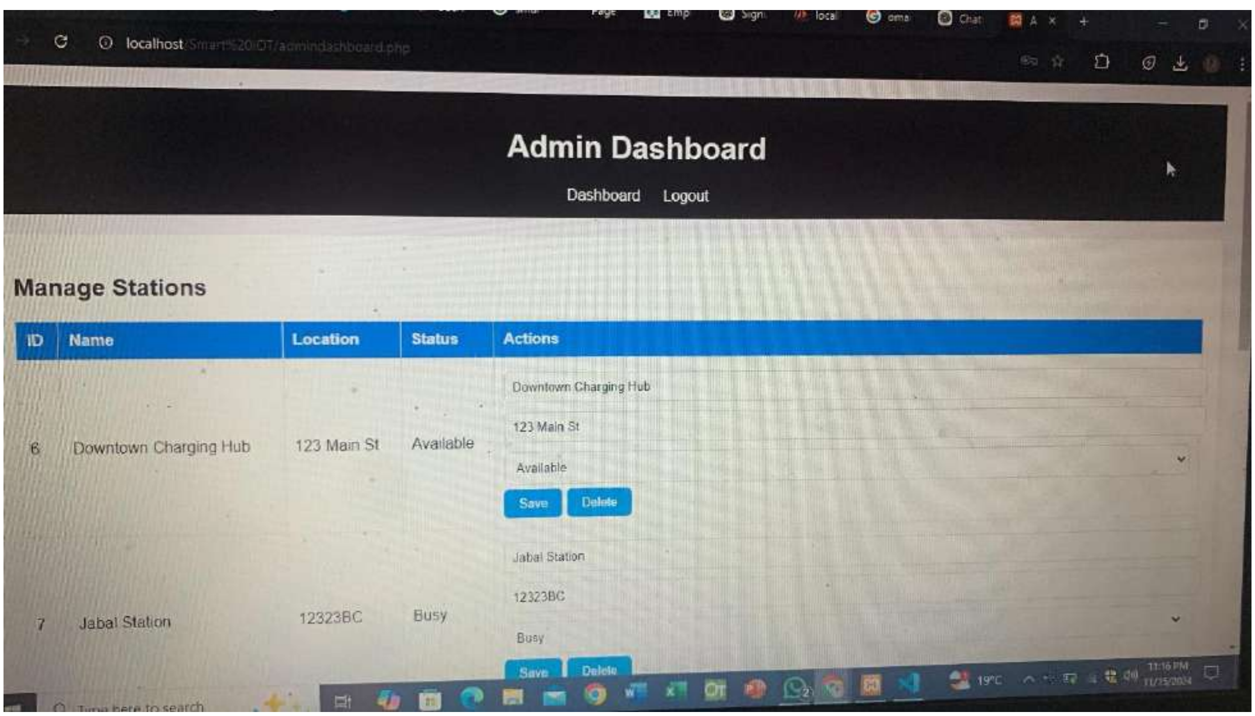
User Dashboard

It affords users with options necessary for charging the battery, current status of charging stations, and the charging session status as well as payment options. It shows the interactive dashboard that allows a subject to begin a session or to pause it. So, it provides more comfort to the users of this feature as well as efficiency.



Admin Panel

The admin interface provides the station operators with the activity logs, setting control and reports access. They can monitor the station diagnostics, control the pricing policies and regulate the users' accounts.



IoT Monitoring Interface

Current characteristics of IoT devices, such as their energy levels and functionality, are also depicted. It illustrates how data feeds from various sensors come into the system and what useful information is supplied by the system.

Discussion of Important Codes

Some of the critical segments were developed to address certain project criteria. Below are a few highlighted examples:

Real-Time Data Processing

The MQTT-based communication script ensures secure and efficient data transfer between IoT devices and the backend server.

```
$mqtt->publish('charging/status', json_encode($data), 0);
```

The following code shows how the data from the devices is sent back real time.

User Authentication

Secure user login was implemented using password hashing and token-based authentication.

```
$passwordHash = password_hash($password, PASSWORD_BCRYPT);
if (password_verify($inputPassword, $passwordHash)) {
    // User authenticated
}
```

This ensures data security and user privacy.

Energy Optimization Algorithm

An optimization algorithm balances grid loads and predicts peak demand based on historical data.

```
if grid_load > threshold:
    delay_charging(station_id)
else:
    start_charging(station_id)
```

This functionality helps reduce energy costs and enhance grid stability.

