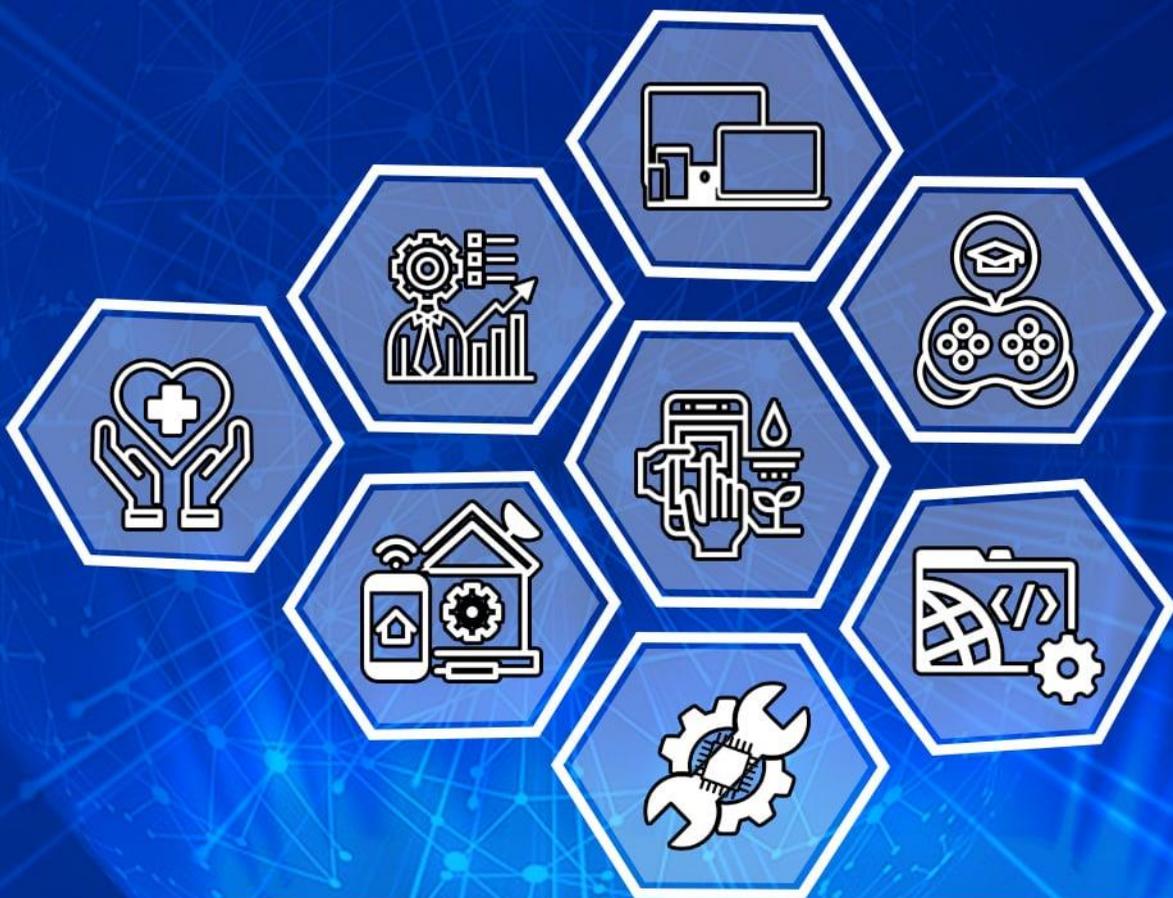


# INFORMATION TECHNOLOGY CROSS-PLATFORM APPLICATION AND DEVELOPMENT



CROSS-  
PLATFORM  
APPLICATION  
DEVELOPMENT

**DR. MYRA G. FLORES**  
Editor



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# Preface

With today's technological age, where technology connects all aspects of human interaction, boundaries between platforms have continued to erase. The ever-increasing demand for cross-platform applications and development responds to the evolving necessity for smooth, efficient, and accessible technological experiences across devices, systems, and environments. It is in this context that this book, "**Information Technology: Cross-Platform Application and Development**," comes to fruition.

This collection of undergraduate Bachelor of Science in Information Technology (BSIT) studies reflects the imagination, innovation, and technical acumen of the future IT professionals. Every research featured in this volume investigates the varied facets of cross-platform technology—starting from web and mobile applications to integrated systems, data-driven applications, and enterprise-level software solutions. The highlighted researches reflect the manner in which the students have utilized the paradigms of software engineering, database management, user interface design, and system integration to create solutions that go beyond the confines of single platforms.

The projects presented here are not only evidence of scholarship but also manifestations of worldly applicability. They are tackling real-world problems that businesses, schools, and communities are dealing with—demonstrating that technological innovation, if informed by purpose and knowledge, can have real impact. The students, through their projects, display their capacity to design and implement systems that are adaptive, scalable, and accessible—systems that resonate with the increasing demand for interoperability in today's digital landscape.

This book is also a celebration of the research and innovation spirit of BSIT learners. It underscores the essence of merging theory and practice, and creating cooperation between scholars, learners, and industry practitioners. Every study is a benchmark in the academic progress of learners—an accomplishment founded on inquiry, experimentation, and devotion to technological excellence.

May this collection motivate generations of researchers to keep exploring new platforms, tools, and frameworks, and create technologies that bring people and concepts together beyond borders. In the constantly changing realm of Information Technology, the only real measure of advancement is not just in the systems we construct but also in the solutions we design to make life smarter, easier, and more interconnected.

# Acknowledgement

The completion of this eBook, *Information Technology: Cross-Platform Application and Development*, would not have been possible without the support and contributions of many individuals who generously shared their expertise, time, and encouragement throughout this endeavor.

Our heartfelt appreciation goes to the authors and researchers whose scholarly efforts serve as the cornerstone of this publication. We also extend our sincere gratitude to the teachers, mentors, and reviewers whose valuable insights and guidance brought authenticity and depth to the research presented. Their technical expertise and commitment have anchored the studies in real-world applications, enriching this eBook with both relevance and practical value.

Special recognition is given to Colegio Santo Cristo de Burgos, Sariaya, Quezon Campus, our esteemed academic partner, whose collaboration was instrumental in shaping this compilation into a meaningful and impactful resource for educators, learners, and researchers alike. We also extend appreciation to its president, Dr. Mary Joyce Manigbas Monzon, for her unwavering dedication to the pursuit of knowledge and education.

This eBook stands as a testament to collaboration, shared vision, and a collective pursuit of innovation in education and technology. To all who contributed, whether through research, mentorship, or unwavering support, thank you for making this work possible.

## The Editor

**MYRA G. FLORES, LPT, DIT, EdD (on-going)** is a dedicated educator with almost 18 years of teaching experience, encompassing 9 years in Senior High School and 9 years in College. She is currently a Master Teacher I and Designated Asst. Principal for Learner Support and Operation in Buenaventura Alandy National High School, Tayabas City Division of the Department of Education (DepEd).



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Within her division, she takes on key specialized roles that impact curriculum delivery and resource management:

*School JDVP Coordinator:* She manages the Joint Delivery Voucher Program (JDVP), a DepEd initiative that provides vouchers for Senior High School students in the Technical-Vocational-Livelihood (TVL) track to take their specialization subjects at partner private schools or institutions to address resource shortages in public schools.

*TLE/TVL Coordinator:* She is responsible Overseeing the review, development, and revision of all TLE/TVL programs, including curriculum guides, course outlines, and teaching plans, to ensure they are aligned with the K to 12 curriculum and industry standards (e.g., TESDA Training Regulations).

She is an active researcher, focusing on the application of technology and information systems in education and environmental management. Her research presentations at both local and international conferences include: "rClaws: Recyclable waste classification system using Neural Network, " "Literature Review of Automated Waste Segregation System using Machine Learning: A Comprehensive Analysis," "Utilization of Automated Voting System for Transparency and Responsiveness of SSG Election Result," and "Correlational Analysis of Senior High School Students."

Her dedication to research and pedagogy has earned her notable recognition, including the Outstanding Researcher in 2018 in the Division of Tayabas. She was also recognized at 2021 Global Leaders & Educators Award for Technology and Vocational Livelihood Category and Outstanding Researcher.

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# Chapter 1

## *Mobile-Based Learning and Teaching*

Welcome to the dynamic world of mobile-based research and development, where creativity, innovation, and technology converge to shape the way people learn, play, and interact. In this chapter, you will explore how mobile applications have become powerful tools not just for communication and entertainment, but also for education, management, and skill development. You will discover how mobile technology serves as a bridge between human needs and digital solutions, bringing ideas to life through smart, accessible, and user-friendly applications.

Mobile devices are now integral to everyday life. From classrooms to workplaces, from farms to homes, they have redefined how people connect and engage with information. Mobile technology offers portability, real-time accessibility, and personalized experiences, making it an essential platform for innovation in various fields.

For BSIT students, the ability to design, develop, and research mobile-based applications is more than just a technical skill—it is a creative pursuit that combines logic, empathy, and design thinking. Through this chapter, you will explore research projects that harness the potential of mobile technology to solve real-world problems, enhance learning, and promote efficiency.

This chapter highlights three unique mobile-based research endeavors that reflect the versatility and purpose-driven nature of mobile application development. Each of these projects represents a blend of innovation, functionality, and human-centered design. They reflect how mobile applications can address diverse needs, whether nurturing early learners, supporting animal welfare, or developing future programmers. Through research, BSIT students learn to analyze real-world challenges, design appropriate digital solutions, and evaluate their effectiveness in promoting meaningful change.

# Game-based Learning Platform for Kindergarten

*Mike Guiller S. Miranda, Joshua A. Chua, Rommel Tanaid & Yuya M. Eto*

The incorporation of digital game-based learning and other technological innovations in education has received considerable attention in recent years (Castillo, 2019; Konok et al., 2021; Yang et al., 2018). The widespread accessibility of devices such as tablets and smartphones has provided children with greater opportunities to engage with educational resources and interactive games (Liao et al., 2019). Many children today demonstrate a high level of familiarity with these technologies, suggesting strong potential for their integration into the learning process (Konok et al., 2021). However, it is equally important to recognize the risks associated with excessive video game use. Studies indicate that video game addiction can disrupt daily routines and negatively affect both academic performance and social relationships (Newport Academy, 2021; World Health Organization, 2018). These concerns highlight the need for a balanced approach that maximizes the benefits of game-based learning while addressing its possible drawbacks.

Education plays a central role in children's holistic development, shaping their personality, confidence, and sense of responsibility as future citizens (Ranjan, 2021). Consequently, it is essential to identify innovative methods that leverage technology and gamification to make learning more engaging and meaningful. Game-based learning, in particular, has been

recognized as an effective strategy for fostering critical skills such as problem-solving, collaboration, and analytical thinking. By embedding learning activities within interactive games, students are more likely to participate actively and retain knowledge.

Over the years, research has increasingly emphasized the value of game-based learning for children. This approach transforms video games, traditionally perceived as distractions to academic success, into powerful educational tools. When designed appropriately, digital game-based platforms provide immersive and interactive environments that not only capture children's attention but also support skill development and conceptual understanding.

In this study, we developed a digital game-based learning platform tailored for kindergarten students. The platform takes advantage of the interactive and engaging nature of video games to deliver age-appropriate educational content in alignment with the curriculum. By integrating gaming elements into formal learning, this approach fosters higher engagement, improves motivation, and creates opportunities for meaningful learning experiences at an early stage of education.

## **Theoretical Framework**

This study used relevant theories as the foundation for implementing the game-based learning platform for kindergarten students. These theories provide the guiding principles that explain how games can foster motivation, engagement, and learning among young learners.

### ***Motivation Theory by McClelland***

According to McClelland's Motivation Theory, every individual is

driven by three primary motivators, which are developed through one's environment and life experiences. These motivators are achievement, affiliation, and power. Achievement refers to the emotional drive to progress quickly, complete tasks successfully, and attain higher levels of performance. Individuals with a strong need for achievement often display behaviors such as striving to win at all costs, seeking to be on top, and desiring recognition for their accomplishments. Affiliation, on the other hand, is the drive to be liked and accepted by others. Those with a high need for affiliation prefer to be in environments where they feel welcomed and included. Finally, power represents the emotional drive to gain influence, status, and control over others. Individuals with a strong need for power often thrive on competition, seek authority, and aim to dominate in order to feel successful.

### ***Theory of Gamification by Jared Fulton***

Jared Fulton's Theory of Gamification highlights that gamification in education is a strategy designed to motivate students to learn academic content more effectively. Unlike games that are solely intended for entertainment, gamified educational platforms use the principles of games, such as challenge, rewards, and progression, to foster engagement and learning. Through gamification, learners are encouraged to strategize, apply information, and reach objectives, while at the same time experiencing enjoyment similar to playing games.

### ***Theoretical Foundations of Game-Based Learning for Kindergarten***

One key foundation is constructivism, which emphasizes active participation and problem-solving. Game-based learning aligns with constructivist principles by allowing children to construct knowledge

through exploration and interaction.

Another important foundation is play-based learning, which recognizes the role of play in early childhood development. By integrating play-like elements into academic activities, game-based learning ensures that children remain engaged, motivated, and immersed in a positive learning environment.

Finally, cognitive development theories highlight how game-based learning supports the growth of essential mental skills in young learners. Through educational games, kindergarten students can enhance their critical thinking, problem-solving abilities, memory, and attention span, all of which are crucial for their overall academic and personal development.

### ***Game-based Learning***

Game-based learning has emerged as a promising educational approach for acquiring new concepts and skills through both digital and non-digital games (Grace, 2019). Research has shown that the use of games in education can significantly improve learning outcomes (Kula, 2021; Syafii, 2020). By integrating games into the learning process, game-based learning provides a balanced approach that combines theoretical content with interactive and engaging gameplay (Chen et al., 2018).

The effectiveness of game-based learning, however, varies depending on the domain of knowledge. Kucher (2021) noted that game-based approaches are particularly effective for interdisciplinary subjects requiring critical thinking, interpersonal communication, and debate skills. Students who participate in game-based learning are more likely to retain knowledge due to the active and immersive nature of these experiences. Similarly, Kühn et al. (2019) emphasized that the core elements of successful video game play, such as persistence, creativity, and problem-

solving, can also be cultivated in educational contexts. When students engage deeply with the narrative and characters in learning games, they enhance their deductive reasoning while fostering a sense of immersion.

The integration of Information and Communication Technology (ICT), particularly digital game-based learning, has become increasingly vital in modern education (Barrera et al., 2020). Digital games create interactive and dynamic learning environments that can be applied across various disciplines (Al Fatta et al., 2019). Beyond improving learning outcomes, they also generate enthusiasm, motivation, and experiential learning opportunities. Abdulrahim and Mabrouk (2020) further argued that digital game-based learning not only enhances student achievement but also strengthens the instructional competencies of educators. Through such platforms, students develop essential skills in critical thinking, cognition, and problem-solving, all of which contribute to achieving academic goals (Talib et al., 2019).

