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Tree Inventory using Near-Field Communication (NFC) Tag

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***Abstract*—Urban green spaces play a vital role in community well-being; however, effectively maintaining and managing these spaces, particularly in terms of individual tree health, can be challenging. Conversely, Geographic Information Systems (GIS) technology offers a promising solution. This study aims to develop a web-based GIS system for tree park maintenance. The research problem stems from risks such as tree death, overgrowth, nutrient deficiencies, and pest infestations, which resulted from inadequate maintenance and monitoring practices, the current manual monitoring methods, and the lack of a dedicated maintenance system. The research objectives encompass reviewing existing approaches, developing a web-based GIS with Near Field Communication (NFC) technology, and conducting testing. The methodology involves the development of a web-based tree inventory system and its integration with the Web NFC API, following the System Development Life Cycle (SDLC). The output is a process flow for updating on-site tree inventory using the NFC tag feature through a web-based GIS application, which enables users to submit real-time maintenance activities and allows administrators to view the data. The benefits include enhanced durability and reliability in the field, as the use of NFC tags, compared to traditional QR codes, offers better resistance to weather conditions. This leads to more consistent data retrieval, improved monitoring and management, and informed decision-making for future maintenance, ultimately contributing to healthier and safer urban green spaces.**

***Keywords*—Urban green spaces, Geographic Information System (GIS), Web-based GIS, Park maintenance, Near Field Communication (NFC)**

I. INTRODUCTION

Urban green spaces, including parks and tree-lined streets, are essential for the well-being of communities. Maintaining these spaces in a healthy and sustainable manner poses significant challenges for park management and maintenance staff, particularly in monitoring and managing the health and growth of individual trees [1,2]. Geographic Information Systems (GIS) technology provides a promising solution to address these challenges. By developing a web-based GIS system, park management and maintenance staff can easily monitor and manage tree maintenance activities within the park. This system enables efficient data collection, storage, analysis, and visualisation, allowing for the identification of patterns and trends related to tree health.

Improper tree maintenance and monitoring in parks can lead to various issues, such as tree death, overgrowth, nutrient deficiencies, and pest infestations, posing risks to both the trees and park visitors [2,3]. The reliance on manual methods for recording maintenance activities hinders data storage and decision-making for future maintenance. In contrast, the absence of a dedicated maintenance system complicates tree management in parks [4,5,6,7]. To address these challenges, the use of Geographic Information Systems (GIS) and Near Field Communication (NFC) technology has been explored. A web-based GIS system enables efficient data collection, storage, analysis, and visualisation of tree maintenance activities, while NFC technology facilitates convenient data submission and retrieval [8,9,10]. Implementing these technologies can enhance data management and decision-making processes, thereby improving the efficiency and effectiveness of tree park maintenance.

The research problem identified in this scenario is the necessity for a more efficient and practical approach to monitor and manage the health and growth of individual trees in urban green spaces, with a specific focus on SIREH Park. The current manual methods of tree maintenance and monitoring, combined with the absence of a dedicated maintenance system, have

resulted in risks such as tree death, overgrowth, nutrient deficiencies, and pest infestations. This lack of adequate care not only endangers the well-being of the park's trees but also poses potential hazards to park visitors [2,3].

Accordingly, the remainder oconcludeer is structured as follows: Section 2 explains the research aim and objectives; Section 3 reviews the relevant literature; Section 4 describes the methodology; Section 5 presents the results; Section 6 discusses the findings; and Section 7 concludes with implications and directions for future research.

II. AIM AND OBJECTIVES

This research aims to develop a web tree park maintenance with NFC technology. The primary objective is to review the existing approaches, systems, and practices employed by urban park owners in managing tree park maintenance in order to identify their strengths and limitations. Valuable insights can be gained by understanding the existing landscape of tree park maintenance, thus providing a solid foundation for the development of an improved maintenance system. The second objective is to develop a web-based GIS application that integrates NFC technology, enabling urban park operators and gardeners to monitor and track tree maintenance activities effectively. This involves selecting suitable software and database solutions, designing the application architecture, determining the appropriate system development methodology, and defining the required functionality. Additional emphasis was placed on developing a user-friendly Graphical User Interface (GUI) to ensure ease of use for the intended users.

In line with the aim and objectives, a comprehensive testing phase was included in this research to evaluate the developed web-based GIS application. The purpose is to assess the system's functionality, usability, and performance. Through rigorous testing procedures, the effectiveness and efficiency of the system were determined, addressing key aspects such as system reliability, data accuracy, and user satisfaction. The testing process adhered to predefined criteria and methodologies to ensure accurate evaluation. Testers with relevant expertise and knowledge were involved in the evaluation process, allowing for comprehensive feedback on the system's performance. By conducting thorough testing, any identified issues or areas for improvement can be addressed, refining the web-based GIS application and enhancing its overall quality and usability.

TABLE I. AIM, OBJECTIVES, AND RESEARCH QUESTIONS

Objectives	Research Questions
To review the existing approach for tree park maintenance	1. What is the existing tree park maintenance system that is currently in use?
To develop a web-based GIS for tree park maintenance using NFC technology	1. What are the software and databases used to create the system? 2. How to design the architecture of the web-based GIS application integrated with NFC technology? 3. What methodology is used in the system development? 4. What functionality needs to be included in the system?
	5. How is the Graphical User Interface designed?
To test the developed application	1. How do we test the system? 2. How is the tester? 3. How is the end-user's feedback?

A. Scope of Study

The scope of this study encompasses tree park maintenance information, including pruning, watering, fertilisation, and tagging. The NFC API was used to read information, including Plot ID, location, maintenance activities, date, and time. The system was developed following a web-based Geographic Information System (GIS), allowing data to be accessed and managed through a website. The data utilised in this project was obtained from relevant sources, such as park management and those responsible for tree park maintenance.

SIREH Park, located in Iskandar Puteri, Johor, Malaysia, was selected as the study area due to its diverse tree collections and existing facilities, making it an ideal location for testing and validating the proposed system. Fig. 1 shows the location of SIREH Park.

Fig. 1. SIREH Park in Iskandar Puteri, Johor

III. LITERATURE REVIEW

A. Existing Approach for Tree Park Maintenance

Past studies have collectively provided empirical evidence supporting the efficacy of web-based GIS systems in monitoring and managing the health of trees in parks. By integrating data collection, analysis, and visualisation, these systems offer valuable insights and tools for efficient urban tree management, leading to the preservation and well-being of these vital natural resources. Table II shows the existing approach for tree park maintenance.