4.2. Project Testing

Alpha of / Beta / Acceptance / Unit / Integration / System Testing

To test the system validity black box and white box testing was done for the system testing. A process of unit testing was conducted for each module like login in user and monitoring of the stations, where the bugs can be found individually. For this integration testing was performed to check how different modules interact with each other such as IoT devices regularly updating the database or the interfaces showing correct information. System testing put the entire system under stress, security, and recovery tests, to determine how well or poorly the system was going to perform under different conditions. Last, the acceptance testing comprised alpha testing by the developers and beta testing with the real users in some of the charging stations to ensure it corresponded to their and the software’s expected functionality.

Test Cases and Results (refer to functional requirements – minimum of 25 test cases)

The IoT-enabled Smart Electric Vehicle Charging Management System has 25 test cases, based on its functional requirements, to assess its outcomes.

Test Case ID	Test Case Description	Preconditions	Test Steps	Expected Result
TC-001	User Registration with valid details	None	1. Go to registration page 2. Enter valid name, email, and password 3. Click Register	User should be successfully registered and receive a confirmation message.
TC-002	User Registration with existing email	User already registered	1. Go to registration page 2. Enter existing email 3. Click Register	System should show an error message for existing email.
TC-003	User Login with valid credentials	User exists in the database	1. Go to login page 2. Enter valid email and password 3. Click Login	User should be logged in and redirected to the dashboard.
TC-004	User Login with invalid credentials	User exists in the database	1. Go to login page 2. Enter invalid password 3. Click Login	System should show an error message for invalid credentials.
TC-005	View List of Available Charging Stations	User is logged in	1. Go to the charging station page 2. Click on 'View Stations'	User should see a list of available charging stations.
TC-006	Reserve an Available Charging Station	User is logged in, station is available	1. View list of stations 2. Click on 'Reserve' for an available station	Station should be reserved successfully

				and updated in the database.
TC-007	Attempt to Reserve an Already Reserved Charging Station	Station is reserved	1. View list of stations 2. Click on 'Reserve' for a busy station	System should show an error message indicating the station is busy.
TC-008	Start Charging Session	User has reserved a station	1. Click on 'Start Charging' for the reserved station	Charging session should start, and user should receive a confirmation.
TC-009	Monitor Real-Time Charging Status	Charging session is active	1. Start a charging session 2. Observe the charging status updates	User should receive real-time updates on charging status (percentage charged, time remaining).
TC-010	Complete a Charging Session	Charging session is active	1. Wait for the charging to complete (100%)	User should receive a notification that charging is complete.
TC-011	Payment Processing for Charging Session	Charging session completed	1. Click on 'Pay Now' after session completion 2. Enter payment details 3. Click Submit	Payment should be processed successfully, and a confirmation receipt should be displayed.
TC-012	Payment Failure Scenario	Charging session completed	1. Click on 'Pay Now' 2. Enter invalid payment details 3. Click Submit	System should show an error message indicating payment failure.

TC-013	View Transaction History	User is logged in	1. Go to transaction history page 2. Click on 'View History'	User should see a list of past transactions.
TC-014	Admin Login with valid credentials	Admin account exists	1. Go to admin login page 2. Enter valid admin email and password 3. Click Login	Admin should be logged in and redirected to the admin dashboard.
TC-015	Admin Add New Charging Station	Admin is logged in	1. Go to charging station management page 2. Click on 'Add Station' 3. Enter details 4. Click Submit	New charging station should be added successfully.
TC-016	Admin Edit Charging Station Details	Admin is logged in, station exists	1. Go to charging station management page 2. Select a station 3. Edit details 4. Click Save	Station details should be updated successfully.
TC-017	Admin Deactivate Charging Station	Admin is logged in, station exists	1. Go to charging station management page 2. Select a station 3. Click on 'Deactivate'	Station should be marked as inactive in the system.
TC-018	Receive Notification for Charging Status	Charging session is active	1. Start charging session 2. Observe notifications	User should receive notifications for status updates.
TC-019	Check Security Measures for User Registration	None	1. Attempt to register with SQL injection in the email field	System should prevent SQL injection and display an error message.

TC-020	Ensure Data Encryption for Payment Details	Payment processing initiated	1. Observe payment transaction details	Payment details should be encrypted and not stored in plain text.
TC-021	Verify User Profile Update	User is logged in	1. Go to profile page 2. Update user information 3. Click Save	User profile should be updated successfully.
TC-022	User Logout Functionality	User is logged in	1. Click on 'Logout' button	User should be logged out and redirected to the login page.
TC-023	Check System Response Time for Loading Charging Stations	User is logged in	1. Go to the charging station page	System should load the list of charging stations within acceptable time (e.g., < 3 seconds).
TC-024	Admin View User Management	Admin is logged in	1. Go to user management page 2. Click on 'View Users'	Admin should see a list of all registered users.
TC-025	Ensure System Logs User Actions	Any user action occurs	1. Perform any action (e.g., login, reserve station)	User actions should be logged for auditing purposes.