Empirical studies have highlighted the potential of digital game-based learning in primary education, where it has been shown to accelerate knowledge acquisition while making learning enjoyable (Vélez-Agosto & Rivas-Vélez, 2018). By incorporating innovative teaching strategies and advanced technologies, digital games enrich the teaching and learning process (Campos et al., 2020). The positive influence of game-based learning on knowledge achievement, motivation, and engagement has been consistently observed in primary-level classrooms (Fokides & Chachlaki, 2019; Yeh & Liao, 2018). Bers (2018) also underscored its role in providing young learners with a richer learning experience and fostering a deeper understanding of the digital world.

The literature strongly supports the effectiveness of game-based learning, particularly in its digital format, in enhancing academic outcomes,

student engagement, and critical thinking skills. By offering interactive and immersive experiences, game-based learning enriches educational practices and encourages deeper subject comprehension, making it a valuable innovation in contemporary teaching and learning.

### ***Game-based Learning Platforms***

In the realm of game-based learning platforms, Bookworm and Math Prodigy serve as noteworthy examples. Analyzing these systems provides valuable insights into their strengths and limitations, which in turn inform the design and evaluation of our proposed system.

*Bookworm.* Bookworm excels in promoting literacy and language skills through its engaging word-building and puzzle-solving gameplay. Its intuitive interface, progressive challenges, and enjoyable rewards foster a positive user experience and sustained engagement. However, its scope is primarily confined to language development, which limits its applicability to other subject areas or broader educational objectives.

*Math Prodigy.* Math Prodigy, on the other hand, effectively integrates gamification elements with a comprehensive library of math exercises to engage students in mathematics learning. Key features such as adaptive assessments, personalized learning paths, and real-time feedback provide students with tailored learning experiences. Nevertheless, its exclusive focus on mathematics restricts its relevance to other educational domains.

Our proposed system seeks to combine the strengths of both Bookworm and Math Prodigy while addressing their limitations. Unlike these platforms, which are subject-specific, our system is designed to encompass a wider range of subjects and learning content. It integrates interactive gameplay, adaptive assessments, personalized learning

pathways, and progress tracking, thereby offering a versatile and holistic learning experience.

While Bookworm and Math Prodigy have each demonstrated strong user engagement and positive educational outcomes within their respective domains, our proposed system aims to provide greater adaptability and inclusivity. By extending game-based learning to multiple disciplines, it seeks to foster a more comprehensive and engaging educational experience. Ultimately, by drawing upon and expanding the effective features of Bookworm and Math Prodigy, our platform aspires to deliver an interactive, adaptable, and student-centered learning environment that supports diverse educational goals across multiple subject areas.

## **Research Framework**

### *Dataset*

The dataset consists of information collected from selected and willing kindergarten schools in Sariaya, Quezon, comprising a total of 63 pupils and 3 teachers. The data provided by the students serve as the foundation for the development of the proposed system. Based on the collected data, the following is a brief:

**Preferred language:** The majority of students (60 out of 63) prefer to learn in Tagalog, reflecting their comfort and familiarity with the language.

**Device accessibility:** Sixty out of sixty-three students have access to the necessary devices for using the game-based learning platform.

**Internet accessibility:** Most students (56 out of 63) have internet access, which is essential for the game-based learning platform.

**Students' game preferences:** The most popular games among the students include Minecraft, Roblox, and Robot Fight. These games span

different genres such as building, virtual worlds, and combat, indicating diverse interests among the students. This also suggests that digital games are highly appealing to kindergarteners.

The data generated from the teachers include the perspectives and practices regarding difficult subjects or topics, students' interests, teaching strategies, suggestions for enhancing student engagement, and their views on the most effective language for teaching.

Difficult subject/topic for the students: Reading, writing and numeracy

Subjects/topics where students are passionate about: Storytelling, playing and watching

Strategies used by the teachers: Repeat lessons, learning through play, and teaching with patience

Suggestion from the teacher: Play-based learning, manipulatives, videos, and interactive teaching

Most effective language for teaching: Tagalog or mother-tongue.

### ***Experimental Design Process***

Although the current study did not directly implement the experimental design, it is important to highlight its potential impact in assessing the integration of game-based learning platforms for kindergarten students. The design aimed to investigate the effects of game-based learning on student engagement and learning outcomes.

Experimental group: Kindergarten students using the game-based learning platform.

Control group: Kindergarten students receiving instruction through traditional teaching methods without the game-based learning platform.

Kindergarten students were randomly assigned to either the

experimental group or the control group. The experimental group was provided with access to the game-based learning platform, which was incorporated into their teaching sessions. Meanwhile, the control group was taught using traditional methods without the integration of the game-based learning platform. Data were then collected on the engagement levels and learning outcomes of both groups to compare the effectiveness of the two teaching approaches.

### ***Research Instrument***

This study employed questionnaires for data collection. The survey was designed to gather factual information and user feedback. It evaluated the system according to ISO 25010 criteria, focusing across eight quality attributes: functionality, performance, compatibility, usability, reliability, security, maintainability, and portability. The system's quality was evaluated using questionnaires based on the ISO 25010 standard. To ensure statistical validity, the sample size formula was applied to determine the appropriate number of respondents.

### ***Modelling***

For the implementation of the system, the study utilized the ADDIE Model as the instructional design framework to guide the execution of the overall plan. The ADDIE Model was specifically chosen due to its flexibility, which allows to modify and adapt the system plan at each phase while continuously refining it throughout the process. This adaptability is valuable in complex projects where requirements may evolve or unforeseen information may arise during implementation.

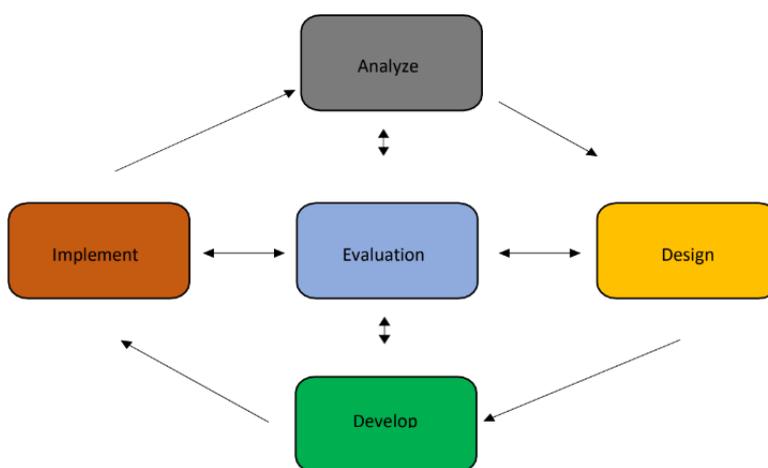
By following the systematic approach of the ADDIE Model, the researchers ensured that all essential steps were addressed, including

thorough analysis, thoughtful design, effective development, smooth implementation, and comprehensive evaluation. Furthermore, the model's support for iterative development enabled the integration of feedback and evaluation into the implementation plan, promoting continuous improvement and alignment of the final system with the intended objectives and requirements.

In addition, the well-established nature of the ADDIE Model, supported by extensive research in instructional design, allowed to draw on existing knowledge and best practices in system implementation. The choice to employ the ADDIE Model provided a structured and adaptable framework that effectively guided the planning, execution, and refinement of the system implementation process.

**Figure 1**

*ADDIE Model*



*Analyze:* In this phase, data were collected through surveys conducted with kindergarten teachers and pupils. These data served as the foundation for the proposed system, guiding its overall direction and

essential components.

*Design:* This phase focused on determining the graphical user interface (GUI) and the overall structure of the platform. The study also identified and tested programming languages and software required for system development. This ensured the feasibility of the plan based on the researchers' skills and expertise. The design phase also emphasized the clear presentation of content.

*Develop:* After collecting and analyzing the data, a prototype of the platform was created. The prototype was tested at various stages, especially when new functions were added. Based on test results, the researchers either continued development at the current stage or made necessary modifications. The system underwent multiple stages of development and testing to achieve the desired outcomes.

*Implement:* Once the desired results were achieved, the system entered its implementation phase. At this stage, the system became available for use by the intended users.

*Evaluate:* The evaluation phase focused on identifying areas for improvement or change within the system. Each phase of the development process underwent evaluation before progressing to the next stage.

## **Technical Framework**

### ***Software Specifications***

*MySQL* – a database management system. This is used by the researchers to manage the database and the tables used by the system to store and retrieve data.

*RPG Maker MV* – a software development program used to create role-playing video games. This third-party software is used to create

“Pixellana”, one of the games in the system.

Gimp – an open-source photo editing software. The software is mainly used for editing and photo manipulation according to resources used by the system.

HTML – the html is the code used to build the GUI or graphical user interface of the platform.

CSS – the language used by the researchers to manipulate the HTML, such as changing its shape, color, and how it would be positioned.

JavaScript – used to create the modals, loading screen and other functions a platform needed.

PHP – the server-side scripting language used by the researchers to store and retrieve data from the database.

WEB Speech API – used for the speech recognition of the game, Abakada Journey. This is used to compare the stored word in the array list retrieve in the database of the platform, with the help of this API checking the speech pattern of the user, it is able to check whether it matches from the word stored.

### ***Hardware Specification***

Device	ASUS VivoBook X542U
Processor	Intel(R) Core(TM) i5-8250U CPU @ 1.60GHz 1.80 GHz
Installed RAM	4.00 GB
System type	64-bit operating system, x64-based processor
Operating System	Windows 10 Pro

## System Design

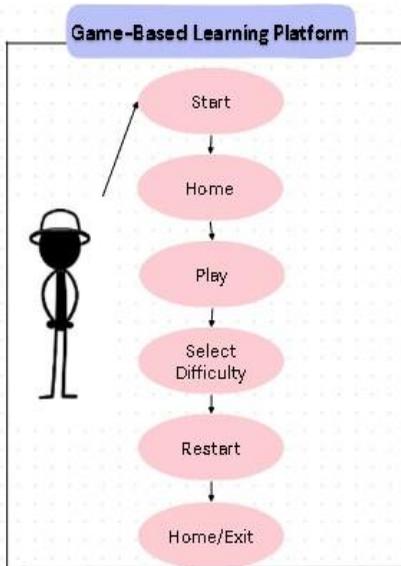
*Use case.* Figure 2 illustrates how a guest, someone who visits without login credentials, interacts with the platform. Guests have limited access; they can play normally, but their progress and achievements are not stored in the database.

Figure 3 shows how a user with login credentials interacts with the platform. The user can log in and play, and their data is stored and retrieved from the database. This allows their progress and achievements to be displayed on the leaderboard.

Figure 4 presents the admin's use case. The admin logs in using administrator credentials, granting access to the admin dashboard. This dashboard allows the admin to upload and modify content and resources in the game. The admin also has the authority to add, edit, or delete user credentials.

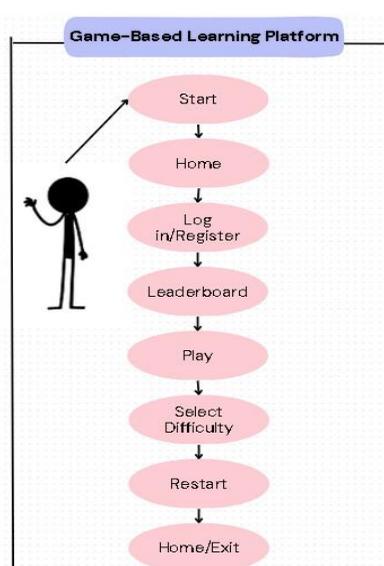
**Figure 2**

*Guest's use case*



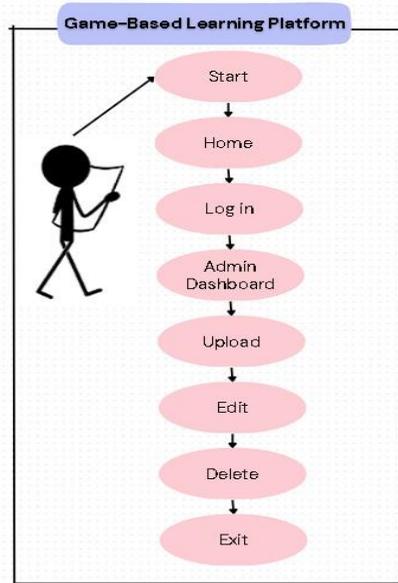
**Figure 3**

*User's use case*



**Figure 4**

*Admin's use case*

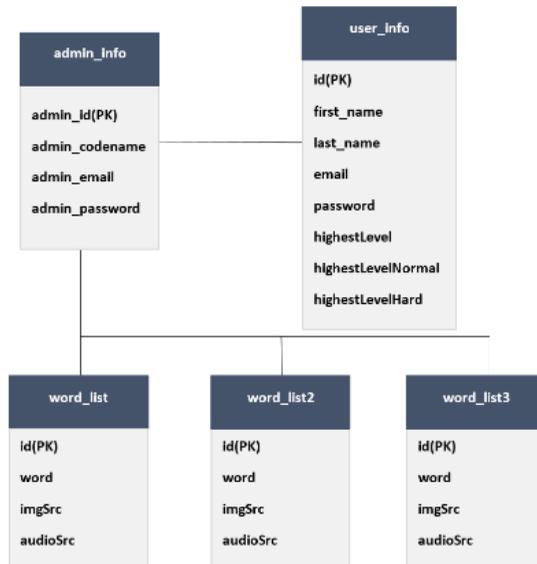


### *Database Schema*

The database schema defines the organization and structure of the database used to store and manage data. It specifies the tables, columns, and relationships that form the database foundation. The schema consists of multiple tables, each representing a specific entity or concept relevant to the research.

**Figure 5**

*Database schema*



## *Development*

During the development phase, the programmer utilized several programming languages, including PHP and JavaScript, to build an efficient and functional system. These languages provide robust functionality and flexibility for web-based applications.

To support development, various tools and technologies were used. Visual Studio, a powerful integrated development environment (IDE), streamlined coding tasks and improved productivity. HTML was used to structure the user interface, while CSS was applied for styling to ensure a visually appealing and intuitive design.

APIs (Application Programming Interfaces) were integrated to enable seamless communication with external services, enhancing system functionality. XAMPP, a cross-platform web server solution, was employed to create a local development environment with Apache, MySQL, and PHP. This setup facilitated efficient testing, debugging, and iterative development.

MySQL served as the database management system, providing reliable data storage and retrieval. The programmer used its query language and tools to design and implement database structures and interactions. Additionally, image-editing software like GIMP was used to enhance visuals, ensuring high-quality graphics. RPG Maker MV, a third-party software, was utilized for game creation, offering features tailored to interactive and engaging game development.

By combining these languages, tools, and technologies, the development team created a system designed to meet user requirements and deliver a positive user experience. Thorough testing and quality assurance were conducted to ensure system stability, reliability, and functionality.

## Testing

To ensure that the system met the researchers' intended functionality, it underwent a thorough testing phase. Every aspect of the system was tested to confirm proper operation.

The test approach outlined the strategy and methodologies used to guarantee system quality and reliability. The primary objectives were to detect and correct defects, validate the system against requirements, and ensure a satisfactory user experience. The approach included:

*Test planning* – A comprehensive plan defined the scope, objectives, activities, required resources, and team responsibilities.

*Test types* – Several testing types were applied, including: functionality testing, verified that each function worked as specified; security testing, identified and addressed vulnerabilities and risks; and usability testing, evaluated ease of use, navigation, and overall user experience.

*Test environment* – A dedicated environment simulated real-world usage with appropriate hardware, software, and network configurations.