TABLE II. EXISTING APPROACH FOR TREE PARK MAINTENANCE

Purpose	Methods	Limitations that identified	Ref.
A web-based GIS system that enabled park managers to track	Manual identification (tree ID / map reference)	No direct physical–digital linkage; prone to misidentification during field work	[7]

Purpose	Methods	Limitations that identified	Ref.
and report on tree maintenance tasks	Maintenance records updated via system interface		
Utilised a web-based GIS to monitor tree health in a park	Sensor-linked tree records (no physical tag) Monitoring-focused; limited maintenance task logging	Not aligned with routine gardener workflows for maintenance on site	[9]
Web-based GIS to monitor and manage the health of urban trees using GIS mapping and remote sensing technology	Supports inspection and visual assessment Enables reporting and reactive maintenance	No mechanism for fast tree-level access during field operations	[11] [12]
Trees are tagged with QR code linked with website	QR code (optical scan) Allows access to tree data via mobile devices	Requires line-of-sight; affected by lighting, dirt, and physical damage; scanning friction	[13]
RFID tree tags for marking trees in the forest	RFID tags with dedicated readers Supports tree identification and tracking	Requires specialised readers Higher cost and training requirements	[14] [15]
RFID tree tags for roadside tree management	RFID and Personal Digital Assistant (PDA) are used to facilitate inspection and diagnosis for tree treatment		[16]
NFC tag for urban street management	NFC tag installed at the street tree	Fast and low-friction 'tap-to-record' Reduces wrong-tree entry Works well with NFC-enabled smartphones Short range means one-by-one tapping (not bulk scanning) Requires NFC-capable devices Tag placement matters	[17]
NFC tag for providing information about species in botanical garden	NFC tag installed at dedicated species		[18]
A blockchain-based web application implementing a NFC traceability system for the smart management of forestry nurseries	NFC tag is used for each sapling in the nurseries, providing transparency and traceability for consumers regarding the origin and cultivation operations of the plants		[19]

Several studies related to trees have employed RFID for tracking and tracing purposes. For example, RFID has been used to track hikers in dense forest environments, enabling monitoring for search-and-rescue operations [20]. In contrast, [21] applied RFID to track the olive oil supply chain from farm to final consumers. Table II compares existing case studies that provide tree inventory systems, either through web-based GIS platforms or via tree tagging technologies such as QR codes, RFID, or NFC.

As shown in the table, existing web-based GIS systems enhance urban tree management primarily through data centralisation and visualisation. However, they often fail to address the operational "last-meter" challenge of reliably identifying the correct tree record during on-site maintenance. While QR codes and RFID have been used for plant and tree identification and inspection, they present limitations related to optical reliability (QR codes) and field usability or device requirements (RFID). NFC-based tagging has demonstrated promise for efficient tree information retrieval and editing through tap-based interaction. Nevertheless, there is limited research on integrating NFC with web-based GIS platforms for routine tree park maintenance, as well as on systematically evaluating such systems with park operators and gardeners.

Fig. 2 presents a radar chart comparing NFC, RFID, and QR code technologies based on criteria relevant to tree maintenance workflows, using a five-point qualitative scale. NFC demonstrates strong performance in per-tree identification certainty, on-site maintenance updates, and low reader cost due to smartphone-based operation. RFID excels in long-range, mass scanning capabilities, whereas QR codes offer low-cost accessibility but are limited in terms of durability and distance-based scanning. Overall, the chart highlights the trade-offs among these technologies and supports the suitability of NFC for tree-level maintenance applications.

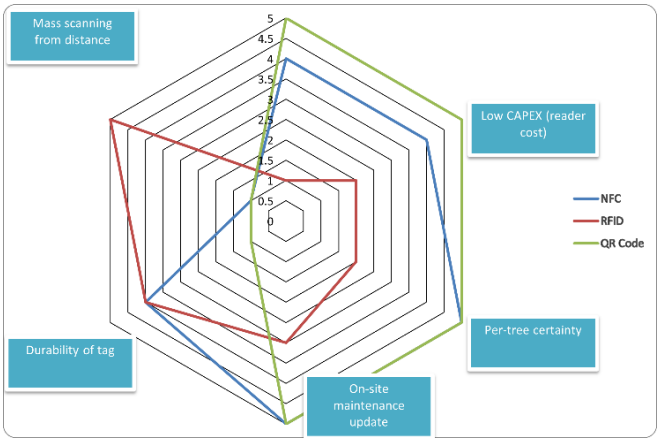

Fig. 2. Comparison of NFC, RFID, and QR code technologies for tree maintenance applications

B. Web-Based GIS Application

A web-based GIS application refers to a software system that harnesses internet-based technology to offer access to geographic data and spatial analysis tools through a web browser. These applications serve various purposes, such as visualising and mapping data, managing data resources, and performing spatial analysis tasks. They are also accessible from anywhere with an internet connection, thus facilitating real-time collaboration and data sharing among users [22,23,24]. The scope of web-based GIS applications extends across numerous fields, including urban planning, environmental monitoring, natural resource management, transportation, and public health. Prominent examples of web-based GIS applications include popular online mapping platforms such as

Google Maps, ArcGIS Online, and OpenStreetMap, as well as tailored applications created for specific organisations or projects [25].

C. Tree Park Management

Tree park management involves the comprehensive care and maintenance of trees within a designated park or public green space. It encompasses a range of tasks, including tree planting, pruning, removal of dead or diseased trees, and control of pests and diseases. Compliance with local regulations and safety guidelines is also a crucial aspect of tree park management [26,27,28,29].

A long-term tree park management plan goes beyond immediate maintenance activities and focuses on broader objectives. This includes establishing clear goals and strategies to enhance the overall health and diversity of the park's tree population over several years or even decades. Regular monitoring and assessment of tree health and the park's ecosystem are conducted to identify areas requiring attention or improvement. Maintenance and care practices, such as pruning, watering, fertilisation, and addressing pest or disease issues, are also implemented. Restoration and reforestation efforts are undertaken to rehabilitate damaged or degraded areas and promote biodiversity. Additionally, education and outreach initiatives are developed to raise awareness about the significance of trees and engage the local community in supporting the park's management endeavours [30,31,32,33].

D. Near Field Communication (NFC)

NFC is a wireless short-range communication technology built on the current infrastructure's RFID standards. An NFC device generates radio frequency signals in the 13.56 MHz range for communication and has a short-range of 4 to 10 centimetres. It is known as High Frequency (HF), which is commonly used for contactless credit cards and tickets. The magnetic inductive coupling technique is used to transmit and receive data between two closely positioned devices. Additionally, NFC supports data rates of 106 kbps, 212 kbps, and 424 kbps [34,35].

IV. METHODOLOGY

This section describes the resources, methodology, and materials used to develop a web-based GIS for monitoring tree park maintenance using near-field communication (NFC), as well as the steps taken to test the system. The purpose is to ensure the consistency and reliability of the results and to establish a clear understanding of the procedures. This study comprised five research phases: planning, analysis, design, system development, and system evaluation. Fig. 3 illustrates the specifics of each phase.

A. Planning

This study commenced with the planning phase, which aimed to clearly define the research problem by identifying specific issues or knowledge gaps to be addressed. A thorough review of relevant literature was done to formulate a problem statement that explains the importance and relevance of this research.

B. Analysis

The analysis phase contained several key objectives that aimed to gain an in-depth understanding of the proposed system, thus ensuring that it has effectively met the users' needs. It also serves as a foundation for the subsequent stages of system development. Various tools and techniques were employed to visualise and describe the proposed system, allowing for a comprehensive review and analysis of user opinions. By examining the gathered information, conclusions were drawn regarding the system's required functionality, interface design, and overall analysis. Ultimately, the analysis phase enabled the identification of the desired features and functionalities as expressed by the target users through interviews and other assessment methods.