Table 05: Test Results

4.3. System Evaluation

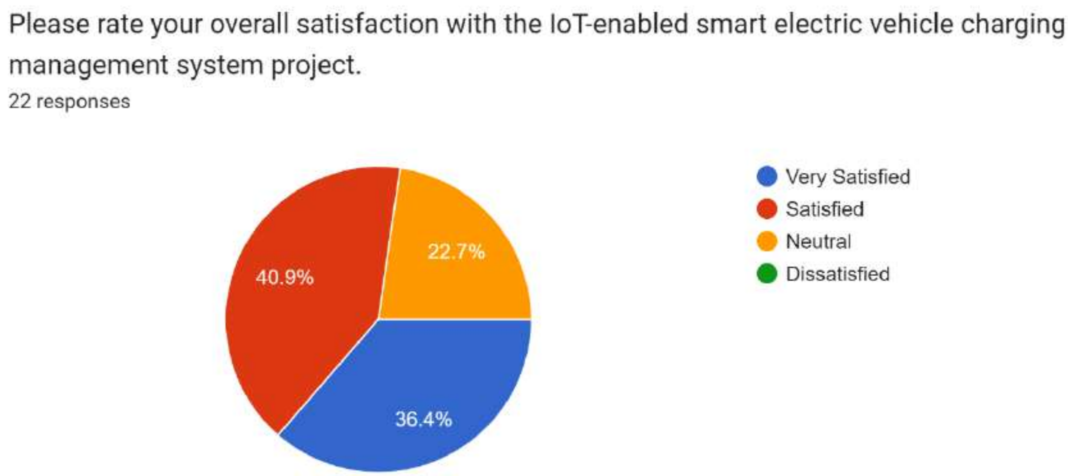


Figure 10: Overall Satisfaction

High satisfaction level can be explained by the fact IoT is used in this case for enhancing information search and for making the interface between EVs and charging stations as convenient as possible. Current data availability, well-connected networks, stated energy-saving objectives, unambiguous designs, and proper timely customer support enhance constructive attitudes. Nonetheless, 22.7% were neutral, meaning that there is still work to be done on the relative simplicity of the interface and further connection with clients and EMC and particularly on the customer support. The following issues will assist in raising the level of satisfaction and acceptability by users: Lack of ‘‘Dissatisfied’’ options proves that the system is quite efficient; however, constant monitoring and new changes need to be applied to support the high degree of satisfaction.

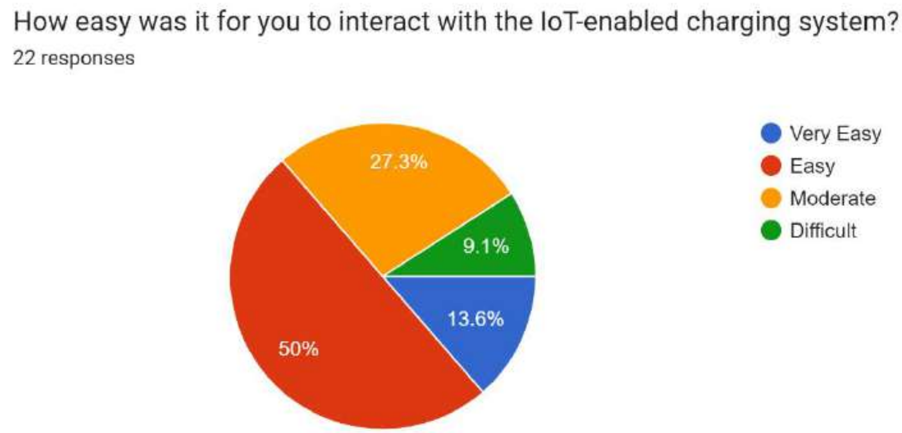


Figure 11: Interactions with IoT-enabled Charging System

To make further improvements in interaction experience, to ascertain what specific barriers these users faced in order to rate their experience as “Difficult” or “Moderate”, some information from these users should be collected. ‘This feedback could specify general issues for concern or specific problems that may recur. The following suggestions can be undertaken to improve user satisfaction level: i) User Interface improvements: The IoT enabled charging system can be adapted with a new user interface which would be easy to understand and use for more satisfied customers. The tutorials: The system developers can provide exhaustive tutorials on the UI and other features provided with the IoT enabled charging system so as to simplify its functioning for the users. Technical Support: Installing a strong line of technical support to counter customer

