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Development of an Integrated Enterprise Asset Management System for Enhancing Industrial Resources Lifecycle in the Construction Industry

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Abstract **-** This study presents the development of an integrated Enterprise Asset Management System (EAMS) designed to enhance the lifecycle management of industrial resources within the construction industry. The proposed EAMS aims to streamline operational processes, improve equipment utilization, and facilitate cost-effective resource allocation, particularly for startup construction companies. Through the integration of centralized asset tracking, maintenance scheduling, and inventory control functionalities, the system addresses existing inefficiencies and promotes sustainable asset usage. The research also explores the potential for future expansion, including predictive analytics, cross-platform compatibility, and scalability to accommodate the demands of larger enterprises. The findings emphasize the importance of adaptive technology solutions in optimizing project timelines, reducing operational costs, and ensuring long-term asset performance in a competitive construction environment.

Keywords**:** Construction Projects, Enterprise Asset Management System, Equipment and Machinery Management, Scheduling, Borrowing

1. Introduction

The construction industry significantly contributes to the economic development of the Philippines, accounting for nearly 7% of the country's Gross Domestic Product (GDP) in 2022. This substantial contribution underscores its importance as a key driver of national economic growth [1]. Despite its traditional foundation, the industry faces significant challenges, particularly resistance to adopting modern practices. Research has identified factors such as inflation and rising interest rates as potential threats to its continued growth trajectory [2]. In today's technology-driven environment, automated systems have become indispensable for businesses, especially in managing increasing operational demands. For start-up construction companies, the lack of automation presents numerous issues, particularly in managing assets, inventory, workforce, and payroll. Manual systems not only hinder efficiency but also contribute to increased operational costs and mismanagement of resources. The implementation of automated systems, particularly for asset and equipment management, offers a solution by streamlining these processes and reducing overhead. These systems provide real-time insights into resource availability, minimize errors associated with manual tracking, and optimize maintenance scheduling. Studies emphasize that such systems can significantly enhance operational performance in construction by enabling precise allocation of equipment and timely maintenance, ultimately avoiding project delays and cost overruns [3]. Moreover, automated Enterprise Asset Management Systems (EAMS) empower companies to make informed decisions, maintain a competitive edge, and adapt to the rapid evolution of construction technologies through tools like QR tagging, barcode scanning, and data analytics [4]. These systems not only track equipment location and schedule but also identify re-sponsible personnel and issue preventive maintenance alerts, which help extend equipment lifespan and avoid breakdowns. Efficient asset management is essential for maintaining productivity, especially under strict inventory and resource management practices. This research aims to address the challenges start-up construction companies face in resource management by replacing outdated manual systems with comprehensive EAMS. The proposed system is a web-based platform and mobile application tailored for the construction sector, designed to simplify maintenance and inventory operations. Its core features include QR code scanning for tracking and borrowing equipment, real-time updates on equipment status and location, automat-ed maintenance alerts, and detailed

usage logs. With distinct roles assigned to Super Admins, Admins, Project Managers, and Project Staff, the system ensures coordinated and accountable project resource management. The preventive maintenance feature supports continuity, minimizes downtime, and protects against equipment failure, ultimately enhancing operational effectiveness [5].

The primary objective of this study is to develop and implement an Integrated Enterprise Asset Management System (EAMS) that enhances the lifecycle management of industrial resources within the construction industry. Specifically, the research focuses on improving operational efficiency, eliminating time-consuming manual processes, and introducing real-time monitoring and automated tracking through QR code integration. The EAMS will be designed with multiple user roles in mind, enabling seamless interaction between the web-based system (for Super Admins and Admins) and mobile applications (for Project Managers and Staff). This integration aims to resolve resource allocation issues, minimize equipment downtime, and support better decision-making in project execution—particularly within start-up construction firms. To achieve this, the research will: (1) integrate technology to auto-mate project operations and reduce manual tasks; (2) develop a web-based and mobile-accessible system tailored to different user roles; (3) enhance communication and coordination between administrative and field teams; (4) ensure a user-friendly experience across platforms; and (5) rigorously test and validate system performance to confirm its practical usability. These objectives aim to deliver a robust, intuitive, and efficient EAMS that harnesses QR technology, mobile functionality, and data analytics to automate procedures, reduce human error, and drive smarter project and resource management.