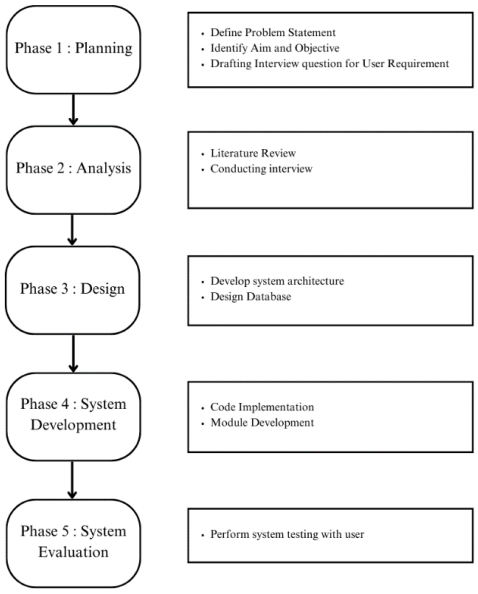

Fig. 3. Research workflow

C. Design

The design phase encompassed the creation of a blueprint for developing a software product. All requirements gathered in the previous stage were carefully analysed and utilised to craft a detailed design of the system. It involved specifying the system architecture, user case diagram, activity diagram, and entity relationship diagram. Visual aids, such as diagrams and flowcharts, were also used to communicate the design to the development team and stakeholders effectively. The primary objective of the design phase was to establish a clear and comprehensive plan that served as a guiding framework for the implementation phase, ensuring a smooth and efficient development process. Fig. 4 shows the system architecture of this research, while Fig. 5 shows the use case of the system.

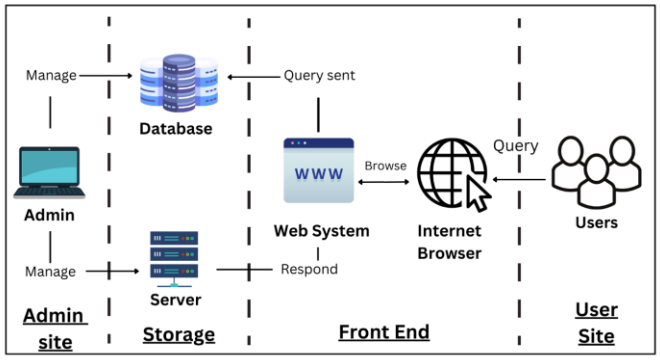

Fig. 4. The system architecture of web-based GIS for monitoring tree park maintenance system using NFC

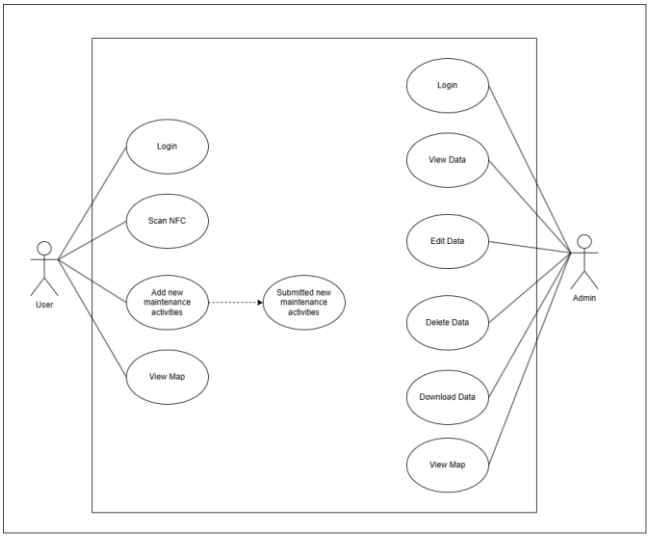

Fig. 5. Use Case Diagram of the system

Fig. 6 illustrates the flow for submitting new maintenance using the activity diagram, and Fig. 7 displays the entity relationship diagram of the system.