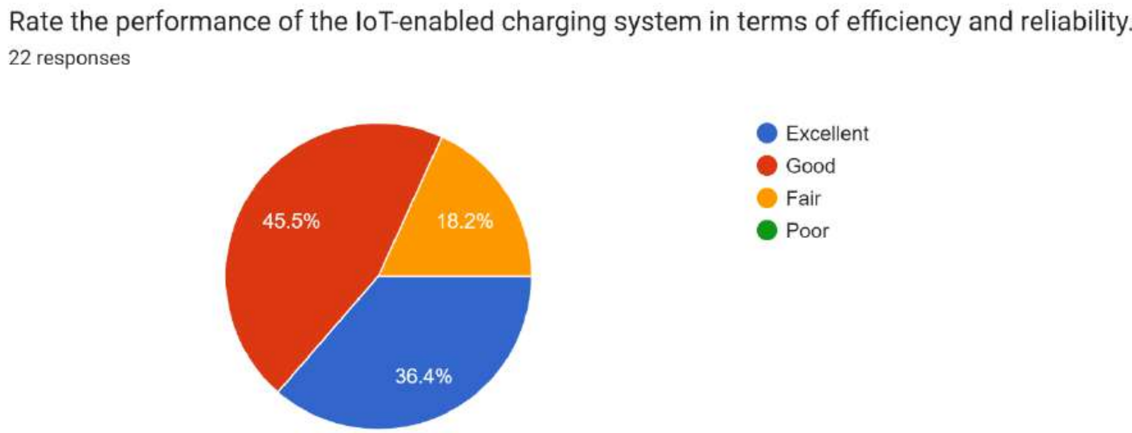


Figure 12: Rating of Performance of IoT

Strengthen the approach based on finding the causes for specific issues and addressing them as the reason for “Fair” ratings. For this reason, conduct user feedback sessions in detail in order to identify them right down to a T. Enhancing User Experience: When the respondents have given the rating of the system as ‘Good,’ areas of enhancement are as follows: The system could simply be enhanced to be better rated as ‘Excellent. ’ This could mean refining an existing program to give it high returns or increasing the durability of a tool, developing enhanced materials with new applications, or offering appropriate service to users. Maintaining Excellence: Sustain the function areas that got “Excellent” ratings and encouraged them so that they can remain efficient. Maintaining these features will be useful in establishing an overall high level for these features throughout the general user population.

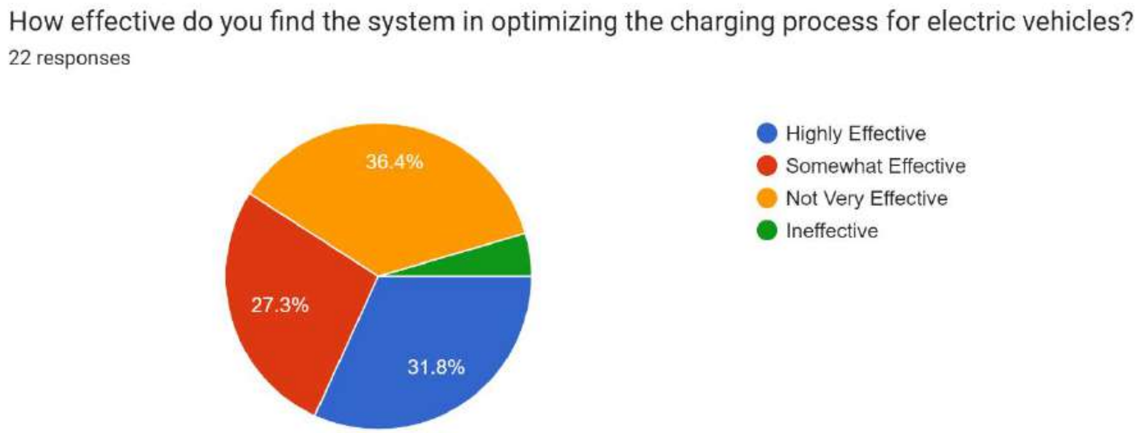


Figure 13: Effectiveness in optimizing the charging process

Looking at a wide variety of users and their response and noticing that of dealing 'Highly Effective' and 'Somewhat Effective', this shows that the system has a firm base and is effective for a significant number of users. Yet it is visible that the size of the audience who rated the system as 'Not Very Effective' is significant enough to conclude that there are issues and scenarios in which the systems fail to enhance the charging process.