*Test execution* – Test cases were executed per the plan, and results were documented. Any issues were logged for resolution.

To confirm that the system functioned correctly, several tests were performed on functionality, security, and usability.

**Table 1**

*Test case*

Test Case Type	Description	Test Step	Expected Result	Status
Functionality	Ensure that the game would run in the platform	The tester launch or play the game using the platform	The game should launch without any problem	Pass

Test Case Type	Description	Test Step	Expected Result	Status
Security	Confirm that the Log in/Register process is working correctly	Created	The data should be stored in hashing method when storing the data/The system should be able to decrypt the encrypted password when logging in	Pass
		The tester would input the Username and Password/Register with a pseudo credentials		
Usability	The navigation button should link to other webpages	The tester clicks on the navigation buttons of the Platform	The buttons should take the tester to other webpages where it is linked to	Pass

### ***Deployment and Maintenance***

For deployment, the HTML, JavaScript, CSS, and other resources (e.g., images, audio) were uploaded to the hosting service. The database required for the system was also created within the hosting service. Hostinger was selected for deployment due to its user-friendly and manageable services, making it suitable even for first-time developers testing web-based systems.

For ongoing maintenance and support, Hostinger was chosen for its reliable features and ease of use. The maintenance plan included:

*Bug tracking and issue resolution* – A bug tracking system captured and managed user-reported issues. The development team prioritized and fixed bugs promptly.

*Regular updates and enhancements* – Periodic updates improved system functionality and added new features, tested in a development environment before live deployment.

*Performance monitoring and optimization* – System performance was regularly tested, with adjustments made as needed.

*Database maintenance* – Routine backups and optimizations

ensured data integrity and security. Hostinger’s MySQL tools supported efficient management.

*Security maintenance* – Regular software updates and security patches were applied, and users were educated on best practices.

*System backup and disaster recovery* – Full system backups, including databases, were scheduled and tested to ensure reliable recovery in case of failure.

### ***Cost Benefit Analysis***

Table 2 shows the monthly operational costs of running the platform. Actual expenses may vary depending on services used and the location of operations.

**Table 2**

*Monthly operational cost*

<b>Services</b>	<b>No. of Months</b>	<b>Cost</b>	<b>Total</b>
Internet fee	1	₱ 1,700.00	₱ 1,700.00
Hosting Services	1	₱ 349.00	₱ 349.00
Domain Name (1 year)	12	₱ 50.00	₱ 50.00
Electricity	1	₱ 890.00	₱ 890.00
<b>Total</b>			<b>₱ 2,989.00</b>

### ***System Evaluation***

Table 3 presents the results of the evaluation of the game-based learning platform based on responses from a total of 107 participants. The weighted mean formula was used to analyze and interpret the collected data.

**Table 3***Weighted mean distribution of the criteria for developed system*

<b>Criteria</b>	<b>Weighted Mean</b>	<b>Remarks</b>
Functionality	3.20	Agree
Performance	3.42	Strongly Agree
Compatibility	3.42	Strongly Agree
Usability	3.27	Strongly Agree
Reliability	3.35	Strongly Agree
Security	3.03	Agree
Maintainability	3.07	Agree
Portability	3.25	Agree
<b>Average</b>	<b>3.25</b>	<b>Agree</b>

The results present the total average weighted mean of the system based on the evaluation using ISO 25010. The results gathered from respondents show an average weighted mean of 3.25. Using the Four-Point Likert Scale, this corresponds to “Agree,” which indicates that the developed system is functional, performs well, is user-friendly, and can be used across different devices, although there is still room for improvement.

*Economic feasibility.* To assess whether the system is economically feasible, a cost-benefit analysis was conducted to identify and present the expected expenses. The services required to maintain the platform’s operation are deemed economically feasible.

*Technological feasibility.* Since the system does not require additional hardware or specialized tools to run, anyone with access to the internet, a smartphone, or a computer can use the platform. The system relies only on commonly available devices that are widely used today, making it technologically feasible.

*Operational feasibility.* Based on the results of the ISO 25010

evaluation, respondents found the game-based learning platform for kindergarten to be satisfactory. From this, it can be concluded that the system is operationally feasible based on user feedback.

## **Conclusion**

The findings indicate a commendable level of satisfaction and confidence in the system across these aspects. They validate the effectiveness of the design and development efforts, confirming that the system meets user needs and expectations. However, it is important to note that while respondents expressed agreement, further analysis and continuous feedback should be considered to better understand the system's strengths and areas for improvement. Overall, the positive consensus among respondents demonstrates the system's success in meeting user requirements, providing a satisfactory user experience, and exhibiting commendable qualities.

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# HAYO-FUN: An Android-based Mobile Application for Raising Farm Animals

*John Kiervin C. Arias, Joel R. Bolido, John Kenneth V. Marquez & Jeremy D. Santiago*

As the proverb goes, without knowledge, action is useless, and without action, knowledge becomes futile. Socrates once remarked, “*To know that we know what we know, and to know that we do not know what we do not know.*” Knowledge is indeed a valuable treasure that people can apply in their daily lives to improve their well-being. While knowledge derived from textbooks remains essential, students today often perceive it as insufficient or unappealing. They frequently turn to the internet for answers to their questions, yet learning through video games offers another promising avenue, one that combines engagement with education, making the acquisition of knowledge more interactive and enjoyable.

There are notable studies demonstrating the potential of educational games. Empirical findings revealed that using games as a learning medium produced positive educational outcomes among students (Alotaibi, 2024; Ren et al., 2024; Cheung & Ng, 2021; Smiderle et al., 2020; Yu et al., 2020; Barroga & Hipe, 2023; Abion et al., 2023). Hence, this study acknowledges

the immense potential of mobile games, which are particularly popular among teenagers, to serve as tools for promoting agricultural literacy. Through educational games, students can acquire essential agricultural knowledge in a way that feels less burdensome and more engaging than traditional learning methods. Unlike textbooks or online resources, which may feel tedious to those without a natural interest in agriculture, mobile games can make learning enjoyable by combining education with entertainment.

Although some critics argue that games distract students from meaningful learning (Rüth & Kaspar, 2021; Murphy et al., 2014), a broader perspective suggests that games and education do not have to exist in opposition. Instead, their integration can create a powerful, motivating, and enjoyable approach to learning, one that encourages learners to engage voluntarily rather than perceive it as an obligation. When thoughtfully designed, educational games can reinforce critical thinking, problem-solving, and collaboration skills, bridging the gap between theory and practice. Moreover, the immediate feedback and adaptive challenges inherent in well-structured games can foster a sense of competence and persistence, enhancing both learning outcomes and long-term retention.

The main objective of this study is to develop an educational game designed to teach players how to raise different types of farm animals and identify as well as treat common animal diseases. Specifically, the study aims to design an Android-based mobile game that enables players to raise farm animals from the initial stage to maturity, provides a list of treatments for common animal diseases, incorporates quizzes on diseases and medicines, features a trading market for buying and selling products, and displays player achievements alongside the developmental history of farm animals. Furthermore, the study intends to create this game using GDevelop

with C++ and JavaScript programming languages, and to evaluate it in terms of functionality, performance efficiency, compatibility, and usability.

## **Theoretical Framework**

### ***Theory of Game-based Learning***

The study is anchored in the theoretical perspectives of The Theory of Learning in Games as articulated by Fudenberg (1998) and Levine (1998), who emphasized the potential benefits of utilizing games as a medium for learning. In line with this, Piaget (1962), the first psychologist to systematically investigate children's cognitive development, argued that the growth of a child's intelligence is significantly influenced by the environment and the activities in which they regularly engage, particularly play. Supporting this argument, Abt's (1970) Theory of Serious Games posits that such games are intentionally designed with explicit educational objectives rather than being created solely for amusement. Similarly, Plass (2015) stresses that an integrative approach, one that combines cognitive, motivational, affective, and sociocultural perspectives, is essential in both game design and game research to fully harness the educational potential of games.

Building upon these theoretical underpinnings, the present study incorporates educational principles into a game format while ensuring that entertainment remains central to the learning experience. This balance ensures that learners are both motivated to engage and able to acquire knowledge in a meaningful way.

### ***Gamification in Agriculture: Enhancing Knowledge and Engagement through Mobile Technology***

Agriculture, encompassing the cultivation of crops and the raising

of animals, represents a cornerstone of both local and global economies. Individuals engaged in this sector, commonly referred to as farmers, play a critical role in sustaining livelihoods by providing food, employment, and essential raw materials, while also contributing to economic growth through trade. Among the diverse branches of agriculture, livestock production and selective breeding, commonly referred to as animal husbandry, stand out as vital activities aimed at enhancing genetic qualities and behavioral traits for economic benefit. For many farmers, animal husbandry serves as a primary source of livelihood.

According to Rajinipriya et al. (2018), agriculture is one of the most vital sectors influencing government policy and economic planning. A robust agricultural system enables a nation to achieve self-sufficiency, reduce dependence on imported products, and stimulate economic development through trade, thereby alleviating poverty within local communities. However, as Madayag (2021) observes, the agricultural sector in the Philippines continues to lag behind other Asian nations in terms of technological advancement and access to modern equipment. This underperformance has been attributed to insufficient investment in both traditional and innovative agricultural practices.

Globally, livestock production is dominated by countries such as China, the United States, and Egypt (Global Economy, 2020). China leads in chicken and egg production, the United States specializes in cattle and beef, and Egypt is recognized for its large goat population, which supplies both meat and milk. For the Philippines to enhance its agricultural output, it is crucial to encourage greater engagement among its citizens, particularly the younger generation. Urrutia (2018) reports that the number of farmers in the country has been declining annually, as many choose to work overseas in pursuit of higher income opportunities. This trend highlights the

urgency of cultivating local interest in agriculture.

This study seeks to address these challenges by integrating mobile technology into agricultural education. By targeting younger generations, the research aims to foster early interest in agriculture while equipping learners with foundational knowledge. The objective is to impart essential agricultural concepts at an early age by incorporating entertainment elements, thereby ensuring sustained motivation and engagement.

Video games, defined as electronic games that require interaction through input devices such as controllers, keyboards, or joysticks, provide a versatile platform for recreation and learning alike. Mayra (2020) observes that video games, particularly mobile-based games, have become increasingly popular among adolescents due to their accessibility and widespread use. Leveraging this trend, researchers employ mobile games as innovative tools to promote agricultural literacy. Fatta (2018) emphasizes that gamified learning enables players to acquire practical knowledge, such as animal husbandry, while simultaneously experiencing intrinsic satisfaction through progressive achievements, thereby sustaining interest and long-term engagement.

Continuous advancements in mobile technology have further enhanced computing capabilities, making mobile devices powerful tools for learning. Mobile technology encompasses not only portable devices but also two-way communication systems, computing hardware, and supporting network infrastructure. Leveraging these developments, the present study introduces a novel approach to agricultural education through mobile gaming, enabling young learners to acquire foundational agricultural knowledge in an interactive and engaging way, with the ultimate goal of translating in-game learning into real-life applications.

## *Game-based Learning Systems*

Game-based learning is an active instructional strategy that employs games to enhance student learning outcomes. In this approach, learners acquire knowledge by interacting with game environments, which foster critical thinking and problem-solving skills. Game-based learning can be implemented using both digital and non-digital games and simulations, enabling students to experience concepts in an interactive, experiential manner.

One notable example is FarmVille, an agricultural simulation game developed and published by Zynga in 2009. Its gameplay incorporates multiple aspects of farm management, including plowing land, planting crops, cultivating trees, and raising livestock. The game is distinguished by high-quality graphics and interactive mini-games, which sustain player interest over time. By adopting similar design principles, the researchers aim to ensure that their game maintains user engagement while supporting educational objectives.

While entertainment is a crucial element, the educational dimension of the game is equally important. For instance, incorporating quizzes at each milestone can provide cognitive challenges and reinforce learning opportunities. This concept is exemplified by Kahoot!, a Norwegian game-based learning platform launched in 2013, which utilizes user-generated multiple-choice quizzes accessible via web browsers or the mobile application. By combining knowledge testing with interactivity, Kahoot! demonstrates how games can effectively support education.

Research further suggests that educational games focusing solely on content delivery risk diminishing adolescent engagement. To counter this, effective game-based learning integrates challenging tasks with entertainment, thereby sustaining motivation while promoting knowledge

acquisition. Drawing upon these established concepts and design strategies from existing games, the researchers have identified sufficient theoretical and practical foundations to guide the development of their own educational game.

## **Research Framework**

### *Data*

***Related games.*** After analyzing existing games available in the app store, the researchers identified relevant data that served as the foundation for the development of their own game. Specifically, they reviewed popular farming and learning games to understand their mechanics and features. These insights provided the basis for designing a farming game that integrates quizzes about animals, aligning with the study's educational objectives.

***Information about animals.*** Before developing the game on raising farm animals, the researchers gathered detailed information on how each specific animal is raised. This step ensured that the educational content of the game was accurate, relevant, and reflective of real-world practices in animal husbandry.

***Information about GDevelop.*** As the researchers were new to game development and had no prior experience with GDevelop, they first studied the tool to become familiar with its features and functionalities. Through trial and error, they gradually acquired the necessary skills and knowledge to effectively use GDevelop, eventually gaining the competence to begin the actual development of their project.

***Game assets.*** The researchers also collected and created the graphic and audio assets required for the game. They sourced images online and

edited them to ensure suitability for their design. In addition, appropriate sound effects were selected to enhance player engagement and improve the overall quality of the game. With these assets in place, the researchers were able to proceed with game development, guided by the problem identified in their study.

### ***Experimental Design***

The experimental design employed in this study examined the effect of an independent variable (treatment) on a dependent variable (learning outcomes and engagement). By implementing two treatments and comparing the results, one group using the developed game and another taught through traditional methods, the researchers aimed to achieve maximum precision and draw specific, evidence-based conclusions for the study.

**Table 1**

*Treatment A*

<b>Factor</b>	<b>Level</b>	<b>Response</b>
Based on reality	HIGH - The time for animals to grow is also based in real time.	The players will lose the interest to play the game because of the grinding time needed to make every animal they have grown.
Game rewards	HIGH - Large sum of rewards will be given for each mission achieved.	Even if the game rewards are generous if the time needed for them to achieve these missions is so long it will become not worth it.

**Table 2***Treatment B*

<b>Factor</b>	<b>Level</b>	<b>Response</b>
Based on reality	LOW - The time for animals to grow is fast unlike in reality.	The game difficulty decreased but the game reward also needed to decrease because the player may end the game immediately and result in losing interest in the game also.
Game rewards	LOW - Small amount of rewards will be given for every achievement.	Because the game is not highly based in reality

Having the game highly based on reality can increase the education the players can learn but they will lose the interest eventually because of game difficulty. But if the game is too easy for players, it will decrease the knowledge players can learn from the game. Based on results, the researchers need to balance these two variables to avoid these scenarios and achieve the best result of their study.