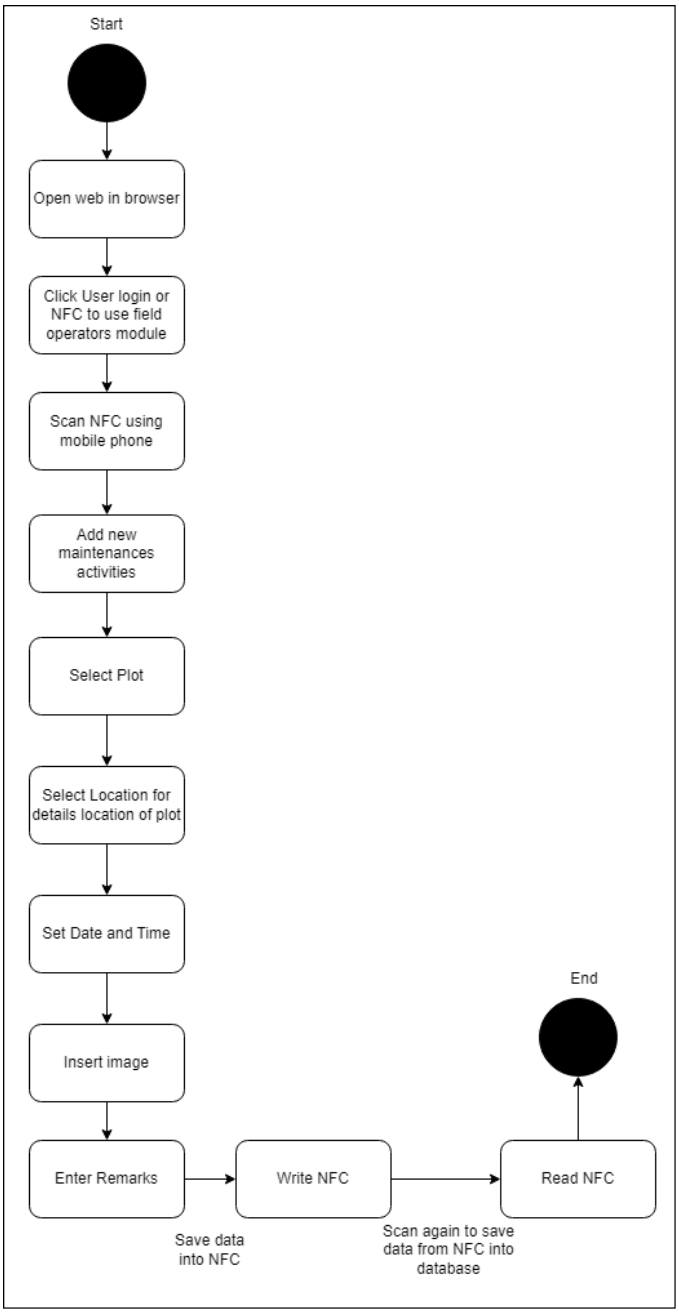

Fig. 6. Activity Diagram to submit new maintenance activities

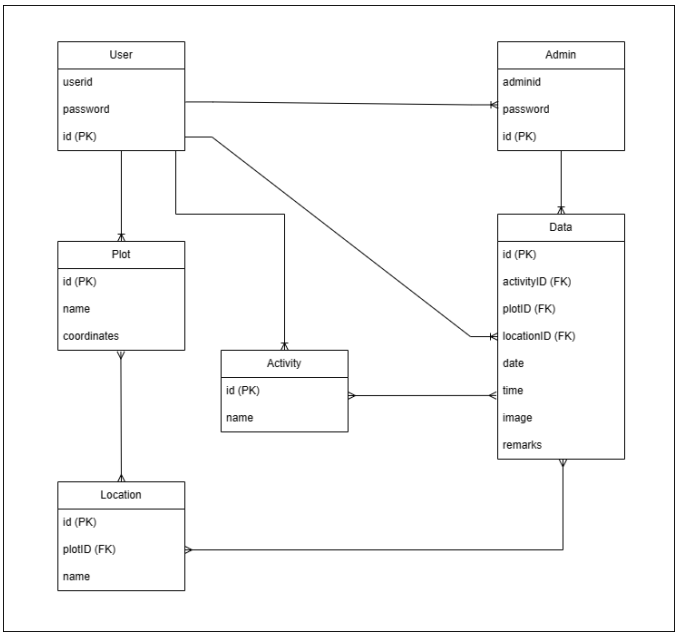

Fig. 7. Entity Relationship Diagram of the system

D. System Development

The development phase compiled all project planning for developers to begin building and coding work. Any changes to the project factor would necessitate adjustments to accomplish the intended objectives. Unit tests for each component were also conducted to test the code and to review, create, and deploy the program into an environment. The development phase consumed the most project time and resources, as the code for each component and variable type had to be tested multiple times before it could be applied in the system. The efficient utilisation of PHP, HTML, CSS, and JavaScript, along with the integration of web NFC API for NFC functionality, Leaflet.js for mapping features, and MySQL for the database, played a pivotal role in expediting the code implementation process. The combination of these technologies facilitated the creation of intuitive user interfaces and seamless integration with the existing codebase. The code implementation phase was successfully executed by harnessing the power of PHP, HTML, CSS, and JavaScript, aligning with the research objectives and design requirements. Meanwhile, the utilisation of web NFC API for NFC capabilities and Leaflet.js for map functionalities further enhanced the application's functionality and user experience. Finally, the integration with MySQL ensured efficient data storage and retrieval, hence contributing to the development of a high-quality and user-friendly web application.

E. Development Framework

PHP is a popular server-side scripting language widely used in creating web-based GIS applications. It provides a wide variety of features and libraries that enable programmers to create dynamic and interactive GIS applications that utilise geospatial data. PHP also integrates seamlessly with HTML, CSS, and JavaScript, allowing developers to create user interfaces that are visually appealing and incorporate interactive mapping features. The creation of engaging and immersive user experiences is made possible by this seamless integration. Furthermore, PHP is a reliable option for creating web-based GIS applications due to its flexibility and extensive community support. This provides programmers with a strong foundation for building robust, scalable solutions to manage and analyse geospatial data.

F. Integrated Development Environment (IDE)

Visual Studio Code (VS Code) is a popular Integrated Development Environment (IDE) widely used for developing web-based GIS applications. The lightweight, cross-platform code editor offers numerous features and extensions explicitly tailored for web development, providing a seamless development experience through its intuitive user interface and extensive customisation options. Aside from supporting various programming languages, VS Code offers built-in support for HTML, CSS, JavaScript, PHP, and popular web frameworks. It also encompasses features such as code highlighting, IntelliSense code completion, debugging tools, version control integration, and extensions for integrating with popular GIS libraries and tools. Additionally, its extensive ecosystem of extensions provides additional functionalities for code linting, formatting, live previews, and collaboration. Overall, VS Code enhances productivity and efficiency in developing web-based GIS applications by delivering a powerful and customisable environment for coding, debugging, and managing project workflows.

G. UI/UX Design

HTML, CSS, and JavaScript are essential components for designing the user interface (UI) and enhancing the user experience (UX) of web-based geographic information systems (GIS) applications. HTML provides the structural foundation by defining the layout and organising the content of the application, including the placement of maps, data visualisations, and user interface elements. CSS complements HTML by styling the UI elements and applying colours, fonts, spacing, and overall visual aesthetics to create a visually appealing and consistent design. JavaScript adds interactivity and functionality to UI, allowing for dynamic interactions, user input validation, and real-time updates. It enables the integration of map libraries, interaction with GIS data, and the implementation of interactive features like zooming, panning, and filtering. Together, HTML, CSS, and JavaScript empower developers to create intuitive, visually pleasing, and highly functional UI/UX designs for web-based GIS applications, ultimately enhancing the overall user experience and usability.

H. Database

MySQL is a widely used open-source relational database management system (RDBMS) that plays a crucial role in web-based geographic information systems (GIS) applications. It provides a scalable and robust platform for storing, organising, and retrieving large volumes of spatial data efficiently. MySQL

enables developers to create structured databases with tables, columns, and relationships, allowing them to store spatial information, including tree locations, attributes, and associated metadata. It also supports spatial data types and spatial indexing, thus enabling the storage and querying of geospatial data. With its SQL-based querying language, developers can perform complex spatial queries, including spatial joins and proximity searches, to analyse and extract meaningful insights from the GIS data. Additionally, MySQL provides reliable data integrity, transaction support, and user management features, ensuring the security and reliability of the GIS application. Overall, MySQL serves as a fundamental component in web-based GIS applications by providing a robust and scalable database management system to store and manipulate spatial data effectively.

I. Services and API

LeafletJS is a powerful JavaScript library designed for creating interactive and visually appealing maps on the web. It provides developers with a lightweight and flexible framework to incorporate dynamic map functionality into their web-based GIS applications. LeafletJS provides a user-friendly API that enables seamless integration of map layers, markers, pop-ups, polygons, and other interactive elements. It supports various tile providers, including OpenStreetMap, Mapbox, and Google Maps, giving developers the flexibility to choose the base map layer that best suits their needs. LeafletJS also enables seamless integration with other GIS services and technologies, allowing for the display and manipulation of spatial data on the map. With its extensive documentation, active community, and extensive plugin ecosystem, LeafletJS has become a popular choice for developers building web-based GIS applications that require interactive mapping capabilities.

The Web NFC API for Chrome is an application programming interface (API) that enables web applications to interact with compatible, Android-powered NFC devices running the Chrome browser. It allows web-based GIS applications to utilise the NFC technology for reading and writing data to NFC tags affixed to trees or other objects in a park. The Web NFC API enables developers to access a device's NFC capabilities, establish communication with NFC tags, and exchange data securely. This API allows for the seamless integration of NFC technology into web-based GIS applications, facilitating the efficient collection, monitoring, and management of tree-related information. It also offers a convenient and standardised way to interact with NFC devices, making it a valuable tool for enhancing the functionality and user experience of web-based GIS applications.

J. Hardware

NFC tags are small electronic devices that can store and transmit information wirelessly to NFC-enabled devices. In web-based GIS applications, NFC tags are used to associate physical objects, like trees or geographic features, with digital data stored in a database or online platform. When an NFC-enabled device is brought close to an NFC tag, it can read the stored information and interact with the web-based GIS application to retrieve or update data related to the object. This enables efficient data collection, management, and monitoring of geographic features, allowing field workers to easily record activities and update information in real-time. NFC tags provide a seamless bridge between the physical and digital realms, enhancing the functionality and usability of web-based GIS applications. Fig. 8 shows a nail-shape NFC.