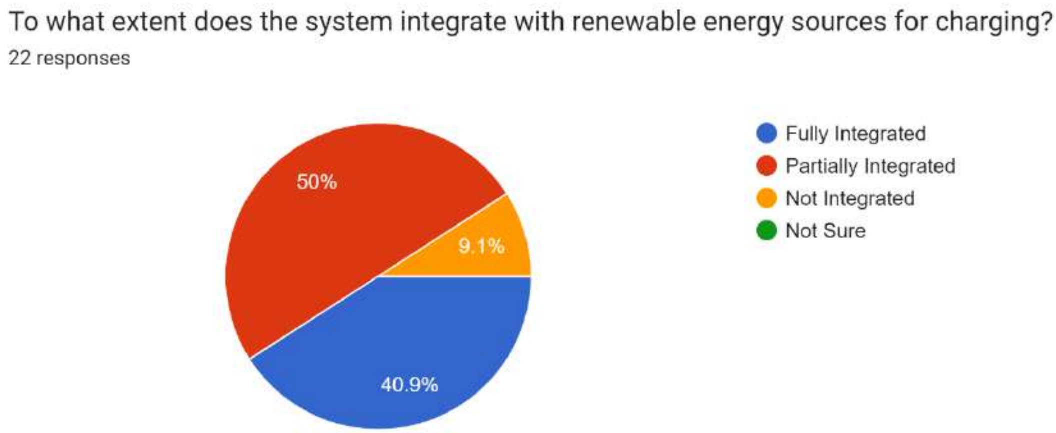


Figure 14: System Integration

To improve the acceptance of renewable energy sources in charging systems of electric vehicles, attention has to be paid to the development of the powerful energy control and optimization algorithm providing the maximum usage of renewable sources. It consists in the modernization of the charging station network by integrating facilities, namely photovoltaic panels, into renewable energy systems as well as engaging wind energy suppliers. Also, informing users to integration of renewable energy into the system via, live feed of the sources of power used to recharge the vehicles may increase user satisfaction. To modify customer behaviour and further incentivise charging sessions based on renewable resources, rewards such as discounts or loyalty points should be given out to the customers. Last of all, daily monitoring of the system, and thus bringing data and making adjustments to the system periodically, will ensure that the system develops for energy sustainability goals.

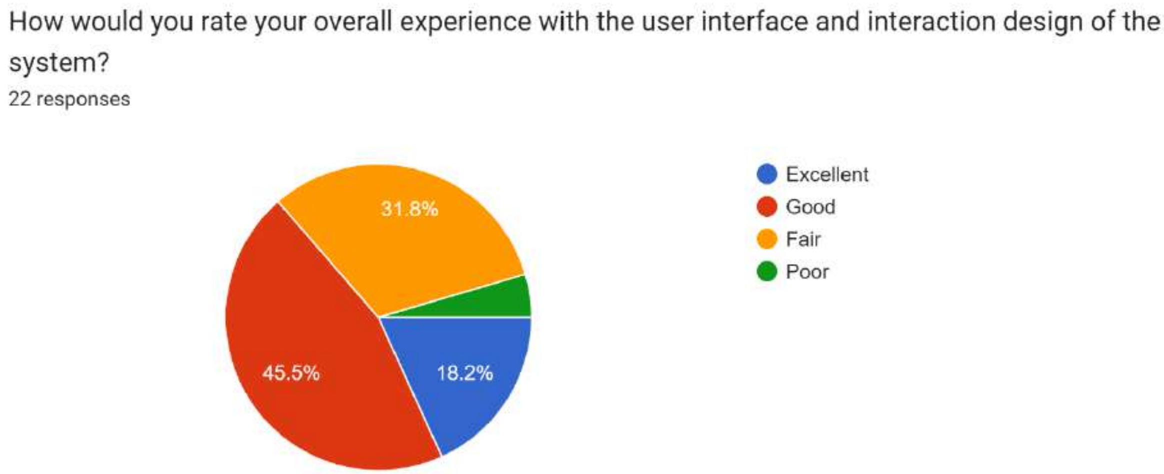


Figure 15: Experience with User Interface

The viewpoints show the respondents' fairly high level of satisfaction with the interface and interaction design but with certain flaws. In order to improve user satisfaction, the following measures should be taken Additional information: Various measures can be employed to improve user satisfaction. First, the concept of user-centered design and usability testing will be notable for weaknesses and poorly protected areas. Further improvements in elegance could also bring more aesthetic appeal to the interface and thereby attract more users. There are areas of better performance, in the current and future scenarios, such as, enhancing processing speed and minimizing throughput time. Further enriching the experience though could be implemented by including features such as customization for the application, notifications about the charging status, as well as more information on each charging session. It should also be accessible to the disabled like use of screen reader, text for images as well as high contrast designs with ease to read. Moreover, the validation process will be uninterrupted to get feedback from users, which will be useful to improve the interface constantly.