### ***Ethical Consideration***

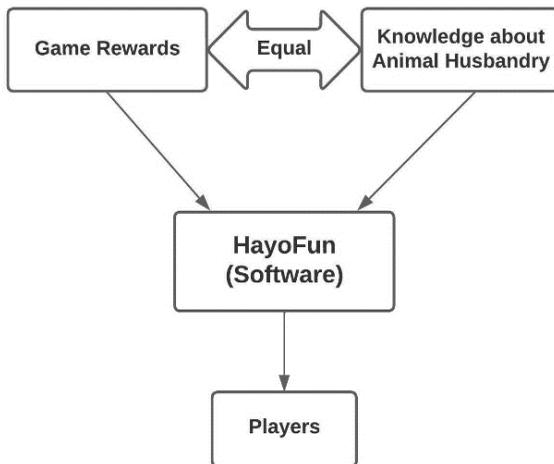
The researchers adhered to a set of ethical principles throughout the study. Prior to gameplay, they obtained informed consent from all participants. Potential risks or harms to the players were identified and mitigated to ensure safety. The confidentiality of participants was strictly maintained, and any conflicts of interest were carefully managed. Throughout the study, the well-being of the players was prioritized to ensure an ethical and responsible research process.

## ***Modeling***

The model in Figure 1 illustrates the goal-directed simplification of the study. Through this visual representation, the purpose, variables, and overall system process can be clearly and effectively demonstrated.

**Figure 1**

*Modeling*



The two primary variables of the study are game reward and knowledge about animal husbandry. These variables must be carefully balanced to prevent potential negative effects on the outcomes of the study. Once the appropriate balance between these two variables is achieved within the developed software, HayoFun, the intended impact will be directed toward the Players, who serve as the target sample of the study.

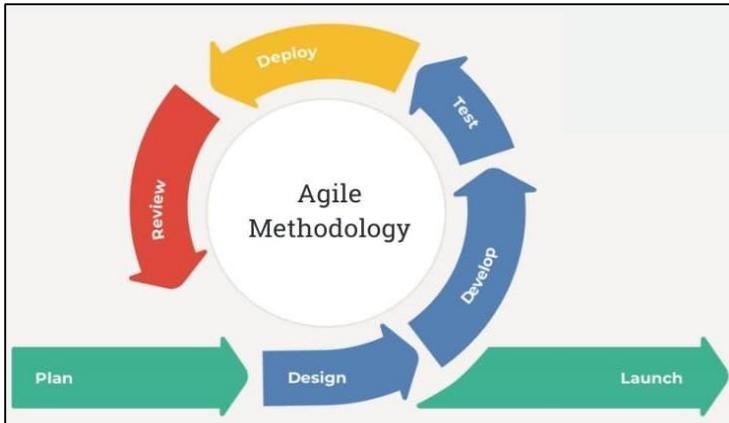
## ***Procedures of the Different Phases***

The study used an Agile Methodology approach to keep progress and achieve positive results. The Agile methodology is a way to manage a project by breaking it up into several phases. It involves constant

collaboration with stakeholders and continuous improvement at every stage. Once the work begins, teams cycle through a process of planning, executing, and evaluating.

**Figure 2**

*Agile Method*



**Plan.** In this stage, the researchers initiated the development of the system by carefully planning and analyzing the variables necessary for the project. This included identifying the data to be gathered, the scope of the game, and the objectives to be achieved. Proper planning served as the foundation for ensuring that the game development process was systematic and aligned with the study’s goals.

**Design.** The researchers then proceeded to design the game, titled HayoFun. This phase involved creating graphical layouts and conceptualizing how basic knowledge of animal husbandry could be applied within the game. All relevant variables that could influence gameplay and educational outcomes were considered and integrated in a manner that would best support the study’s objectives.

**Develop.** During the development phase, the researchers utilized the

GDevelop engine, a free and open-source 2D cross-platform tool primarily used to create PC, mobile, and HTML5 games. The game was subjected to multiple rounds of testing to identify and resolve bugs, with continuous iterations and improvements made based on development progress. These refinements ensured that the application operated efficiently and provided a smooth user experience.

**Test.** This stage involved systematically testing the software product to verify that all components functioned as expected. The game's code and features were repeatedly tested and adjusted to ensure stability and seamless operation. Continuous iterations were made to address issues promptly and enhance the overall quality of the game.

**Deploy.** In the deployment phase, the researchers selected beta testers to play the game. Beta testing provided a valuable opportunity to identify bugs, usability concerns, and other issues that may not have been detected during internal testing. Since real users interact with the game in authentic contexts, beta testing offered insights that more closely simulated real-world application.

**Review.** After beta testing, the researchers collected feedback from the testers. This process enabled the identification of areas requiring improvement and refinement. The feedback served as a critical tool for ensuring that the final product aligned with user expectations while meeting the educational and entertainment goals of the study.

**Launch.** Once the necessary revisions had been made and the game achieved the set objectives, the researchers prepared it for launch. The game was released publicly outside of Google Play and distributed through shareable online links, making it accessible to the target audience.

## Technical Framework

### *Hardware Specification*

The researchers utilized an available computer to develop the game. Since the game editor they selected was accessible online, it was convenient to use, allowing them to easily access and edit the game at any time. This also minimized the risk of file loss, as assets needed for the game were uploaded directly into the platform. In addition to computers, mobile devices were employed in certain stages of the development process. Mobile applications were used to edit some of the graphic art, as these tools proved to be more efficient and user-friendly compared to computer-based software. Furthermore, mobile devices were essential for testing, as the final product was intended to be published as a mobile game.

### *Software*

***GDevelop.*** The primary tool used for development was GDevelop, an online game maker that provided all the necessary features for the project. GDevelop is a 2D cross-platform, open-source engine designed for creating PC, mobile, and HTML5 games. Since the researchers had limited prior knowledge of game development, they searched for an engine that was both accessible and compatible with their needs. Given the popularity of mobile gaming among teenagers, the researchers chose to publish the game on mobile platforms, making GDevelop an ideal choice.

***Fotor Online Photo Editor.*** To edit the graphics incorporated into the game, the researchers used Fotor, an online photo editor. Fotor provided a variety of tools that were instrumental in creating and enhancing the game's visual elements. This free photo editor offers both standard image editing functions and specialized features such as AI photo effects, HDR

adjustments, and RGB editing, which allowed the researchers to design high-quality graphic art for the game.

**BG Remover.** The researchers also employed BG Remover as a supplementary tool in editing images. Its primary function is to remove image backgrounds, rendering them transparent. When used alongside Fotor, BG Remover ensured that the graphics met the quality standards required for integration into the game. Together, these tools enabled the researchers to produce polished and professional-looking game assets.

**Font Meme.** Another tool used was Font Meme, an online font generator capable of producing unique text designs. The researchers used this tool to customize the in-game text, including titles and interface elements. Font Meme also allows the addition of glow effects and styling features, which were particularly useful in designing hover buttons and enhancing the visual appeal of the game.

### ***Requirement Analysis***

Requirement analysis, also referred to as requirement engineering, is a process used to determine the needs and expectations of a new product. Before identifying specific requirements, it is necessary to define the key stakeholders and end-users. In this study, the key stakeholders are the researchers themselves, as they serve as the developers and owners of the product. The end-users are youths aged 12 and above, who represent the target audience of the game.

Once the stakeholders and end-users were identified, the researchers gathered and categorized the requirements into functional requirements (describing what the game should do) and technical requirements (describing the hardware and software specifications needed to support the game). Table 3 presents these requirements in a categorized format.

**Table 3***Functional requirements*

<b>Functional Requirements</b>	<b>Description</b>
Game Player	The actual human that plays the game.
User Input	Functional mechanism to control the direction and action of a player.
User Interface	Medium of interaction between players and the game. Consist of a set of screens and visual elements in the game.
Gameplay Character	Set of characters that are being controlled by the player or the game itself. It consists of player character, enemy character or dynamic object modeling.
Rigid Modeling	Set of characters that are not affected by any forces, collision or gravity during the gameplay.
Media Content	Medium for immersion and engagement such as music, sound effects and animation.
Structural Functionality	Requirements that form the base of the game and coordinate the elements such as scene management, rendering, collision detection and physical systems.
Rewarding System	Motivational aspect includes points, badges and achievements for completing the game.

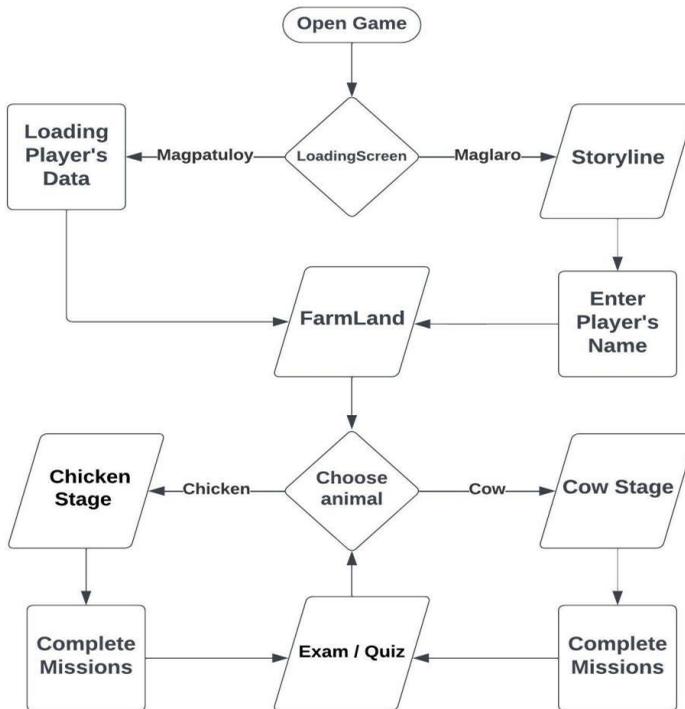
**Table 4***Technical requirements*

<b>Technical Requirements</b>	<b>Description</b>
>2GB RAM	The minimum requirement for the game is having the device's 2gb RAM. The game may not work if a device has slightly less than 2gb RAM.
Dual Core Processor	The minimum requirement for the game is having the device dual core at least.
Android 4.4 (KITKAT), API 19	The minimum requirement for the game is having the device software updated up to Android 4.4.
Open WebGL Support	Common requirement for games that is created from GDevelop to ensure that the game is working properly.
Screen Size	The minimum requirement for screen size is 1920 x 1080 for good gaming experience.

## System Design

Figure above (Figure 4) illustrates the flow of the game. The game began with the players choosing whether to continue an existing game or create a new one.

**Figure 3**  
System flowchart



If the players selected to create a new game, a short storyline appeared, after which they were required to input a name before starting. Players then choose between two available animals, cow or chicken, to begin their gameplay. Once the initial animal was selected, players were tasked with completing all missions to unlock additional features such as buying and selling. The Talaan feature was also unlocked after mission

completion. This feature was essential as it served as a library where the latest information about the unlocked animal could be accessed. Players were expected to study and review the contents of this library since the quiz questions were drawn from the topics found there. To progress in the game and unlock the second animal, players first needed to achieve a satisfactory score in the quiz.

### ***Development***

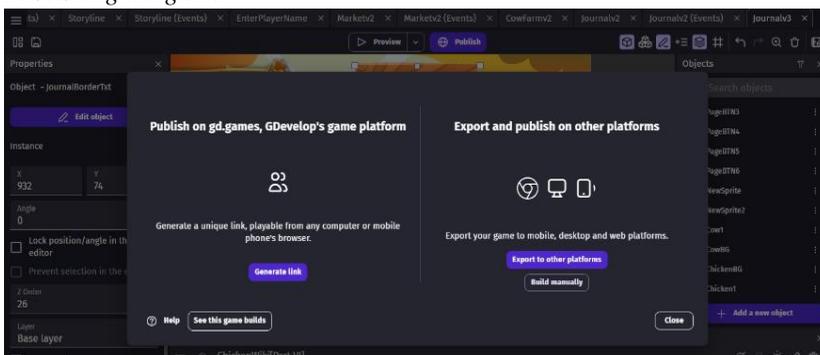
In terms of development, the researchers continuously uploaded new updates and added new animals to the game. They also addressed bugs that appeared in each patch. Through this process, the researchers maintained the game’s functionality and sustained player engagement.

### ***Deployment and Maintenance***

The actions undertaken by the researchers to deploy and upload new content into the game are outlined in the following sequence.

**Figure 4**

*Publishing the game*

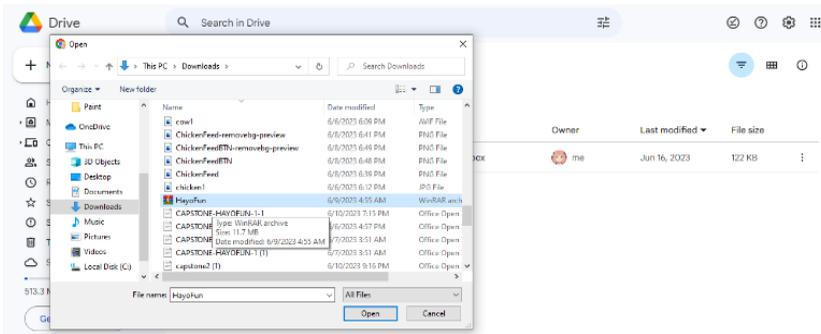


***Sequence 1: Publishing the Game.*** After the researchers completed the development of the game, they proceeded with its publication.

GDevelop provides two publishing options: one through the Google Play Store and the other outside of Google Play. The researchers opted for the latter and published the game independently, making it accessible outside the Google Play Store.

**Figure 5**

*Uploading to GDrive*



**Sequence 2: Uploading to Google Drive.** Figure 6 illustrates the subsequent actions taken by the researchers to deploy the game. After publishing the game outside the Google Play Store, the researchers uploaded it to Google Drive and modified the share settings to “Anyone with the link,” ensuring that the game was accessible and downloadable by all users.

**Sequence 3: Sharing the Link.** Finally, the researchers promoted the game through social media platforms, leveraging their popularity to reach a wider audience. To attract players, they used engaging taglines and compelling quotes designed to encourage downloads and active participation in the game.

**Evaluation of the System**

**Opening screen.** Figures 6 and 7 illustrate the initial screens

displayed to players upon opening the game. If the game had just been installed and no previous data existed, the interface displayed the layout shown in Figure 6. However, if the player had previously played the game and saved progress, the display shown in Figure 7 appeared instead. The New Game button allowed players to create a new game progress, while the Continue button enabled them to resume a previously saved game.

**Figure 6**

*Newly installed*



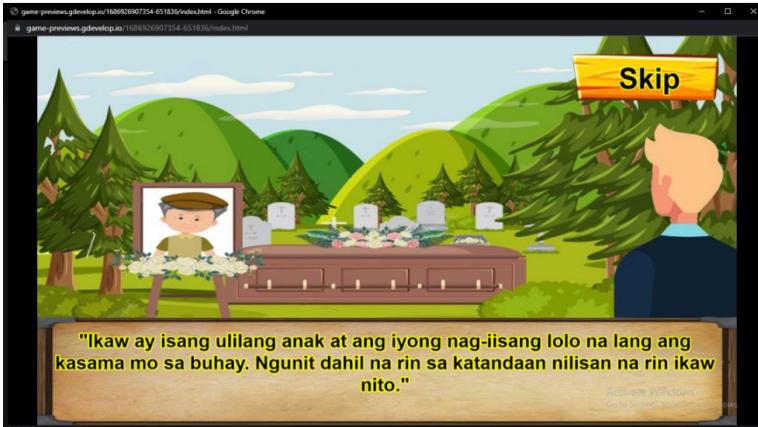
**Figure 7**

*Game already played*



## Figure 8

### *Storyline*



**Storyline.** Figure 8 illustrates the scene that appeared when players selected the New Game button. A storyline was presented, depicting a boy who lost his parents at an early age and was required to manage his family's farmland. Before he could fully take ownership of the farm, the boy needed to learn how to raise the farm animals. Players were given the option to skip the storyline by clicking the Skip button located at the top of the screen.