Fig. 8. Nail-Shape NFC

K. System Evaluation

The system evaluation phase primarily focuses on a comprehensive evaluation of web-based GIS for monitoring tree park maintenance systems using Near Field Communication (NFC). It requires careful testing and evaluation of various aspects, such as system functionality, usability, and performance, to ensure that the application effectively meets the needs and expectations of the intended user. Such a goal was achieved in this study through a thorough testing approach involving users who were the managers and employees of SIREH Park. These users were given access to the web and encouraged to navigate its features, from opening the website to submitting new maintenance activities. Throughout this process, they provided valuable feedback on the application's overall usability, user interface, and functionality. Important areas for improvement were also identified by gathering insights and feedback from these stakeholders, which were then used to make necessary adjustments to boost user satisfaction and enhance the application's overall effectiveness.

V. RESULTS

A. Web-Based GIS

The developed web-based GIS system serves as an efficient tool for monitoring and managing tree park maintenance integrated with NFC technology. With its user-friendly interface and intuitive design, the system aims to empower park maintenance workers and streamline the data collection process. It also enables seamless communication and real-time updates between field workers and the central database by utilising the widespread use of web technologies.

The web-based GIS system allows park maintenance workers to easily access and update tree-related information, thus ensuring accurate and up-to-date data on tree conditions and maintenance activities. The integrated NFC technology can facilitate real-time updates through wireless communication with NFC tags placed on trees. This enables efficient data collection and management, which can optimise maintenance efforts and improve overall care for the park.

Taking a user-centred design approach, the web-based GIS system provides a user-friendly experience even for individuals without technical expertise. Its intuitive interface and

streamlined data entry forms facilitate efficient data submission, thus empowering park maintenance workers to monitor tree status and track progress over time. The system supports long-term planning and informed decision-making processes by providing valuable insights into the park's maintenance activities, such as plot monitoring.

In summary, the web-based GIS system, integrated with NFC technology, provides an effective solution for monitoring and managing tree park maintenance. Its user-friendly interface, real-time communication capabilities, and support for community engagement empower park maintenance workers and facilitate data-driven decision-making. This technology-driven approach plays a crucial role in enhancing the management and maintenance of urban green spaces, ensuring their long-term well-being. Fig. 9 shows the system's Web Dashboard, which contains a map, login button, and NFC function; Fig. 10 shows the User Login page; Fig. 11 shows the User Dashboard for adding new maintenance; Fig. 12 shows the Admin Login page; Fig. 13 shows the Admin Dashboard for viewing submitted data; Fig. 14 shows the Edit Record function for the admin to edit and delete submitted data; Fig. 15 shows the function to write NFC; and Fig. 16 shows the function to save NFC data into the database.