2. Methodology

2.1. Software Development Methodology

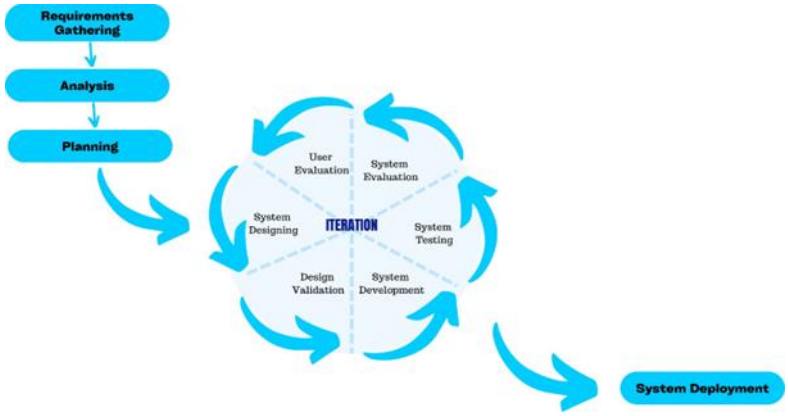

Fig. 1: Iterative Methodology

The figure above illustrates the iterative system design methodology model used in this research, outlining the sequential and cyclical steps undertaken to develop a web-based Enterprise Asset Management System (EAMS) for administrators and a mobile application for project managers in start-up construction companies. Researchers applied various data gathering methods to use in informing system design by scrutinizing current asset management practices and emphasizing key issues. Surveys and interviews provided user experience input, system useability, and organizational requirements. Observations and document analysis of workflow inefficiencies and areas where improvements could be made informed design of user interfaces, system design, and preventive maintenance workflows. Functionality like equipment monitoring and scheduling for maintenance was made a reality by way of adequate technologies. With wide testing being done, change management and training helped in adopting the system. Performance measurement and feedback continuously help to improve the system. Incorporating preventive maintenance, the EAMS will operate towards prolonging asset life, reducing downtime, and enhancing efficiency and profitability.

2.2. Project Development

The functional hierarchy diagram was designed to provide a clear visual representation of the system components and functionalities assigned to each intended user, helping to understand their roles and access within the EAMS platform.

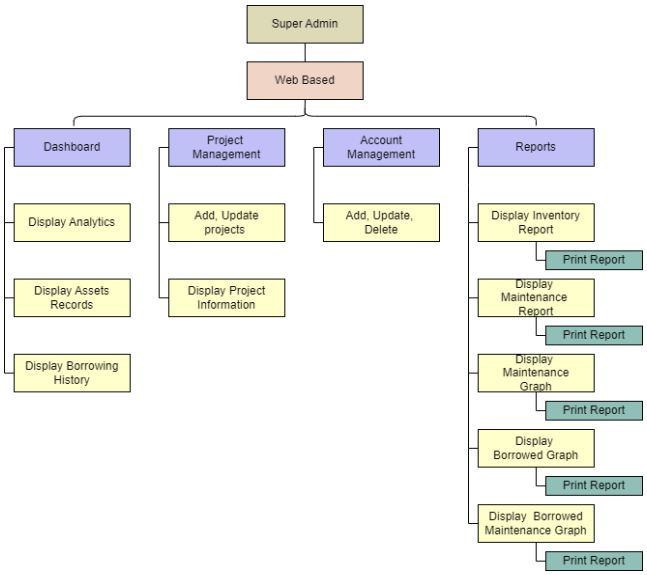

Fig. 2: Super Admin Hierarchy Diagram

The above figure is a Super Admin hierarchy diagram for a web-based system de-signed for efficient equipment and machinery management. The login serves as the primary security to prevent unauthorized access. Upon the login the user will redirect to dashboard showing the analytics of the total equipment and machinery stored, under maintenance, and borrowed equipment and machinery. The Project Management section allows for adding and overseeing project specifics information, an important tool for maintaining project timelines and resources. Moreover, Account Management allows the Super Admin to manage the user profiles and privileges to ensure data integrity and security. In the Report section, it provides detailed reports of asset management, maintenance, and borrowing activities and can be printed ensuring that all stakeholders are well informed regarding ongoing operations. Finally, the logout feature will end the session between the super-admin and the user.