### *Entering Player's Name*

## Figure 9

### *Enter player's name*



Figure 9 shows the scene where the players need to insert a name that will be used in the entire game.

**Figure 10**

*Farmland*



*Farmland / Bukirin.* In the farmland section, players could access the animals they were tasked with raising, as well as interact with Uncle Teddy, who administered quizzes and facilitated the unlocking of additional animals. At the start of the game, players were given the freedom to select which animal they wished to raise first.

**Figure 11**

*Chicken tutorial*



**Chicken tutorial.** Figure 11 illustrates the scene that appeared when the player chose to unlock the chicken first. The game guided players on how to raise the chicken and how to sell it in the market. Upon completing the assigned missions, additional features were unlocked, including the market, journal, achievements, and access to quizzes administered by Uncle Teddy, which allowed players to unlock the second animal.

**Figure 12**

*Cow tutorial*



**Cow tutorial.** Figure 13 illustrates the scene that appeared when the player chose to unlock the cow first. The game guided players on how to raise the cow and how to sell it in the market. Upon completing the assigned missions, additional features were unlocked, including the market, journal, achievements, and access to quizzes administered by Uncle Teddy, which enabled players to unlock the second animal.

**Journal / Talaan.** After players completed all the missions, this feature was unlocked, providing access to all the information about the animals they had recently raised. This section proved particularly helpful

for players preparing to take quizzes in order to unlock the subsequent animals.

**Figure 13**

*Journal / Talaan*



**Figure 14**

*Market / Tindahan*



**Market / Tindahan.** In the market section, players were able to sell matured animals and purchase additional feed for their livestock. This feature enabled players to earn in-game currency, which was essential for progressing and continuing gameplay.

**Figure 15**

*Achievements / Nakamtan*



*Achievements / Nakamtan*. Figure 15 illustrates the features that were unlocked after a player completed a mission for a particular animal. Players could earn additional rewards upon successfully accomplishing all assigned tasks.

**Figure 16**

*Uncle Teddy (Minigame)*



*Uncle Teddy (Minigame)*. Figure 16 illustrates the section where players could take daily quizzes to earn additional rewards, which could be used to support the raising of animals. This section also served as the

location where players needed to complete quizzes in order to unlock subsequent animals.

### ***System Evaluation***

The study employed a Four-Point Likert Scale consisting of the following categories: strongly agree, agree, disagree, and strongly disagree, which served as the response options for each survey question. Each scale point was assigned a specific mean range to facilitate the evaluation of the developed system.

**Table 5**

*Weighted mean distribution of the criteria for developed system*

<b>Criteria</b>	<b>Weighted Mean</b>	<b>Remarks</b>
Functional Suitability	3.95	Strongly Agree
Performance Efficiency	3.57	Strongly Agree
Compatibility	3.95	Strongly Agree
Usability	3.35	Strongly Agree
<b>Average</b>	<b>3.71</b>	<b>Strongly Agree</b>

Table 5 shows the result weighted mean of each term based on ISO 25010 gathered from 50 respondents. The result of the systems evaluation survey is a 3.71 average weighted mean. The survey results indicate that respondents were generally satisfied with the developed game across all evaluated criteria. In terms of functionality suitability, the game effectively supported players in raising farm animals, accessing the library, using the information in quizzes, and unlocking additional content. This demonstrates

that the game met its intended functional objectives, allowing for meaningful interaction and engagement. Performance efficiency was also rated positively, as the game operated smoothly despite minor bugs, saved progress accurately, and allowed players to recover lost data, ensuring uninterrupted gameplay. Compatibility received strong agreement, with respondents noting that the game ran reliably across different mobile devices and Android versions, including both older and newer models, indicating high adaptability and accessibility. Usability, while generally satisfactory, showed some room for improvement, particularly regarding the user-friendliness of the interface; however, respondents confirmed that buttons and sound interfaces functioned properly, supporting effective interaction. Overall, the weighted means for all criteria ranged from 3.35 to 3.95, with all categories falling under Strongly Agree, indicating that the developed game successfully met its functional, performance, compatibility, and usability goals, providing a reliable and engaging learning experience.

***Economic feasibility.*** Economic feasibility assesses whether the anticipated benefits of a system outweigh its projected costs, thereby determining the value and viability of the application. In this study, the developed game demonstrated high economic feasibility. The game was created using a free platform, GDevelop, and the researchers only required knowledge of the game maker and a reliable internet connection. Compared to other systems that may require paid software or extensive technical resources, this approach provided a cost-effective solution without compromising the quality and functionality of the game.

***Operational feasibility.*** Operational feasibility evaluates whether a system can be effectively used by its intended users. Survey results indicated that the game was operationally feasible and user-friendly.

Respondents reported that the system was easily understandable, and only a brief demonstration was needed for players to navigate and interact with the game efficiently. This suggests that the game can be successfully implemented with minimal training, making it accessible to its target audience of young learners.

**Technical feasibility.** Technical feasibility examines whether the system can be developed using the available tools, resources, and expertise. The game was successfully developed using GDevelop, which requires no prior programming knowledge. Beginners can learn to use GDevelop effectively through the tutorials provided, ensuring that the development process is technically achievable. Additionally, the researchers' understanding of graphic design was essential, as the visual quality of the game depended heavily on the graphics and images integrated into the gameplay. These factors collectively confirmed the technical feasibility of the project.

## **Conclusion**

The study developed an Android-based mobile game that allowed players to raise farm animals from the initial stage to the final stage. The game included a library feature providing detailed information on common animal diseases and their corresponding treatments. A quiz feature was incorporated to assess players' knowledge and reinforce learning. The market feature enabled players to sell matured animals and purchase necessary items such as feed, supporting continuous gameplay. Additionally, an achievement system rewarded players for reaching milestones, thereby enhancing engagement and motivation.

Following testing and evaluation, the game met the standards

outlined in ISO/IEC 25010. It demonstrated high performance across key criteria, including functional suitability, performance efficiency, compatibility, and usability. These results indicate that the developed game not only functions effectively but also provides a reliable, engaging, and accessible learning experience for its users.

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# PLAYJAVA: An Android-based Tutorial Game for Learning Basic Java Programming

*Ann Valare P. Alcantara, JV R. Galasan, Regine J. Remojo & Jovi Rose P. Camacho*

Computer programming surrounds daily life, enabling activities such as ordering takeout, streaming movies, and accessing online services. Technology companies now extend beyond software to offer services like personal training, meal delivery, taxi assistance, and even influence political outcomes. At its core, computer programming involves creating code to perform specific operations on computers, applications, or software programs, providing instructions for execution (Adams & Truong, 2022).

Although programming consists of various methods and practices, academic courses typically focus on essential, practical skills that allow learners to read and write code replicating real-world objects and interactions (Cote, 2022). Computer programmers, as specialists, write and test code to ensure smooth software and application performance. As the internet and the Information Technology (IT) sector continue to expand, programming languages have become the backbone of the industry, requiring IT professionals to master multiple coding languages to keep pace with evolving software demands (Torres, 2022).

Programming languages vary in difficulty and application. Beginner-friendly options include HTML, JavaScript, C, Python, and Java, while more complex ones, such as C++, Prolog, LISP, Haskell, and Malbolge, demand extensive practice and motivation (Damera & Chiampo, 2022). Java, in particular, is a robust and versatile language suited for complex, large-scale applications. As a compiled language, it is generally faster and more efficient than Python.

The increasing demand for computer use in a globalized, technology-driven society raises questions about whether students are adequately prepared for programming careers. Programming is widely acknowledged as complex, and research shows students often struggle in the early stages of learning. In the study of Derus and Ali (2012), factors such as computer background, prior experience, and ineffective teaching methods were identified as contributors to poor performance. Students reported challenges in building accurate mental models of memory processes, and difficulties were categorized into four areas: weak problem-solving skills, ineffective use of representation techniques, poor instructional strategies, and struggles with syntax and constructs (Ahmad & Abai, 2019).

Gamification has been proposed as a solution to improve motivation and engagement. Prior research demonstrated that applying game elements in non-gaming contexts enhances learning experiences (Hong et al., 2024; Christopoulos & Mystakidis, 2023; Khoshnoodifar et al., 2023; Triantafyllou et al., 2025). A gamified website designed for programming students showed potential to increase motivation and address common challenges (Ahmad & Abai, 2019; Polito & Temperini, 2021; Hellín et al., 2023; Kaya & Ercag, 2023; Ratinho & Martins, 2023).

Meanwhile, the widespread use of smartphones and mobile gaming presents both opportunities and challenges. While mobile phones support communication, advertising, and leisure, excessive gaming can lead to addiction and declining academic performance. A study on senior high school students revealed that popular games like Mobile Legends, Clash of Clans, and Rules of Survival negatively impacted grades. To address this issue, a researcher proposed developing a mobile game to aid in learning programming subjects (Rodica, 2019).

The global demand for software developers further underscores the urgency of preparing students. In 2021, there were 24.3 million active developers worldwide, with 61% under the age of 35 (Kinsta, 2023). Yet, many students still encounter the same challenges identified earlier: weak problem-solving, ineffective strategies, and difficulty mastering programming syntax (Ahmad & Abai, 2019).

To address these gaps, this study proposes PlayJava, an android-based tutorial game for learning basic java programming. The system was developed using GDevelop, a free, open-source, no-code 2D game engine that employs visual coding and scripting (Rival & Luna, 2022). The game integrates Java lessons, covering topics such as Introduction, Conditionals, Operators, Loops, and Arrays, with interactive exercises. After completing a lesson, students will engage in a mini-game, such as card-pairing with 25 programming-related questions. The goal of PlayJava is to enhance students' coding practice, particularly for those with limited programming exposure or those who struggled during online learning. By combining tutorials with interactive gameplay, the system seeks to make programming education more engaging and accessible, enabling learners to acquire fundamental coding skills while enjoying the process. The study's primary objective is to evaluate the functionality and effectiveness of PlayJava in

helping students familiarize themselves with the basic structure of Java code.

## **Theoretical Framework**

### ***Play and Mobile Game-Based Learning***

The use of play in education is not a recent concept, but the rise of mobile games as popular entertainment has raised questions about their instructional potential. Despite this, mobile game-based learning (MGBL) offers significant benefits for both formal and informal education. For instance, Rekhawi and Naser (2018) created a web-based intelligent tutoring system for Android application development. The system provided lectures, user interface design fundamentals, and evaluations. However, it did not adequately support learning to code, highlighting the need for more interactive, code-oriented approaches.

### ***Programming Challenges***

Programming languages such as Java rely heavily on precise syntax. Students must carefully type commands, enclose structures correctly, and maintain logical organization. These demands often distract learners from programming's primary goal: problem-solving. Students can only progress efficiently once they master syntax alongside problem-solving techniques.

Research has emphasized the importance of integrating theory and practice in programming instruction. A study on computer laboratory contexts revealed that successful learning requires balancing both, rather than focusing exclusively on either (Kumari & Gupta, 2024). Phenomenography and variation theory suggest that understanding a concept requires learners to recognize significant aspects and their

variations (Han & Ellis, 2019). For instance, computer programs differ by application area, much like circles differ by diameter size. This framework highlights the diverse ways programming knowledge can be contextualized.

### ***Digital Game-Based Learning (DGBL)***

Digital game-based learning (DGBL) blends educational content with game elements such as storyline, challenge, role-playing, goals, feedback, and social interaction. These features foster engagement and motivation. Competition, in particular, encourages learners to progress, though its effects vary. Chen et al. (2018) found that peer competition enhanced interest and reduced anxiety in science lessons, while individual learning was less effective. However, Acquah and Katz (2020) noted that excessive competition can discourage weaker learners and reduce motivation.

Chang and Hwang (2019), in their review of MGBL studies (2007–2016), identified four key findings: (1) smartphones and tablets were the primary devices; (2) disciplines included science, social studies, and languages; (3) instructional methods often combined project-based learning, contextual learning, and competitions; and (4) studies explored multiple perspectives, including cognition, affective states, and learning outcomes.

### ***Game-Based Learning in Programming***

Educational games have proven effective in enhancing student engagement and outcomes. De Freitas (2018) emphasized that high-quality design elements in games positively impact learning, particularly when combined with collaboration. Liao et al. (2019) found that teamwork in DGBL significantly improved student motivation, especially when paired

with group projects. Examples of programming-focused educational games further support these findings. Battistella et al. (2017) designed games to teach Quicksort and Heapsort, improving motivation and cooperation. Malik et al. (2017) developed PROBSOL, a web-based and mobile tool for fostering problem-solving through pseudocode, which reduced attrition rates in introductory programming courses. Similarly, Sohail et al. (2019) reported that students preferred mobile learning (M-Learning) over traditional e-learning formats.

### ***Text-Based and Coding Games***

Text-based programming games provide another approach to learning. Côté (2018) introduced Rise of the Java Emperor, a text-based game designed to teach Java fundamentals through storytelling and problem-solving. Schildgen's (2014) SQL Island used a text-based adventure format to teach SQL and won recognition at the European Conference on Games-Based Learning. Other coding games like Clash of Codes allow multiplayer coding contests in languages such as Java and Python, promoting speed and competition. Compared to these, the proposed system PlayJava focuses on individual practice with structured Java lessons and exercises. While not multiplayer, it integrates interactive tutorials and mini-games to make learning both enjoyable and educational.

## **Research Framework**

### ***Data***

The study utilized a close-ended questionnaire in which respondents rated or evaluated the system on a numeric scale ranging from 1 (lowest) to 4 (highest). Respondents selected the option that best represented their

opinion. The questionnaire was designed based on ISO 25010 quality attributes: reliability, performance efficiency, compatibility, and usability. The survey was conducted with a total of 86 respondents participated, consisting of 1st- and 2nd-year IT students.

### ***Experimental Design***

The experimental design was developed to test the project's independent and dependent variables.

*Independent Variable:* The scores given to the proposed system. These scores are independent as they can vary depending on the evaluations of students and other beneficiaries.

*Dependent Variable:* The ranking of the proposed system. Ranking serves as the dependent variable, as it is influenced by the variations in the independent variable.

### ***Procedures of the Different Phases***

The proposed system is designed to run on Android mobile devices and can be accessed anytime by students and other users. Upon launching the application, the main menu is displayed, presenting five selected topics in Java. After selecting the Play button, the system provides game instructions, followed by the display of basic Java syntax structures. Learners then complete programming exercises in a fill-in-the-blanks format, consisting of 25 randomized questions.

Upon completion, the system generates a dashboard showing a summary of answers. Scores are displayed and automatically recorded in the game's leaderboard for tracking and comparison.