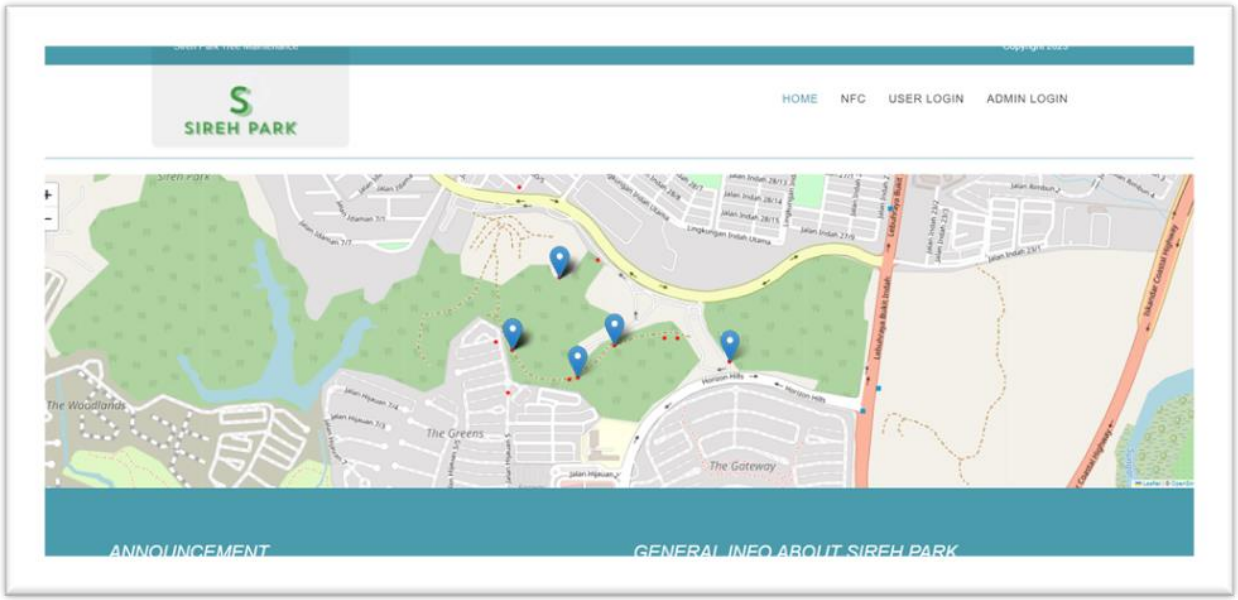

Fig. 9. Web Dashboard

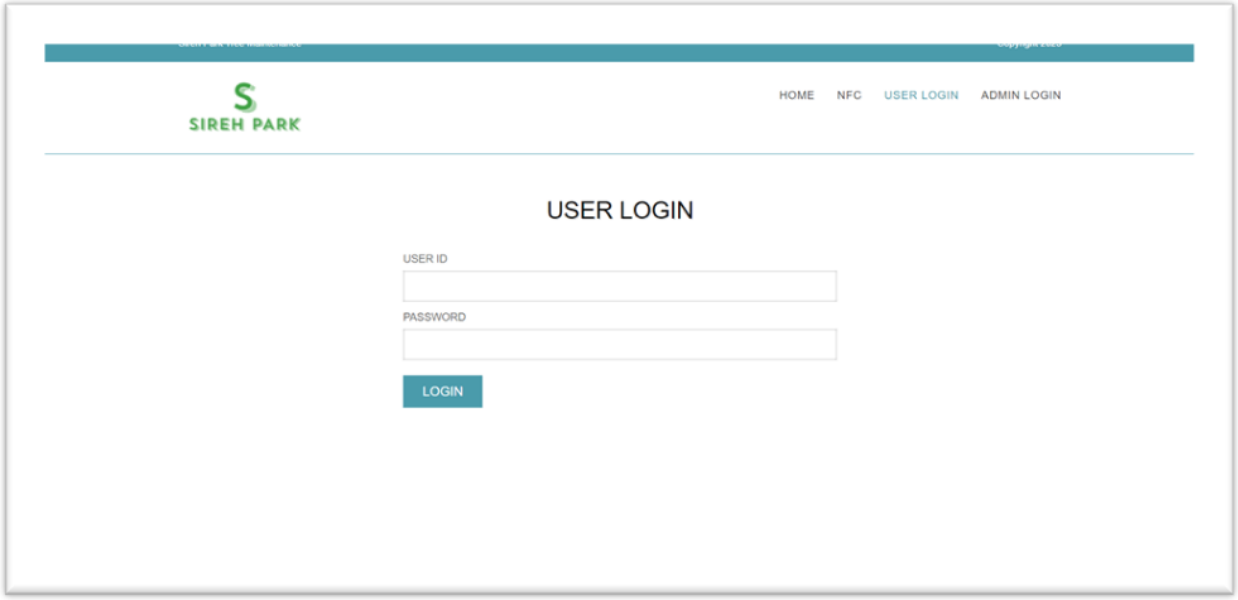

Fig. 10. User Login

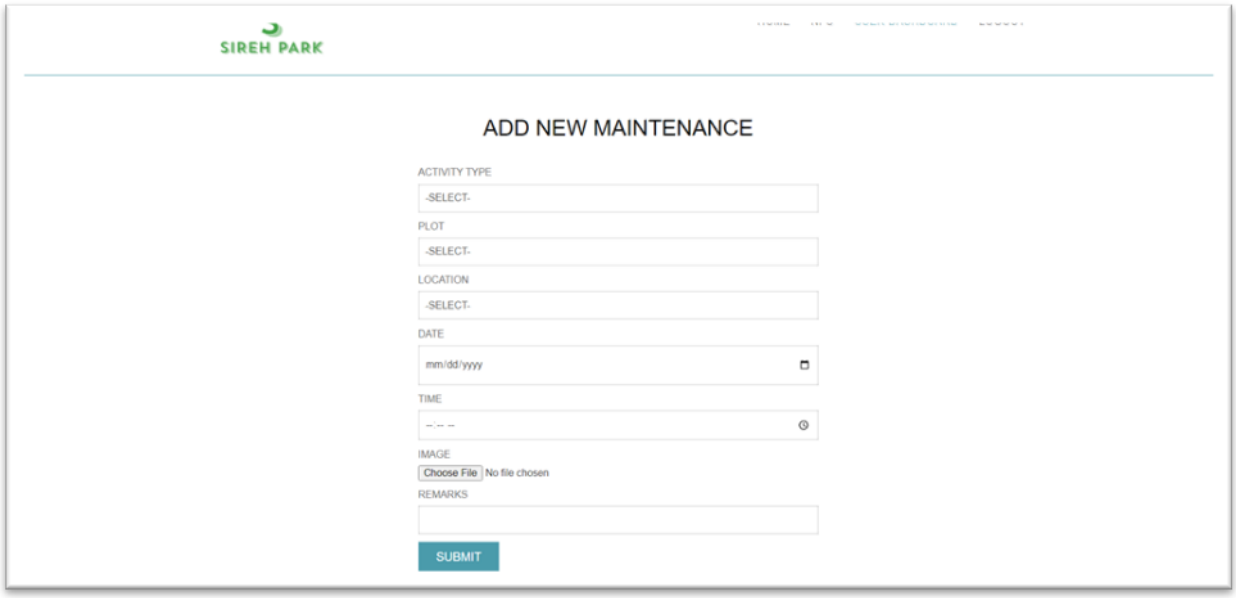

Fig. 11. Add New Maintenance

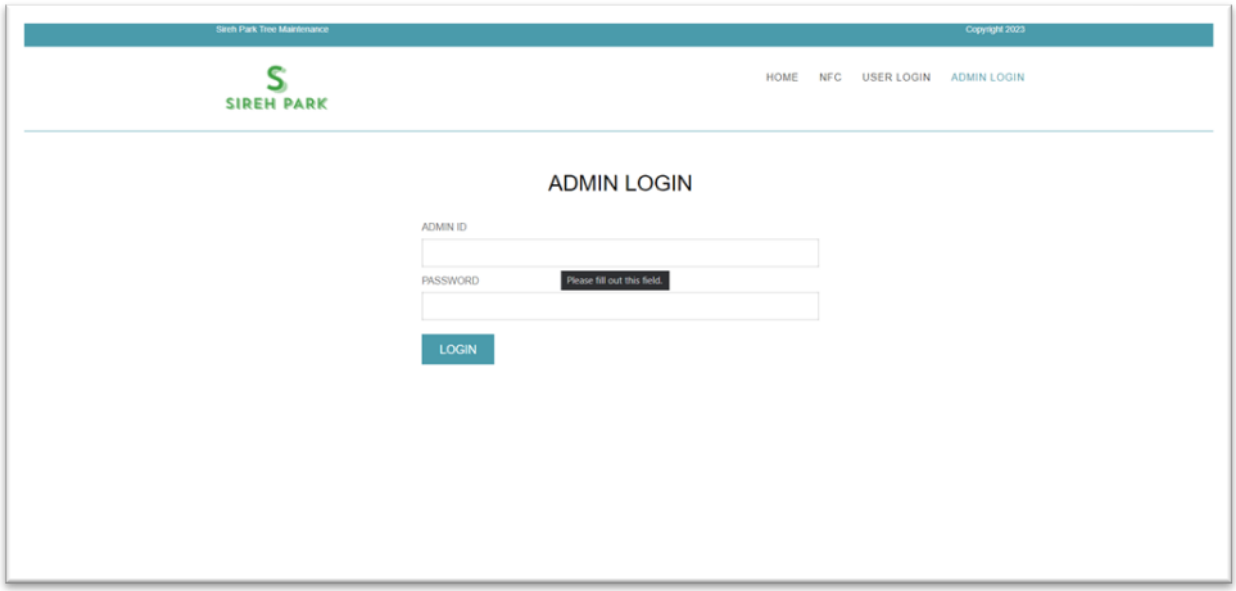

Fig. 12. Admin Login

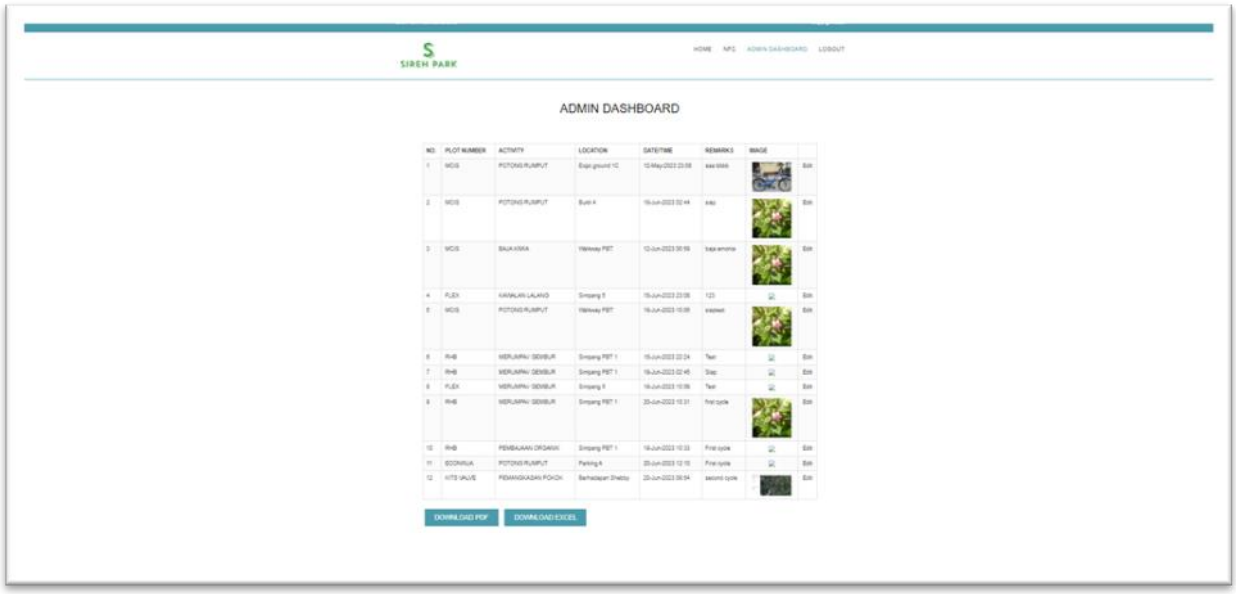

Fig. 13. Admin Dashboard

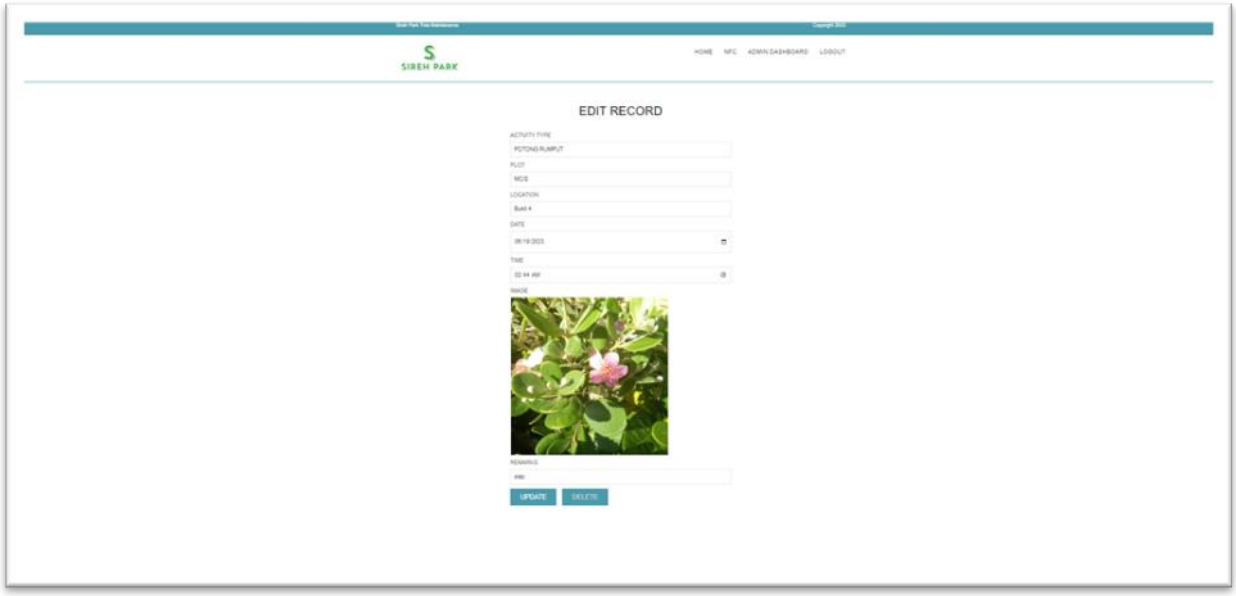

Fig. 14. Edit and Delete for Admin

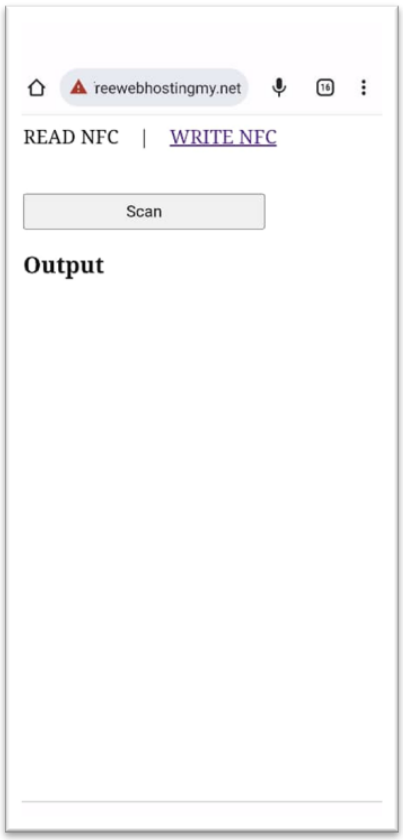

Fig. 15. Write NFC

Fig. 16. Read NFC

B. Database Design and Structure

During the development process of the web-based GIS, the database design and structure played a crucial role in storing and managing the system's data. MySQL, a popular and reliable relational database management system, was utilised for this purpose as it could seamlessly integrate with the system's backend programming language (i.e., PHP). Furthermore, PHP provides the necessary functionalities for establishing a connection with the MySQL database to execute queries and retrieve data. Such integration enables efficient data handling and retrieval, ensuring the system can effectively store and manage essential information.

The database design encompasses several key elements relevant to monitoring tree park maintenance activities. These include storing PlotID, location coordinates (latitude and longitude), maintenance activities performed on the trees, the date and time of the activities, and images associated with the maintenance tasks. The proper organisation and structuring of the database according to these specific fields allows the system to track and manage the relevant data effectively. The integration between PHP and MySQL enables seamless communication between the web-based GIS application and the database. Meanwhile, PHP facilitates the insertion, retrieval, and modification of data in the MySQL