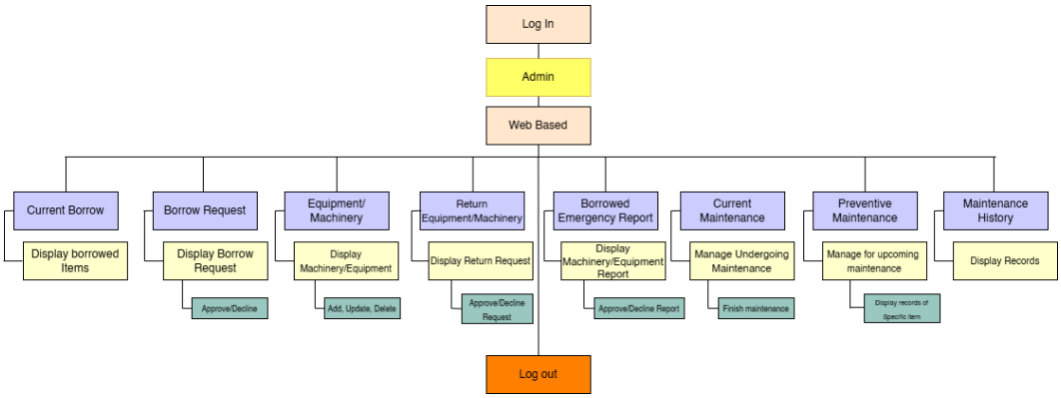

Fig. 3: Admin Hierarchy Diagram

The admin hierarchy diagram illustrates the structure of a web-based system designed for efficient management of equipment and machinery. Admin access is initiated by a secure login that grants complete module control for inventory, borrowing, and maintenance. The system offers real-time monitoring of borrowed assets, approval of equipment requests, and control over inventory records. It also accommodates returns, emergency reports, and regular maintenance activities. Breakdowns can be minimized with scheduled preventive maintenance, and maintenance history is tracked for analysis and audits. Logout provides security to the session. Such a centralized setup optimizes and makes equipment and maintenance processes leaner.

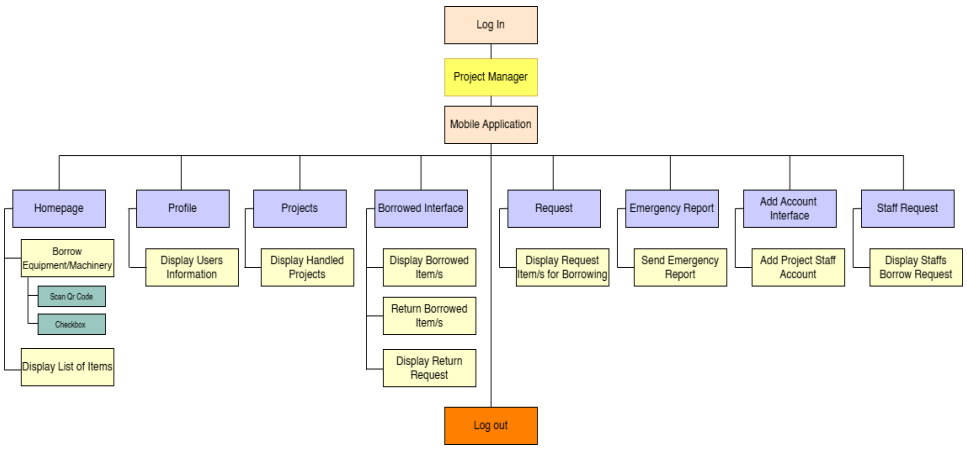

Fig. 4: Project Manager Hierarchy Diagram

On the login page, users can navigate to the homepage where they have the option to borrow equipment using QR codes or checkboxes, as well as view available items in real time. User details are displayed on the Profile page, while ongoing projects are listed under the Projects section. The Borrowed Interface allows users to view borrowed items, initiate returns, and monitor return requests. The Request section tracks equipment loan requests made by staff members, and the Emergency Report feature enables users to send urgent alerts via messages. Additional features include an Add Account Interface, which allows project managers to create member accounts, and a Staff Request section that displays loan or project-related requests from staff members. All these functions are seamlessly supported by a mobile application, ensuring efficient and streamlined project management.