## Modelling

Figure 1

System flow modeling

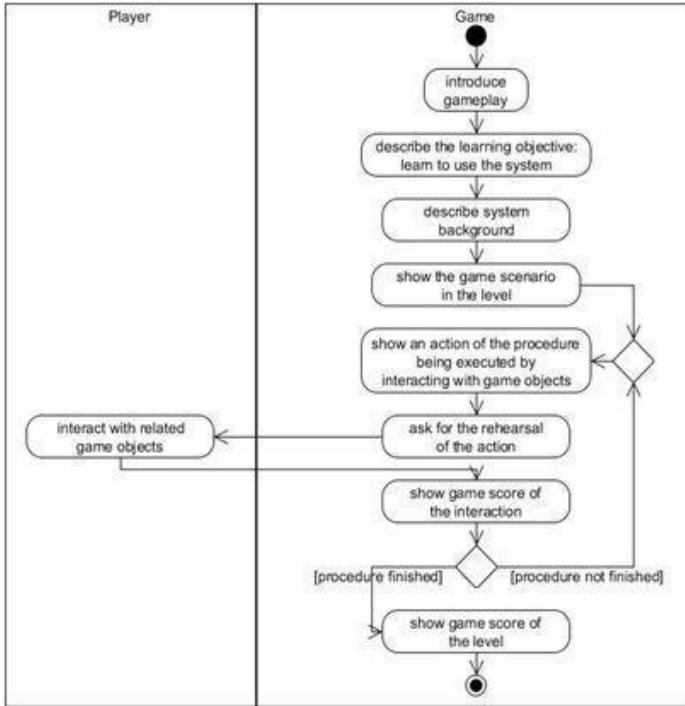
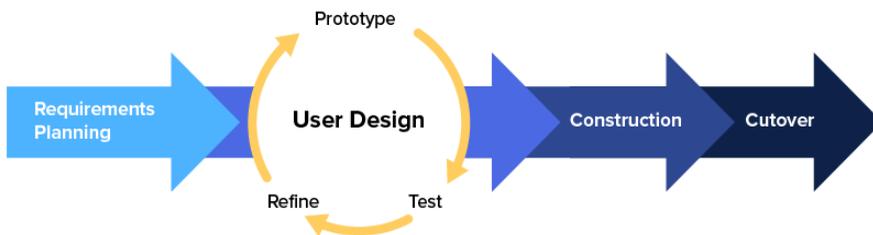


Figure 2

Rapid Application Development (RAD)



## System Development Life Cycle (SDLC) Phases

*Requirements planning.* This phase combines the planning and analysis stages of the SDLC. Through observation and data collection, the

researchers identified problems and set objectives for potential solutions. By examining system requirements, including the necessary materials and their specifications, the researchers determined the actions needed to address issues in the existing system. Key activities included defining the problem, gathering information, setting goals, and identifying and evaluating software requirements. The outcome of this phase was a plan for the subsequent user design stage.

*User design.* In this phase, user-developed models representing system operations, inputs, and outputs were created. Through continuous interaction, users could understand, modify, and approve a functional model that meets their needs. The researchers focused on realizing the logical design of the proposed system, addressing operating system, programming, and security concerns. Plans also included the user interface for system development and management.

*Construction.* This phase involved finalizing the system design, constructing the software, and testing its performance. The goal was to develop a system that functioned at an acceptable level while preparing essential documentation for operation. Transitional software was designed, developed, and tested, along with the procedures required to prepare the system for conversion into production.

*Cutover.* The cutover phase consisted of the final implementation tasks. Activities included system setup, user training, and completion of all necessary documentation to ensure smooth deployment and operation.

### ***Deployment and Maintenance***

*Preparation:* During this phase, researchers gather all deployed code, libraries, configuration files, and resources required for the application. These components are packaged as a single software release.

Developers also ensure that the host server is correctly configured and operating without issues.

*Testing:* Updates are first deployed to a test server, where they undergo pre-configured automated tests. Results are evaluated, and any identified faults or errors are corrected before the update is released to the production environment.

*Deployment:* After thorough testing, updates are pushed to the live environment. Necessary scripts may be executed to update relevant databases. The final stage involves monitoring the live server to identify and resolve any remaining errors, ensuring an optimal user experience.

### ***Ethical Considerations***

Developing a mobile-based tutorial game for learning Java programming entails several ethical considerations:

*Privacy:* The system collects and stores players' names in the game leaderboard. All information is secured and used solely for scoring purposes.

*Accessibility:* The game is designed to be accessible to all users, regardless of prior programming experience, by introducing basic Java lessons.

*Fairness:* The system ensures fair and equal access to all players.

*Responsibility:* The developers are responsible for maintaining the security of the system and protecting all users' personal information.

## **Technical Framework**

The study used various tools and software to design, develop, and document the proposed system.

## *Software*

**Table 1**

*Software specification and software platforms*

<b>System Type</b>	<b>X64-based PC</b>
Database	GDevelop
Game Engine	GDevelop
Operating System	Windows 11

One of the primary tools utilized was GDevelop, a free, open-source, and no-code 2D game engine. Its accessibility and cost-free nature make it ideal for educational purposes, regardless of the number of users. GDevelop was employed in developing the proposed game, particularly in creating its functionalities, dashboard, and leaderboard features. In addition, Microsoft Word was used as a documentation tool. As a widely recognized word processing software developed by Microsoft, it enabled the researchers to prepare, edit, and organize project documentation such as reports, user manuals, and other written outputs necessary for the system's development.

## *Hardware*

The implementation of the proposed system requires an Android phone with at least 2.00 GB of RAM or higher to ensure optimal performance. The specifications presented above illustrate the compatibility of the developed system with different Android phone models that meet or exceed these requirements.

**Table 2**  
*Hardware requirements*

<b>Device Name:</b>	Oppo A5s
<b>Model:</b>	CPH1909
<b>Android Version:</b>	8.1.0
<b>Processor:</b>	Octa – Core
<b>RAM:</b>	3.00 GB
<b>Device Storage:</b>	32.0 GB
<b>Version:</b>	CPH1909EX_11_A.46
<b>Device Name:</b>	Infinix Smart 5
<b>Model:</b>	X657C
<b>Android Version:</b>	10
<b>Processor:</b>	Helio H20
<b>RAM:</b>	2.00 GB
<b>Device Storage:</b>	32.0 GB
<b>Version:</b>	XOS v6.2.0 (Q-P89-2006i8)
<b>Device Name:</b>	Infinix Note 7
<b>Model:</b>	Infinix X690B
<b>Android Version:</b>	10
<b>Processor:</b>	Helio G70
<b>RAM:</b>	6.00 GB
<b>Device Storage:</b>	128.00 GB
<b>Version:</b>	XOS v6.1.0 (Q-P69-200225)
<b>Device Name:</b>	RedMI 9
<b>Model:</b>	M2004J19G
<b>Android Version:</b>	11
<b>Processor:</b>	Octa – Core Max 2.00 GHz
<b>RAM:</b>	4.00 GB
<b>Device Storage:</b>	64 GB
<b>Version:</b>	11 RPIA.200720.011
<b>Device Name:</b>	Vivo 1906
<b>Model:</b>	Vivo 1906
<b>Android Version:</b>	11
<b>Processor:</b>	1.95 GHz Snapdragon 439 Octa – Core
<b>RAM:</b>	3.00 GB
<b>Device Storage:</b>	32.0 GB
<b>Version:</b>	PD1930CF_EX_A_6.8.59

## System Design

**Main page.** The first screen of the system serves as the introductory interface, displaying the game logo and the title Play Java. It contains two interactive buttons: Main Menu and Exit, which allow the user to either proceed to the main content of the application or close it.

**Lesson screen.** Upon selecting the Main Menu, the user is directed to the Lesson Screen, which presents the key topics covered in the Java tutorial. These include Java Introduction, Java Conditionals, Java Operators, Java Looping, and Java Array. This screen functions as the starting point for users to navigate and explore the lessons provided by the system.

**Figure 3**

*Main page and lesson screen*



**First topic selection.** This screen displays the first lesson, titled “Java Introduction,” providing users with an overview of the foundational concepts of the Java programming language.

**First topic: Java introduction.** This screen presents introductory information about the Java programming language, providing users with a basic understanding of its purpose, features, and applications.

**Figure 4**

*The first topic*



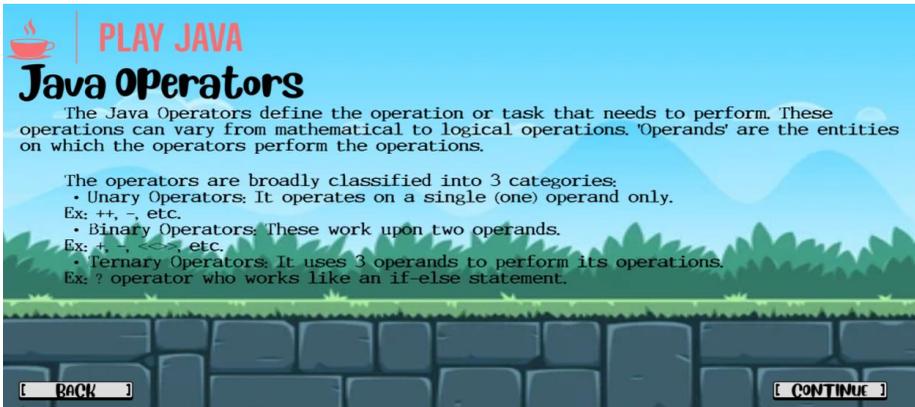
**Selecting second topic (Java Conditionals).** This screen presents the lesson on “Java Conditionals,” which is the second topic in the tutorial. It provides users with information on conditional statements in Java, explaining how decisions are made in programs based on certain conditions.

**Selecting third topic (Java Operators).** This screen provides information on Java Operators, introducing users to the symbols and expressions used to perform operations on variables and values in Java programs.

**Java operators.** This screen presents the lesson on Java Operators, including explanations and examples that demonstrate how operators are used to perform calculations and manipulate data within Java programs.

**Figure 5**

*Third topic*

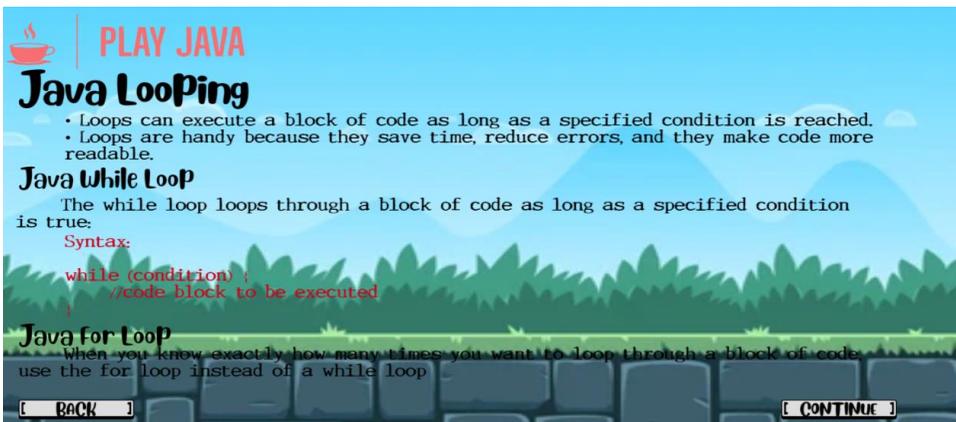


*Selecting fourth topic.* This screen presents the lesson on Java Looping, including explanations and examples that demonstrate how loops are used to execute repeated actions and control the flow of a Java program.

**Java looping. Description:** This screen displays the lesson on Java Looping, providing explanations and examples that illustrate how loops are used to perform repetitive tasks and manage program flow in Java.

**Figure 6**

*Fourth topic*

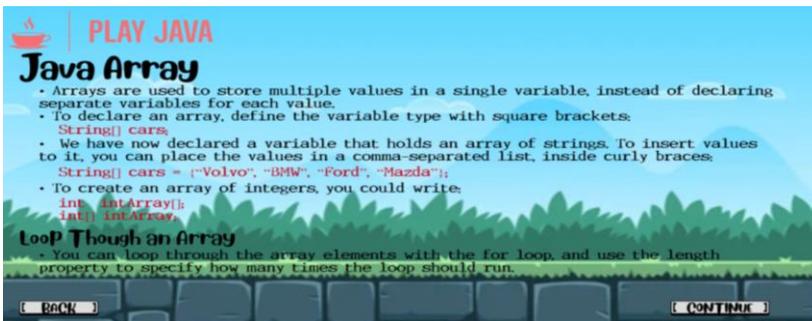


**Selecting fifth topic.** This screen presents the lesson on Java Arrays, including explanations and examples that demonstrate how arrays are used to store, access, and manipulate multiple values within a Java program.

**Java array.** This screen displays the lesson on Java Arrays, providing explanations and examples that illustrate how arrays are used to store and manipulate multiple data elements in a Java program.

**Figure 7**

*Fifth topic*



**Main screen of the game.** This screen displays the Start button, which directs the user to the game section of the system, initiating the interactive learning activities.

**Figure 8**

*Game screen*



*Pairing cards mini game.* This screen presents the Java programming exercises, featuring a pairing card activity where users match answers to complete fill-in-the-blank questions, reinforcing their understanding of the lesson concepts.

**Figure 9**

*The mini game*



*Wrong answer.* This screen appears when a user provides an incorrect answer, offering feedback to indicate the error and guide the user toward the correct response.

**Figure 10**

*Wrong answer screen*



**Correct answer.** This screen appears when a user provides a correct answer, confirming the response and reinforcing the learning outcome.

**Figure 11**

*Correct answer screen*



**Input player's name.** This screen prompts the player to enter their name after completing all twenty-five questions, allowing the system to record and display their results on the leaderboard.

**Figure 12**

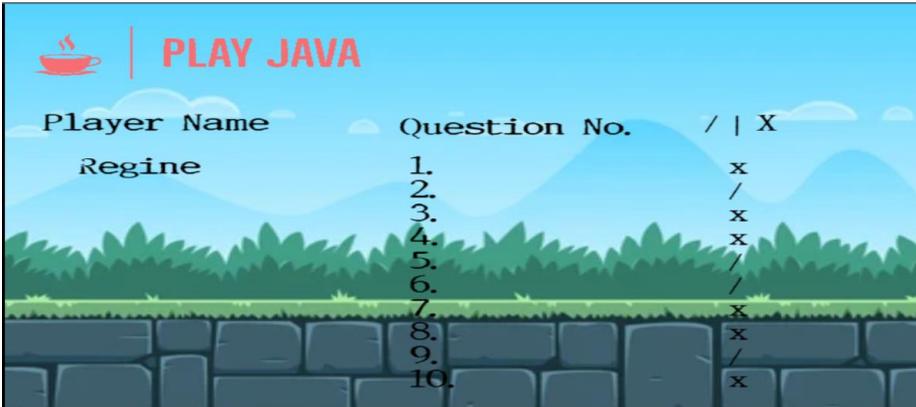
*Screen to input player name*



**Dashboard.** This screen displays a summary of the user's responses, showing both correct and incorrect answers to provide feedback on their performance.