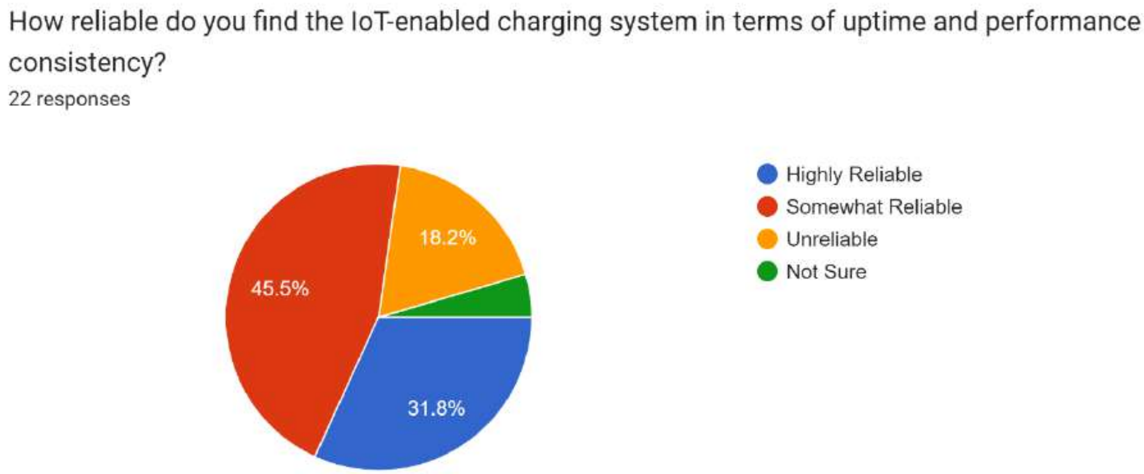


Figure 16: Reliability with IoT

The survey findings show that there is a general satisfaction with the aspect of the information providing since 63% of users state that the schedules of the TV matches their interest while 31.8% of the sample complain of reliability problem in the IoT-enabled charging system. There are several measures, which need to be put into practice for enhancing system reliability. First, maintenance and active monitoring of the system is important for alerting on performance problems and this includes constant watch on the manufacturing process to avoid disruption. Furthermore, the system would be arranged to have backup components for increased uptime when the other goes down due to failure. Improvement of performance, especially in back-end systems, should involve scalability when working in heavy loads balancing and resource optimization. There can be a way of integrating the feedback of the users to recognize regularity concerns and ensure users about the conditions that prompt system disability or have bugs. Last of all, there should be a system that can be improved periodically, with smaller changes acquiring user and data feedback to make the system more reliable step-by-step.

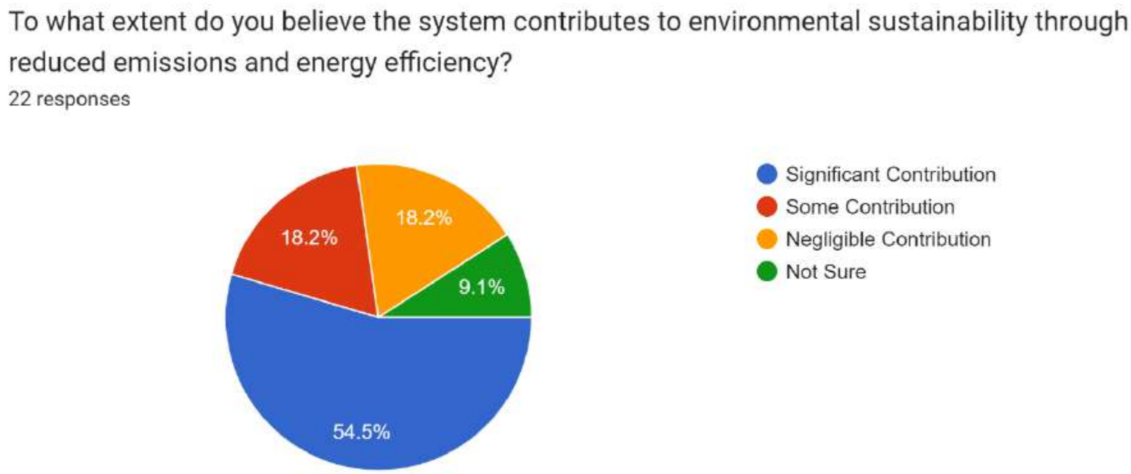


Figure 17: Contribution towards environmental sustainability

A total of 72.8% of the users indicated that they either have a low environmental awareness of the system or are not sure about the environmental impact on sustainability. This implies there is need for improvement in information on the positive impacts of the system on the environment. Still, to enhance the performance of mobile applications, several enhancement can be done. The commitments made on emissions reductions, energy, conservation and the use of renewable energy should be backed up by a detailed written account in the non-financial report section of the website. Others are also a result of awareness since users can be educated about the sustainability impact through informative content on the digital platform or App notifications and sensitisation workshops. Additional features should include energy modes, green power, and tips towards eco-friendlier charging.