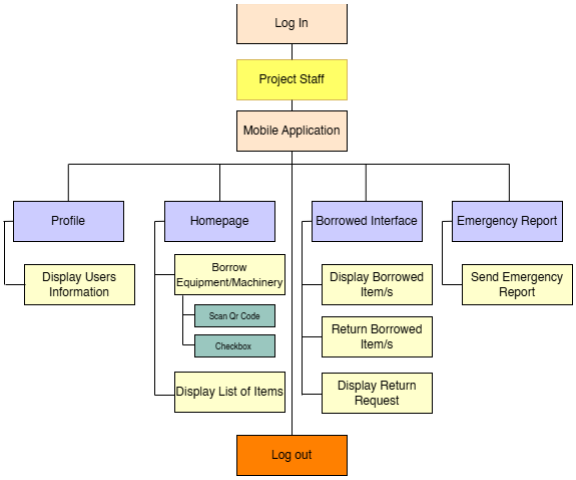

Fig. 5: Project Staff Hierarchy Diagram

The mobile application is specifically developed to support efficient equipment management and facilitate prompt emergency reporting to the Project Staff. Upon successful login, users are directed to the homepage, where they can borrow equipment either by scanning QR codes or selecting items via checkboxes. The system also provides real-time visibility into currently lent items. User-specific information is available within the Profile section for quick reference and verification. The Borrowed Interface allows users to view their borrowed equipment, initiate return processes, and track the status of return requests. In the event of an emergency, the application includes an Emergency Report feature that enables users to send immediate alerts to the designated personnel. Designed with simplicity and functionality in mind, the application ensures that staff members can manage equipment and respond to emergencies efficiently, even while operating in the field or on the move.

2.3. Project Evaluation

The researchers employed convenience sampling to evaluate data collected from thirty respondents who were selected based on their availability and willingness to participate. This practical and cost-effective approach ensured the inclusion of a diverse range of participants from various departments—including procurement, project management, site management, and finance—as well as user roles such as administrative staff, maintenance technicians, end-users, and managerial personnel. The aim was to assess the effectiveness and efficiency of the newly implemented Enterprise Asset Management System (EAMS) within the construction company. To ensure the sample size was statistically appropriate, Slovin's Formula was used, considering the total population and acceptable margin of error. For system testing, the Equivalence Partitioning technique was applied to group test inputs into equivalence classes, allowing for efficient and comprehensive evaluation without redundancy.

In measuring system performance and usability, the researchers conducted a post-survey using a structured questionnaire based on a five-point Likert scale. This method enabled participants to rate statements from strong agreement to strong disagreement, offering a reliable and efficient way to collect user feedback. The Likert scale data helped identify the system's strengths and areas for improvement across different user experiences.

Table 1: Five-Point Likert-Type Rating Scale and Mean Interpretation

Response	Response Interpretation	Mean Range	Mean Interpretation
5	Strongly Agree	4:51-5:00	Excellent
4	Agree	3.51-4.50	Very Satisfactory
3	Neutral	2.51-3.50	Satisfactory
2	Disagree	1.51-2.50	Fair
1	Strongly Disagree	1.00-1.50	Poor

To interpret the survey data, the researchers utilized the percentage method to normalize results and highlight the frequency of specific responses or issues reported. This approach provided insights into common problems encountered while using the AMS and quantified user perceptions effectively. The formula for calculating percentage is:

$$Percentage\ (\%) = \left(\frac{Frequency}{Total\ Number\ of\ Respondents}\right) x\ 100 \quad (1)$$

Additionally, the researchers applied the Arithmetic Mean Formula to analyze the overall responses from the Likert-scale-based survey. The arithmetic mean, or average, is a fundamental statistical tool for identifying the central tendency of

a data set. It was particularly suitable for summarizing the Likert-scale responses and determining the general perception of the system's performance and usability. The formula for calculating the arithmetic mean is:

$$Arithmetic\ Mean = (\Sigma x)/n \quad (2)$$

where Σx is the sum of all responses and n is the number of responses.

By using these statistical tools and techniques, the researchers were able to draw meaningful conclusions regarding the system's impact and effectiveness. Furthermore, throughout the development and evaluation process, the study adhered to the FURPS model—addressing Functionality, Usability, Reliability, Performance, and Supportability—to ensure the system comprehensively met the needs and expectations of all intended users.

3. Results and Discussion

3.1 Project Structure

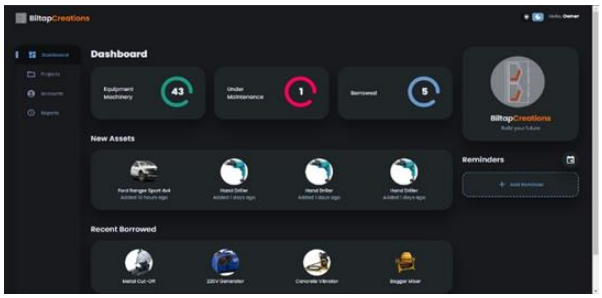

Fig. 6: Super Admin Landing Page

Upon login, the Super Admin is directed to the dashboard, which provides a com-prehensive overview of the system's key metrics. Dashboard displays vital information, including the total number of equipment and machinery, the number of items currently under maintenance, those that have been borrowed, newly added assets, and recently borrowed equipment. Designed for clarity and efficiency, the dashboard offers a centralized summary to support effective monitoring and management of all equipment-related activities within the system. Additionally, other essential features are accessible via the left-side navigation panel, where modules such as Projects, Accounts, and Reports are conveniently displayed.