**Figure 13**

*Summary of answers screen*



**Figure 14**

*Activity diagram for PlayJava  
(Mini Game)*

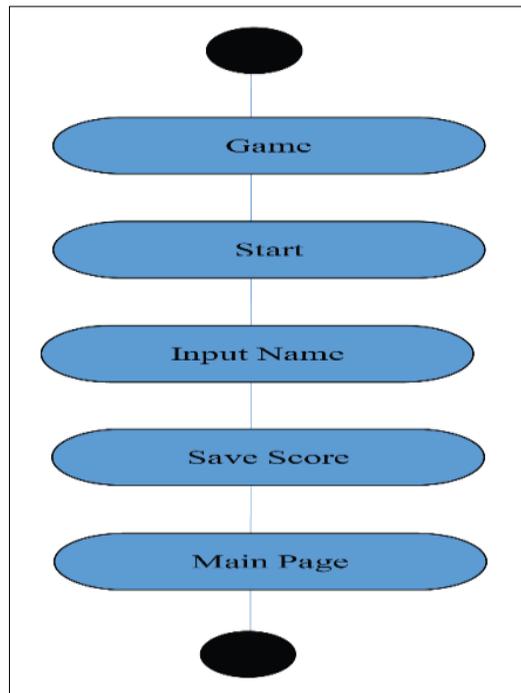


Figure 14 illustrates the process flow of the developed system. Users begin by entering the game and answering all randomized questions based on the selected topics. Upon completing the exercises, users input their name, after which the system provides a summary of correct and incorrect answers.

**Figure 15**

*Activity diagram for PlayJava (Java Introduction)*

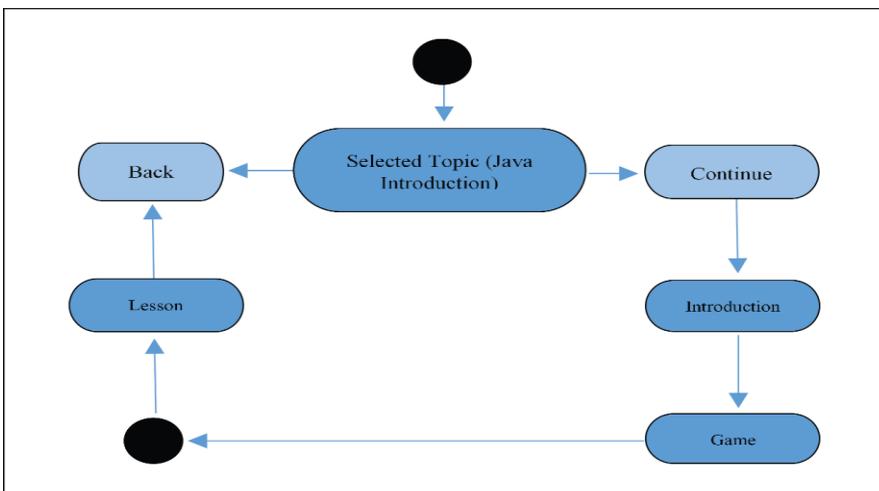
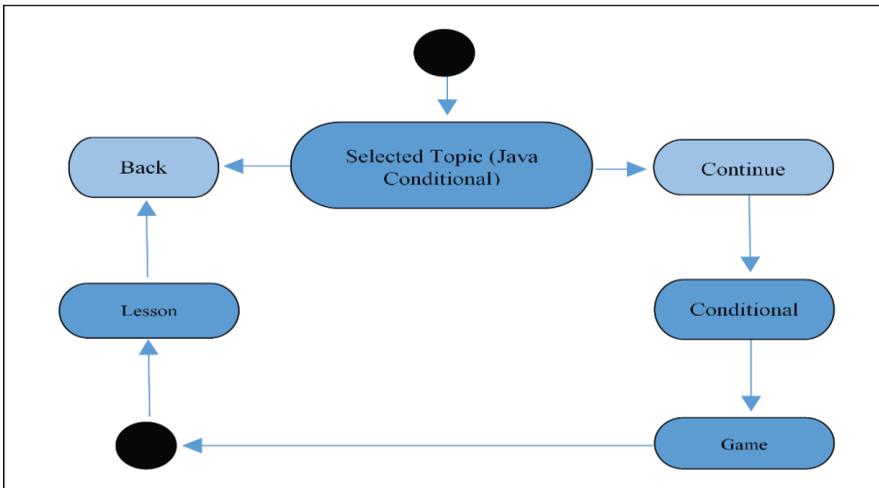


Figure 15 illustrates the process that occurs when the user clicks the “Java Introduction” button on the main page. The system immediately displays the corresponding lessons and examples, allowing the user to explore the foundational concepts of Java programming.

Figure 16 illustrates the process that occurs when the user clicks the “Java Conditional” button on the main page. The system immediately displays the corresponding lessons and examples, allowing the user to learn about conditional statements in Java.

**Figure 16**

*Activity diagram for PlayJava (Java Conditionals)*



**Figure 17**

*Activity diagram for PlayJava (Java Operators)*

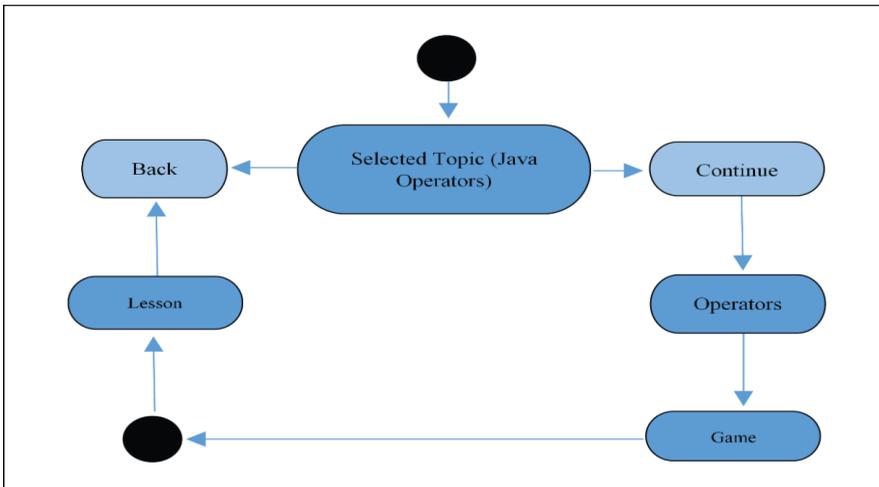


Figure 17 illustrates the process that occurs when the user clicks the “Java Operators” button on the main page. The system immediately displays the corresponding lessons and examples, enabling the user to learn how operators are used in Java programming.

**Figure 18**

*Activity diagram for PlayJava (Java Looping)*

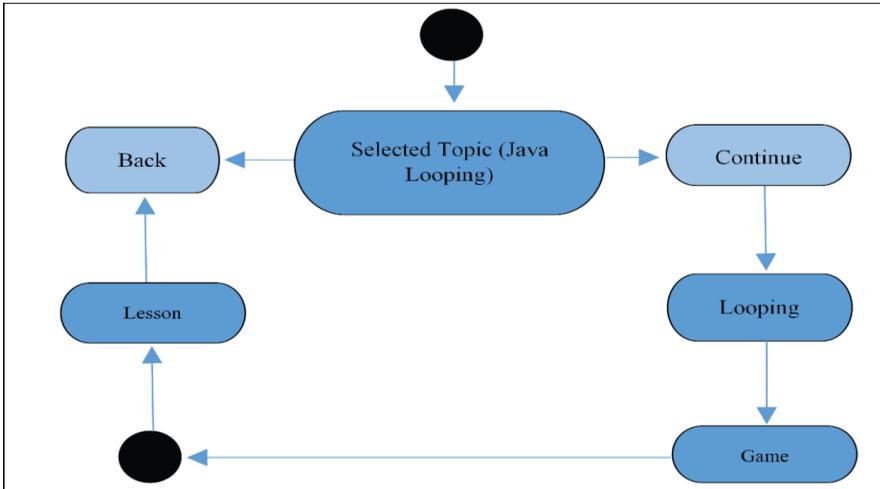


Figure 18 illustrates the process that occurs when the user clicks the “Java Looping” button on the main page. The system immediately displays the corresponding lessons and examples, allowing the user to understand and practice loop structures in Java programming.

**Figure 19**

*Activity diagram for PlayJava (Java Array)*

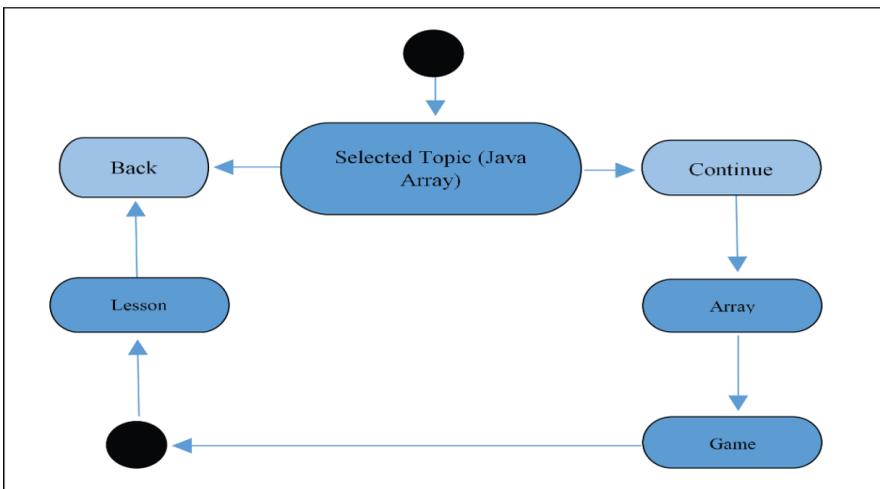


Figure 19 illustrates the process that occurs when the user clicks the “Java Array” button on the main page. The system immediately displays the corresponding lessons and examples, enabling the user to learn how arrays are used to store and manipulate data in Java programs.

**Figure 20**

*USE case diagram of the proposed system*

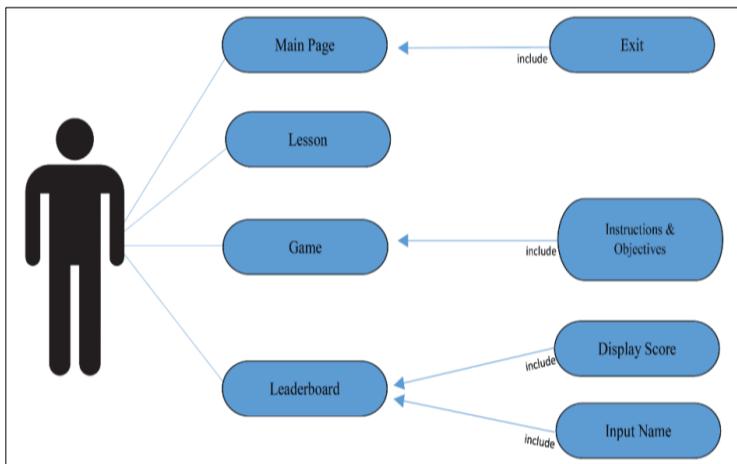


Figure 20 illustrates the process for using the system from the player’s perspective. Each stage of system access is represented, beginning with the player clicking the Start button to launch the game. Players must complete each assignment sequentially before progressing to the next level, and they cannot choose which mini-game to play.

### ***Development and Maintenance***

The development and maintenance of an Android game involve several stages. During development, game designers collaborate to create the game concept, including mechanics, graphics, sound, and other features. The development team then uses GDevelop, a no-code 2D game engine, to

implement the necessary code and functionalities. Following development, the game undergoes testing to identify and resolve any bugs or glitches. Once tested, the game is deployed on Android devices.

During the maintenance phase, developers monitor game performance, collect player feedback, and address any issues that arise. Maintenance may also include introducing new features, updating the game to remain compatible with new operating system versions, and resolving hardware or software compatibility issues. Effective development and maintenance ensure that the game remains functional, engaging, and relevant to its users.

### **Testing**

The study adopts a proactive test approach, initiating the test design process as early as possible to detect and correct bugs before the system build is completed.

**Table 3**

*Integration testing*

<b>Item No.</b>	<b>Test Case Objectives</b>	<b>Expected Result</b>	<b>Passed</b>	<b>Failed</b>	<b>Change Control #</b>
1	Test the functionality of the game main menu	The game can be launched	/		1
2	Test the movement of the flipping cards	Flipping cards are accurate based on the command	/		2
3	Test the leaderboard	Player's name and summarization of the answer will stored in the leaderboard	/		3
4	Test the accuracy of lesson	The accuracy of the lesson is correct based on the given topics.	/		4
5	Test the sounds and design	The game sound and design is accurate	/		5
<b>Test Completed by:</b> Ann Valare P. Alcantara, JV R. Galasan, Regine J. Remojo & Jovi Rose P. Camacho			<b>Date Completed:</b> June 11, 2023		
<b>Test Case Outcome</b>			<b>Accepted</b>		

The application name corresponds to the system name, while the test case version represents the series of tests conducted. Each test identifies a specific procedure, with the objective and expected result defined according to the system process. Any issues identified during testing are recorded with a corresponding change control number. The integration test focuses primarily on the interfaces and the flow of data between modules, ensuring seamless interaction. The test form is used to document all required data systematically.

### ***System Evaluation***

This section presents the results of the survey with a total of 86 respondents. The sample size was determined using the Raosoft formula, and respondents were selected through a random sampling method. The questionnaire was designed based on ISO 25010 quality characteristics, including usability, reliability, performance efficiency, and compatibility. Data collected from the survey were analyzed using the weighted mean formula. A four-point Likert scale was employed, with the response options: strongly agree, agree, disagree, and strongly disagree. Each scale corresponds to a defined mean range, which was used to interpret and evaluate the respondents' feedback.

**Table 4**

*Weighted mean distribution of criteria for developed system*

<b>Criteria</b>	<b>Weighted Mean</b>	<b>Remarks</b>
Usability	3.49	Strongly Agree
Reliability	3.52	Strongly Agree
Performance Efficiency	3.32	Strongly Agree
Compatibility	3.52	Strongly Agree
<b>Average</b>	<b>3.42</b>	<b>Strongly Agree</b>

The overall average weighted mean of the survey is 3.42, indicating that respondents rated the system as outstanding in terms of reliability, compatibility, usability, and performance efficiency. This suggests that the system is capable of performing its intended functions effectively. Positive feedback from respondents highlighted that the system design is visually comfortable and the interface is intuitive, allowing users to understand and navigate the system easily.

Specifically, the reliability of the system received an average weighted mean of 3.52, demonstrating that the system performs its intended functions consistently without glitches or errors. For performance efficiency, the average weighted mean is 3.32, indicating that the system operates efficiently during use. The compatibility dimension also scored 3.52, showing that the system runs correctly across different devices and models. Finally, the summary of the weighted mean results confirms that the system meets the quality standards outlined in ISO 25010 for usability, reliability, performance efficiency, and compatibility.

***Economic feasibility.*** An economic feasibility assessment was conducted through a cost-benefit analysis to determine whether the projected benefits of the Android-based application outweigh its development costs. This analysis considered the system's advantages and disadvantages and evaluated its applicability. Feedback on the system's functionality and economic feasibility was gathered through the ISO 25010 questionnaire-based survey, providing insight into its value relative to cost.

***Technological feasibility.*** The system was found to be technologically feasible. Respondents noted that it is helpful for learning the basic syntax of Java, user-friendly, and compatible with various Android phone brands and models.