CHAPTER 06

5. CONCLUSION

The concept noted for the development of the Smart Electric Vehicle (EV) Charging Management System based on IoT helps to achieve a greater advancement toward the global challenge of extremity of the EV charging management system. The goal of this project was to utilize IoT technologies in this project, optimize operation and the experience related to EV charging. The outcome effectively achieved the goals to provide the system with the means to monitor operation in real time, to use secure payment systems, and to optimize the consumption of energy. To this end, this chapter measures the extent of accomplishment of the project and synthesises lessons learned, future improvement and personal professional development gained.

By offering attention to the detailed specifics of the respective project, one can identify a significantly high level of success. The frameworks that have been used in this project; for instance, agile development, and the use of predictive analytics to manage energy also came out as success stories in this context. Agile enabled incremental development cycles beneficial for likely refinements and incorporation of stakeholder feedbacks, while, Predictive helped charging schedules optimization and lessening of the grid load. In addition, the aspects of the system included easy-to-use interfaces, real-time monitoring aspects, and Internet of Things-based optimization to overcome the problems of accessibility and convenience in the conventional approach to EV charging. However, some of the problems like, how IoT devices would be incorporated or even incorporation of the fry with standards regulatory policies caused some level of problem. Nevertheless, all these difficulties allowed to deliver the project within the timeline stipulated, and the efficiency of applied approaches is confirmed.

The completion of this project made me gain many things as I went through different tasks. In a technical perspective, it improved the efficiency in important technologies used in device communication via MQTT protocol, back-end operations in PHP, and database operations in MYSQL. It also brought practical exposure to IoT interconnection and how it can be easily managed regarding the software and the hardware substructure. Apart from the actual technical competencies, this project helped to enhance problem-solving skills on such problems as, for example, data sync or protecting users' data privacy. Projects such as incorporating token based authentication showed that strengthened system security could be easily integrated boosting early perception of possible flaws. It also confirmed the benefits of completing a high-complexity usability testing exercise, as initial feedback from the users shaped subsequent improvements to interfaces.

It would be possible to observe that future improvements of the system could lead to even higher functioning and operation of the system. One of them could be charging infrastructure reinforcements using renewable energy sources for charging electric vehicles. Delivering options to the consumers with real time information on energy sources might help create consciousness regarding the environment. Further, increasing the scalability of the system with respect to the models of EVs and charging protocols would be beneficial to the general adoption of the system. The features that may help make user experience enriched can include customization, proactive queries and recommendations, voice recognition commands, and brilliant data analytics. Additional security measures are also available, including accelerating the recording of transactions in the blockchain to make them transparent, and adding an extra layer of identification to account security.

The development, both professionally and academically, has been rather impressive in the course of this project. Overcoming the challenges of designing and implementing an advanced IoT-based system has helped to gain more confidence when it comes to software project management. In this, it meant that for problems to solve as is the case in the real world, various technologies should be combined. Also, assuming the leadership role best enhanced project management skills such as time management, communication and decision-making. Working with other team, as well as presenting the progress in front of the stakeholders improved communications skills which were used to describe the technical information in the language comprehensible for the general public.

This project also underlined the importance of training to make sure you keep coming up to par with your technological and competitive counterparts. Staying abreast of current trends in IoT, energy efficient solutions, and end user interface design became critically important for the development of enhanced solution. The course knowledge and skills, not only enhance professional competence in the short run, but also provide the fundamentals for the future plan of sustainable technology developments.

Therefore, the proposed IoT enabled Smart EV Charging Management System substantiates the IoT technology on the path to revolutionize the existing EV charging system. Through the approaches that provide for accessibility, efficiency and sustainability of this project, show how innovation serves as the tool for change. Of course, there is potential for additional improvements, yet, the existing system has substantial potential for making our world more sustainable, based on the principles of interconnectedness. The success of the project shows that utilization of technical knowledge, projecting skills, and practice enhancement in turning difficult issues into significant contributions in the sphere of sustainable technology management is possible.

References:

Anderson, M., & Jenkins, R. (2020). "Cloud-based learning management systems: A new approach to employee training." *Journal of Cloud Computing*, 9(1), 101-115.

Angeline and Rajkumar, M.N. (2023). Integration of electric vehicle with smart grid using bidirectional SEPIC–zeta converter. *Electrical engineering*. doi:https://doi.org/10.1007/s00202-023-02116-7.