database, ensuring that the system remains up-to-date and accurate. This integration ensures that the web-based GIS application can efficiently interact with the database and enables users to perform various tasks, such as querying for specific tree maintenance activities or retrieving location information. Overall, the use of MySQL as the database management system, combined with the integration of PHP and MySQL, provides a robust and efficient foundation for developing a web-based GIS for monitoring tree park maintenance systems using NFC. It enables storage, retrieval, and management of essential data, which in turn contributes to the overall effectiveness and functionality of the application. Fig. 17 illustrates the database required for developing the web-based GIS.

C. Module Development and Implementation

i. User Login and Admin Login

All users and administrators were assigned unique usernames and passwords to access the system. This ensures that only authorised personnel, such as gardeners and managers, can access the system. The module establishes different levels of access, allowing administrators to have additional privileges and control over system settings.

ii. Data Submission and Retrieval

The Data Submission and Retrieve module enables users to submit maintenance activity data for each plot. It allows users to provide input information, such as pruning, watering, fertilisation, and any additional remarks, as well as enables administrators to manage the submitted data, including the ability to delete or update entries as needed. Data submission is facilitated by NFC technology, which allows users to interact conveniently with NFC tags placed on trees. The module also supports data retrieval for tracking previous maintenance activities, helping users and administrators to identify patterns or potential issues.