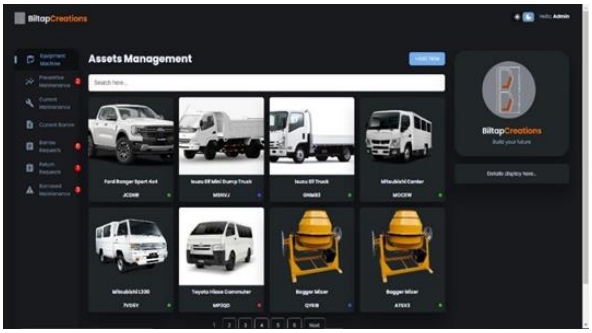

Fig. 7: Admin Landing Page

The figure above shows the interface that the admin is redirected to after logging in. This landing page provides a comprehensive view of all equipment and machinery registered in the system. Each asset is displayed with a color-coded status indicator for quick and easy identification: green indicates availability, blue denotes borrowed items, and red represents equipment currently under maintenance. This visual cue system helps streamline monitoring and decision-making. In

addition to asset visibility, the admin has full control over each item, with options to view, update, delete, and access a graph of maintenance history, allowing for effective tracking and analysis of each asset's lifecycle. Furthermore, other key features are accessible via the left-side navigation panel, including modules for Preventive Maintenance, Current Maintenance, Borrowed Items, Requests, Returns, and Emergency Reports. This structured layout ensures the admin can efficiently manage all aspects of asset operations within a centralized and user-friendly interface.

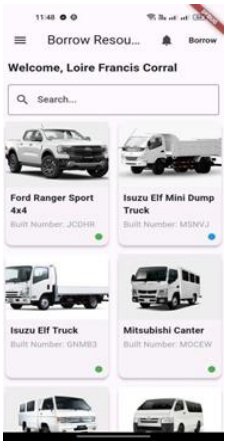

Fig. 8: Project Manager and Project Staff Landing Page

The landing page displays all available equipment and machinery, each accompanied by a color-coded availability indicator—green for available, blue for borrowed, and red for under maintenance. When a user clicks on a specific item, a pop-up window appears, presenting the full details of the selected equipment or machinery. This page also features a search function, allowing users to easily browse and select multiple items they wish to borrow. Once selections are made, users can proceed by clicking the "Review" button, which redirects them to the Accountable Page for further processing and confirmation of their borrow requests. Additionally, if the assigned project staff or project manager needs to borrow or report machinery and equipment, this can also be done by the project staff, but it will notify the project manager to move further.

3.2 Summary of Findings

Table 2: Four Users Summary of Test Results

Metrics	Total Mean	Interpretation
Functionality	4.59	Excellent
Usability	4.47	Very Satisfactory
Reliability	4.73	Excellent
Performance Efficiency	4.63	Excellent
Security	4.03	Very Satisfactory
Maintainability	4.30	Very Satisfactory
Portability	4.73	Excellent
User Satisfaction	4.50	Very Satisfactory
Grand Mean	**4.50**	Very Satisfactory

Based on summary of the result of (4) user, system effectiveness gained a grand mean of 4.50 and that is interpreted as excellent.

4. Conclusion and Recommendations

In conclusion, the implementation of the integrated EAMS provides a promising solution to the challenges faced by construction firms in managing their industrial resources efficiently. The system contributes to enhanced operational efficiency, improved asset lifecycle management, and measurable cost savings, particularly in project execution and equipment utilization. To ensure its continued relevance and effectiveness, it is crucial for developers to incorporate user feedback, update system capabilities, and expand features such as predictive analytics and integration with other project management tools. Future iterations of EAMS should also prioritize scalability and cross-platform compatibility, including iOS support, to cater to broader organizational needs. Ultimately, this study underscores the transformative role of enterprise asset management in driving innovation and productivity within the construction industry.

For the recommendation, future studies in this regard should aim to assess the effectiveness of the system in enhancing operational efficiency and resource management within startup construction companies. These evaluations can be based on measurable improvements such as shortened project timelines, increased equipment utilization rates, and cost savings achieved through the implementation of EAMS. It is also recommended that future developers regularly review user feedback on the system to identify areas for improvement. Additional features could be introduced, including advanced analytics for equipment failure prediction, integration with other commonly used project management tools, and iOS compatibility for project managers and staff. Furthermore, future implementations of EAMS should incorporate scalability features to support larger inventories and more complex operations in bigger organizations. Continuous system updates and ongoing user training should also be prioritized to ensure the program remains effective and relevant considering evolving technology and industry requirements.

Acknowledgements

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