Asaad, M., Ahmad, F., Saad Alam, M. and Rafat, Y. (2017). IoT enabled Electric Vehicle's Battery Monitoring System. *Proceedings of the The 1st EAI International Conference on Smart Grid Assisted Internet of Things*. doi:https://doi.org/10.4108/eai.7-8-2017.152984.

Big Data Mining of Energy Time Series for Behavioral Analytics and Energy Consumption Forecasting. (2018). *Energies*, 11(2), p.452. doi:https://doi.org/10.3390/en11020452.

Chen, C., Zarazua de Rubens, G., Noel, L., Kester, J. and Sovacool, B.K. (2020). Assessing the socio-demographic, technical, economic and behavioral factors of Nordic electric vehicle adoption and the influence of vehicle-to-grid preferences. *Renewable and Sustainable Energy Reviews*, 121(121), p.109692. doi:https://doi.org/10.1016/j.rser.2019.109692.

Cruz, P.L., Iribarren, D. and Dufour, J. (2019). Life Cycle Costing and Eco-Efficiency Assessment of Fuel Production by Coprocessing Biomass in Crude Oil Refineries. *Energies*, 12(24), p.4664. doi:https://doi.org/10.3390/en12244664.

Deb, S., Essam A. Al Ammar, AlRajhi, H., Alsaidan, I. and Shariff, S.M. (2022). *V2G Pilot Projects: Review and Lessons Learnt*. [online] www.igi-global.com. Available at: https://www.igi-global.com/chapter/v2g-pilot-projects/293776 [Accessed 25 Apr. 2024].

Deb, S., Tammi, K., Kalita, K. and Mahanta, P. (2018). Review of recent trends in charging infrastructure planning for electric vehicles. *WIREs Energy and Environment*, 7(6). doi:https://doi.org/10.1002/wene.306.

Gupta, V., Sharma, N., Deepesh Maram and Himanshu Priyadarshi (2020). IOT enabled data acquisition system for electric vehicle. *AIP conference proceedings*. doi:https://doi.org/10.1063/5.0031401.

Indra Teja Vadium, Das, R., Wang, Y., Putrus, G. and Kotter, R. (2019). Electric vehicle Carbon footprint reduction via intelligent charging strategies. doi:https://doi.org/10.1109/mps.2019.8759783.

Patil, P. (2019). Electric Vehicle Charging Infrastructure: Current Status, Challenges, and Future Developments. *International Journal of Intelligent Automation and Computing*, [online] 2(1), pp.1–12. Available at: https://research.tensorgate.org/index.php/IJIAC/article/view/25

Savari, G.F., Krishnasamy, V., Sathik, J., Ali, Z.M. and Abdel Aleem, S.H.E. (2019). Internet of Things based real-time electric vehicle load forecasting and charging station recommendation. *ISA Transactions*. doi:https://doi.org/10.1016/j.isatra.2019.08.011.

Shin, S.-J., Woo, J. and Rachuri, S. (2014). Predictive Analytics Model for Power Consumption in Manufacturing. *Procedia CIRP*, 15, pp.153–158. doi:https://doi.org/10.1016/j.procir.2014.06.036.

Shneiderman, B., & Plaisant, C. (2021). *Designing the User Interface: Strategies for Effective Human-Computer Interaction*. Pearson Education.

Siemens, G. (2013). "Learning analytics: The emergence of a new discipline." *American Journal of Distance Education*, 27(4), 204-218.

Sierzchula, W., Bakker, S., Maat, K. and van Wee, B. (2014). The Influence of Financial Incentives and Other socio-economic Factors on Electric Vehicle Adoption. *Energy Policy*, [online] 68(68), pp.183–194. doi:https://doi.org/10.1016/j.enpol.2014.01.043.

Uddin, M., Romlie, M.F., Abdullah, M.F., Abd Halim, S., Abu Bakar, A.H. and Chia Kwang, T. (2018). A review on peak load shaving strategies. *Renewable and Sustainable Energy Reviews*, 82, pp.3323–3332. doi:https://doi.org/10.1016/j.rser.2017.10.056.

Vygotsky, L. (1978). *Mind in Society: The Development of Higher Psychological Processes*. Harvard University Press.

Wang, Z., Li, X., & Chen, M. (2021). "The effect of mobile learning on employee engagement and performance." *Mobile Learning and Technology Journal*, 15(1), 55-70.

Xue, C., Zhou, H., Wu, Q., Wu, X. and Xu, X. (2021). Impact of Incentive Policies and Other Socio-Economic Factors on Electric Vehicle Market Share: A Panel Data Analysis from the 20 Countries. *Sustainability*, [online] 13(5), p.2928. doi:https://doi.org/10.3390/su13052928.