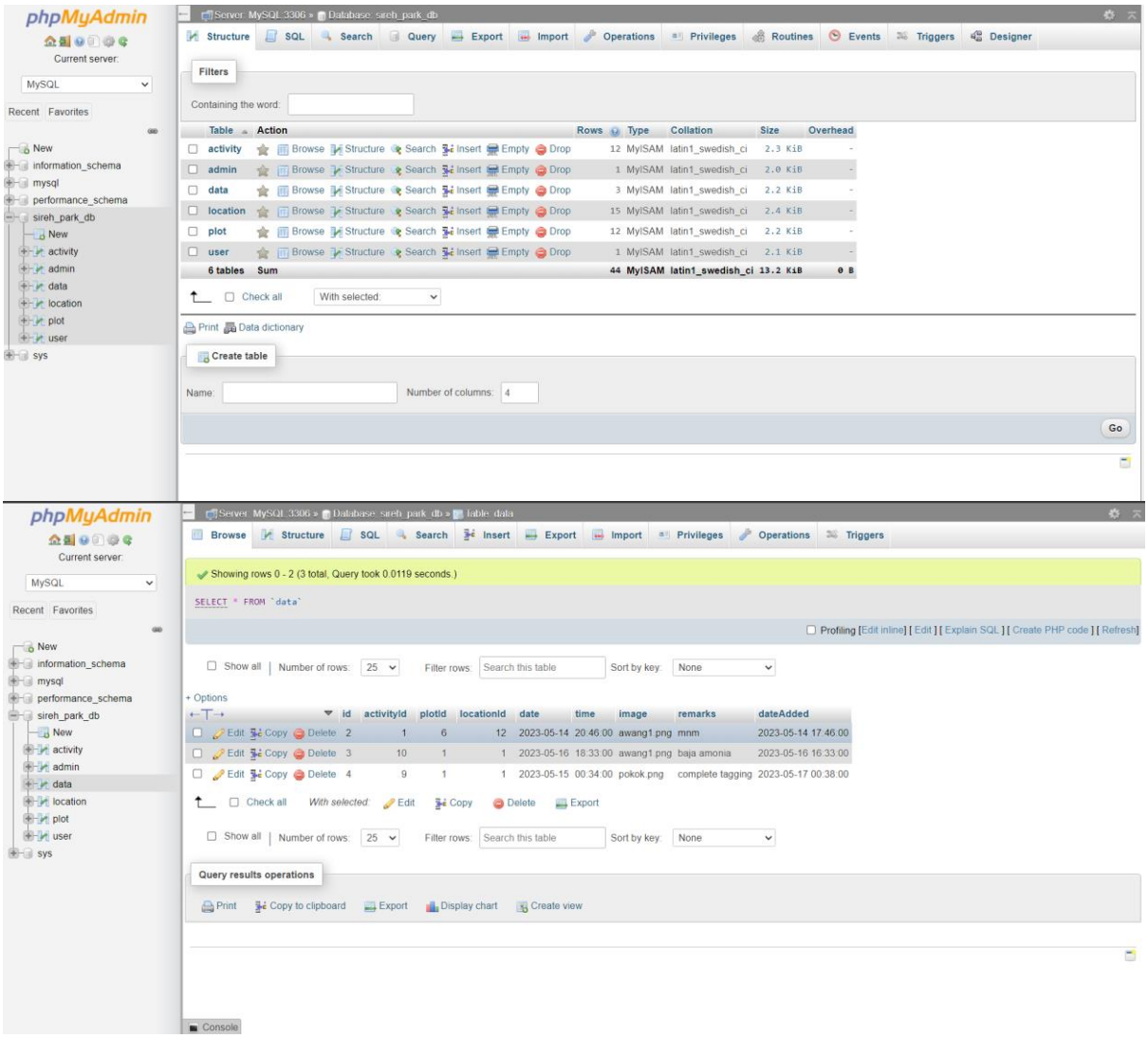

Fig. 17. MySQL Database

iii. Mapping and Visualisation

The Mapping and Visualisation module utilises maps to enhance the user experience and facilitate efficient monitoring. It visually represents the location of each plot on a map, thus providing a clear overview of the tree park. This enables users and administrators to easily identify areas where maintenance activities are required or where progress needs to be monitored. The mapping functionality also helps monitor the work of gardeners and workers, providing real-time updates on their movements and tasks completed. Overall, the module improves spatial awareness and aids effective decision-making and resource allocation.

VI. DISCUSSION

The development and implementation of the web-based GIS system for monitoring and managing tree park maintenance using NFC technology has emerged as a transformative approach that can potentially enhance the management and maintenance of urban green spaces. It is crucial as it affects the neighbourhood community's social interaction [36]. Maintenance work is also closely connected to existing buildings, where poor maintenance can damage surrounding features, including nearby structures [37]. This innovative system seamlessly integrates GIS technology, NFC technology, and geospatial databases for efficient data collection, storage, analysis, and visualisation of tree-related information. By providing a user-friendly interface and intuitive design, the system empowers park maintenance workers with easy access and streamlined updating of tree data. The integration of NFC technology further enhances the system's functionality by facilitating real-time updates through wireless communication with NFC tags placed on trees. This enables the seamless transfer of data between field workers and the central database, ensuring accurate and up-to-date information on tree conditions and maintenance activities. Furthermore, the web-based GIS system supports long-term planning by providing valuable insight into the overall health and distribution of trees within the park. This information helps in decision-making processes, such as tree planting, species selection, and resource allocation

for maintenance activities. The data-driven approach helps optimise resource allocation, prioritise maintenance efforts, and improve the sustainability and resilience of urban green spaces. Additionally, it can accelerate the process of updating the carbon stock of individual trees on site, thereby enabling data-driven calculations for achieving carbon net-zero targets [38].

Beyond operational benefits, the web-based GIS system encourages community engagement and participation by making tree-related information accessible to the public through dedicated portals or mobile applications. Such transparency fosters trust and enables residents to participate actively in the care and management of park trees. Ultimately, this collaborative approach will strengthen the relationship between the community and the park while fostering a sense of ownership and stewardship that benefits the community's overall well-being. This concept is suitable for a system like Geotrees, a system for tree tagging and monitoring [39].

Ultimately, the web-based GIS system, combined with NFC technology, offers an innovative solution for the efficient and effective management of urban green spaces. By integrating GIS technology, NFC technology, and geospatial databases, the system empowers park maintenance workers to facilitate real-time monitoring and decision-making, support long-term planning, and foster community engagement. As cities increasingly realise the importance of urban green spaces, this technology-driven approach plays a crucial role in the sustainable development and preservation of this vital natural resource.

VII. CONCLUSION

In conclusion, the web-based GIS for monitoring tree park maintenance systems using NFC technology has proven effective in efficiently recording and storing maintenance data. The integrated NFC technology has significantly reduced the time required for data recording. The use of NFC could improve the issues with QR codes due to its durability and weather resistance. The incorporation of NFC technology in various applications holds significant importance for the future and can substantially improve efficiency and effectiveness across multiple fields. The ability to analyse and monitor maintenance activities provides valuable insights for decision-making and resource allocation. Overall, the utilisation of web-based GIS and NFC technology in tree park management offers significant advantages and contributes to the sustainable management of urban green spaces. Future studies could incorporate Artificial Intelligence (AI) to automate tree registration using drone imagery, thereby accelerating the registration process. The use of on-site robots to update maintenance work is also feasible, given the rapid advancements in machine learning and robotics technology.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest regarding the publication of this paper.

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