***Operational feasibility.*** The system is operationally feasible, as it is easy to understand and operate. Survey responses indicated that users could quickly grasp its functionality after a brief demonstration, confirming that it meets operational expectations.

## **Conclusion**

PlayJava, an Android-based tutorial game for learning basic java programming, allows Android users to engage with Java lessons while practicing code analysis in a gamified format. Users must complete each lesson before accessing the mini-game, enabling them to learn programming fundamentals while enjoying the experience. The testing and evaluation of PlayJava demonstrated that it meets ISO 25010 standards for performance efficiency, reliability, usability, and compatibility. These results confirm that the system is a viable alternative for learning basic Java programming through mobile-based, gamified instruction.

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## Chapter 2

### *Web-Based Research and Development for Information Technology*

Welcome to the ever-evolving world of web-based research and development, the digital frontier where creativity meets innovation. This chapter serves as your gateway to understanding how ideas become fully functional web applications that shape the modern landscape of business, communication, and society. This is where your journey begins: learning to explore, design, and develop systems that make life simpler, faster, and more connected.

The world today thrives on the web. From managing global enterprises to organizing everyday activities, web applications have become essential tools that connect people and information seamlessly. They offer unmatched accessibility, instant data processing, and the flexibility to grow with user needs, qualities that make them indispensable in today's digital economy.

For an IT student, the ability to conceptualize and create web systems isn't just a technical skill — it's a *core competency*. Understanding how these systems work, from idea to implementation, empowers you to become not just a developer, but an innovator capable of transforming challenges into digital solutions.

Every successful web-based system starts long before coding begins — it starts with research. Research is what turns vague ideas into practical, impactful solutions. It helps you to identify real-world problems that can be addressed through web technology, analyze users' needs and assess existing solutions to find gaps or opportunities and select the right tools, from programming languages and frameworks to databases and algorithms, that best fit your project's goals.

In this chapter, you'll be introduced to the wide spectrum of web-based systems, each with its own purpose, structure, and innovation potential. As you explore these examples, you'll gain insight into the complete Software Development Life Cycle (SDLC) — from identifying a problem and conducting research, to designing, coding, testing, and maintaining your finished system.

# Book2Shine: Web Portal Car Wash Booking System

*Renz B. Dabas, Kenneth P. Saquin, John Lester  
Sabinosa & Gerals Quirante*

A car wash station is a facility that provides cleaning services for various types of vehicles. This can be done manually or with equipment such as foam sprayers, pressure washers, and air dryers. Car wash stations are often located near highways and may also offer additional services such as car tinting, repair, and fueling. Some stations feature self-service options like the “*hulog 5*” system, while others provide full-service packages including washing, drying, and interior cleaning. In most cases, machines are used to simplify the washing process, ensuring thorough cleaning in areas staff may not easily reach.

Today’s technological advancements have encouraged many business owners to adopt innovative systems (Faiz et al., 2024; Mishrif & Khan, 2023). Booking systems, once common only in hotels, resorts, restaurants, parking spaces, and similar establishments, are now increasingly used in service-oriented industries (Zahidi et al., 2024; Deputat et al., 2024). A booking system helps attract new customers, improve service efficiency, and enhance online visibility (Satghare, 2023).

This study aims to create a web portal booking system that benefits both car wash stations and vehicle owners. This system is designed to provide convenience by allowing car wash owners and customers to manage appointments through a single platform. Customers can select a preferred car wash station and book a service directly via the portal. A mobile-friendly version of the system further enhances accessibility, enabling users to book and manage their appointments anytime, anywhere. For business owners, it simplifies recordkeeping, payment management, and customer organization, while also expanding market reach through online engagement.

A web portal booking system acts as a “middleman” between car wash stations and customers, providing a centralized and efficient scheduling tool. This type of system has become increasingly popular due to its convenience for both service providers and clients. According to Aziz (2023), the purpose of implementing such applications is to allow customers to book car wash services through mobile devices. The car wash industry is rapidly expanding, and many customers prefer mobile-based service requests. To enhance reliability, booking systems often provide customized panels for customers, enabling access to a full range of services with a single click. Key features include 24/7 appointment scheduling, service customization, online payment, and user-friendly navigation. These systems save time, reduce manual labor, and provide secure storage of customer information. Customers value the convenience of booking services anytime and anywhere, which reflects the growing demand for digital solutions in the automotive industry (Veena et al., 2024; Mattola et al., 2025).

The study by Aziz (2023) shares similarities with the current research, as both focus on booking systems for car wash services. Both systems allow customers to schedule appointments anytime and from

different locations. However, Aziz's system is mobile app-based, whereas the present study focuses on developing a web-based booking portal.

## **Theoretical Framework**

According to Hu and Gu (2013), the rise of the Internet has significantly transformed hotel operations, particularly in how reservations are made. Modern customers demand booking systems that are diversified, convenient, and tailored to individual needs. However, many hotels still face inefficiencies in managing reservations due to outdated or manual processes. Hu and Gu (2013) argue that designing an online hotel booking system based on the B/S (browser/server) model can address these challenges by providing functionalities such as registration, login, reservation management, and customer management. Implementing such a system improves the efficiency of hotel reservations, enabling real-time processing of bookings and reducing errors associated with manual management.

Similarly, Saito et al. (2019) highlight that the increasing reliance on online booking websites introduces additional challenges, such as last-minute cancellations and the need for overbooking strategies. Their study demonstrates that integrating big data from online booking platforms into hotel revenue management allows hotels to optimize room charges and overbooking levels. By combining a discrete choice model of customer behavior with a quantitative overbooking model, hotels can maximize expected sales while mitigating the risks of over- or under-booking. The findings suggest that leveraging online booking data not only improves operational efficiency but also supports strategic decision-making in hotel management.

Together, these studies emphasize the critical role of online booking systems in modern hotel operations. Both operational efficiency and revenue optimization can be significantly enhanced by adopting technologically advanced systems that automate reservations, manage customer interactions, and utilize data-driven decision-making for pricing and overbooking strategies.

In the study of Vrontis et al. (2022), hotels were found to face challenges in managing online bookings despite the availability of electronic services, which enhance information transparency, interactivity, and market comparisons. The research, conducted with guests of five-star hotels in Beirut, Lebanon, identified key factors influencing customers' intentions to book online, including perceived trust, perceived ease of use, and perceived risk. These findings indicate that even in digital booking environments, customers still require support during the reservation process. Based on this evidence, Vrontis et al. (2022) emphasized that hotels must adopt online booking systems that not only provide convenience but also foster trust and reduce perceived risks, thereby enhancing customer confidence and satisfaction.

Similarly, Jackson et al. (2021) demonstrated the practical benefits of implementing an online-based hotel information system at the University of Benin Guest House, Nigeria. Their system automated data entry, facilitated efficient communication, and enabled rapid retrieval of guest records. By employing PHP and MySQL and modeling the system with Unified Modeling Language (UML), the researchers showed how technology can streamline hotel operations, reduce errors, and improve service delivery. The implementation of such a system allowed for faster processing of reservations and more accurate tracking of guest information,

which ultimately supports both managerial decision-making and operational efficiency.

Together, these studies highlight the importance of adopting online booking and information systems in the hospitality sector. By integrating user-friendly, secure, and efficient technologies, hotels can enhance customer satisfaction, optimize operational processes, and strengthen their competitive advantage in increasingly digital markets.

Similarly, Thosar et al. (2022) proposed a smart parking booking system designed to address the common issue of locating parking spaces in public areas, which often consumes significant customer time. Their system provides vehicle owners with an easy way to reserve parking slots online via a web portal. Through this application, users can view available parking spaces in real time and reserve a slot for a specific time period. Once booked, the slot is automatically marked as unavailable to others during that time. The system also incorporates convenient features such as cancellation options, allowing users to cancel reservations anytime, and a record-keeping function, enabling customers to view their previous parking details. By simplifying the process of finding and reserving parking spaces, the system enhances user convenience and reduces unnecessary delays in urban mobility.

## **Research Framework**

### ***Experimental Design***

The study employed an experimental design to examine the relationship between the independent and dependent variables. The independent variable is the price of the car wash services offered, while the dependent variable is the number of bookings made through the system. The

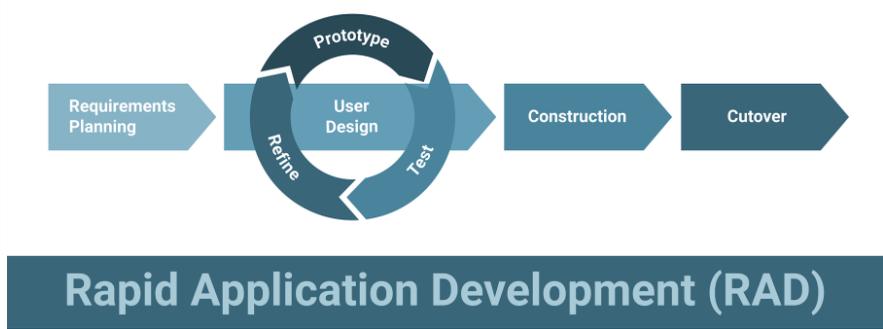
independent variable, service price, can be manipulated or adjusted during the experiment. Meanwhile, the dependent variable, the number of bookings, is measured to determine how it is influenced by changes in service pricing. This design allows the researchers to analyze the effect of pricing strategies on customer booking behavior in the web-portal system.

### ***Procedures of Different Phases***

The study adopted the Rapid Application Development (RAD) methodology, which was deemed the most appropriate for the study due to its flexibility and efficiency. RAD offers several advantages aligned with the system’s objectives, such as accommodating changing requirements, enabling progress tracking, reducing iterative process time, and increasing productivity with fewer resources. Additionally, RAD minimizes development costs, enhances component reusability, and allows for faster prototyping and early feedback. These benefits make it highly suitable for developing the carwash booking system, ensuring timely completion while maintaining quality and adaptability.

**Figure 1**

*Rapid Application Development*



*Requirements planning.* In this phase, the researchers observed and collected data to identify existing problems and establish objectives for specific solutions. By analyzing the current system's flaws and limitations, they were able to determine what actions were necessary to overcome them. This included identifying appropriate materials, specifying their requirements, and defining system needs. Ultimately, the researchers outlined the problem, gathered relevant data, set clear objectives, analyzed software specifications, and developed a strategy to guide the User Design phase.

*User design.* During the User Design phase, users and researchers collaborated to create models representing all system inputs, processes, and outputs. This phase involved a series of interactive sessions where users could review, modify, and approve a working model of the system to ensure it met the specified requirements. The primary focus was on completing the logical design of the proposed system. Key considerations included the operating system, programming requirements, and security measures. Additionally, this phase incorporated the design of the user interface, enabling effective interaction and control of the system.

*Construction.* The Construction phase focused on completing the system's design, developing the software, and conducting rigorous testing. This ensured that the proposed system was functional, reliable, and aligned with user requirements. Importantly, clients were still encouraged to suggest modifications or request additional features during this stage to further enhance the system. Activities in this phase included software development, testing, and preparing the system for deployment.

*Cutover.* The Cutover phase served as the final stage of RAD. It involved training users to operate the system effectively and providing the necessary documentation for reference and support. This stage ensured a

smooth transition from development to actual use, equipping end-users with the knowledge and resources needed for successful system implementation.

## **Technical Framework**

### ***Software***

The development of the system required several software tools and technologies, each serving a specific function:

*Visual Studio Code (VS Code)* – This integrated development environment (IDE) was used by the researchers to encode and manage the source code of the system. Its versatility and user-friendly features make it ideal for web-based development projects.

*PHP* – Selected as the primary programming language, PHP is highly effective in creating dynamic and interactive web-based systems, making it well-suited for the proposed carwash booking system.

*Laravel Framework* – An open-source PHP framework used for server-side coding. Laravel provides robust features such as routing, authentication, and scalability, enabling the researchers to build a secure and maintainable system.

*XAMPP 8.0.3* – This local server environment allowed the researchers to develop and test the system offline. It provided a complete package of Apache, PHP, and MySQL, eliminating the need for constant internet access during development.

*MySQL* – A relational database management system (RDBMS) that stores and manages the system's data. MySQL was chosen due to its compatibility with PHP and Laravel, as well as its efficiency in handling structured queries for the booking system.

## ***Hardware***

The implementation of the system required the use of personal computers or laptops. For the purpose of this study, the researchers provided two laptops to support the development and testing of the web-based booking system. The laptops served as both the development environment and the platform for initial implementation and evaluation.

**Table 1**

### *Hardware*

<b>x64-based processor</b>	<b>x64-based processor</b>
RAM : 4.00 GB	CPU N3710
HDD 1TB	RAM (4.00 GB)

## ***Requirement Analysis***

The system requirements were gathered by analyzing the needs of both carwash owners and customers. The primary goal was to design a platform where customers could conveniently book services and locate the nearest available carwash in their area.

To ensure the system meets these needs, the researchers created a sample prototype to demonstrate its functionality. This allowed users to gain familiarity with the system and provided them with a practical background before full implementation.

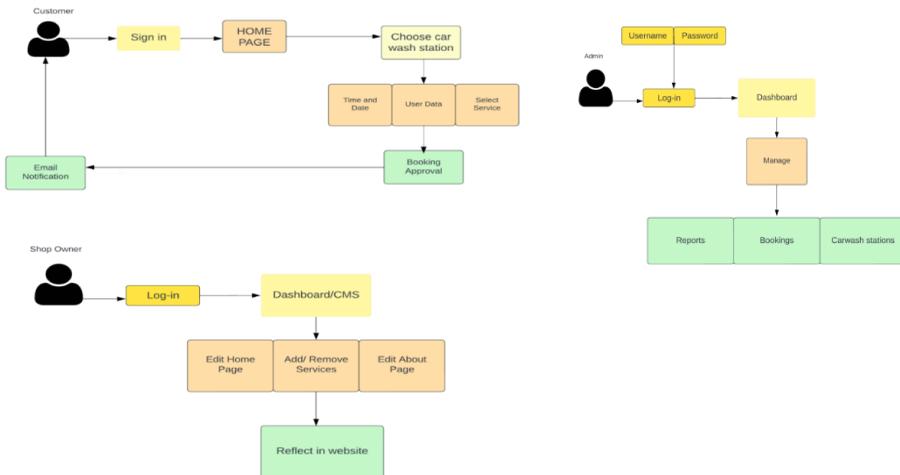
For development, the researchers utilized the following software tools: Visual Studio Code (VS Code) for source code encoding, PHP as the primary programming language, the Laravel framework for server-side development, XAMPP as the local server environment, and MySQL as the database management system.

## Modelling

The Figure 2 displays the procedure for booking a customer through the web-portal carwash booking system.

**Figure 2**

*Use case of the system for customer, shop owner, and admin*



The Figure 2 illustrates the roles of different system users and the level of access they are granted. Customers can access the website after creating an account, which allows them to choose a preferred carwash station and proceed with booking their vehicle. Shop owners or carwash operators can access their own dashboard and Content Management System (CMS) to design their website, customize services, and manage customer bookings. Meanwhile, the administrator (admin) is granted full control over the system, with access to manage reports, bookings, and carwash stations.

## Database Schema

Figure 3 presents the database schema diagram for the web-portal carwash booking system. It illustrates the UML diagram and the relationships among different entities in the proposed system for carwash

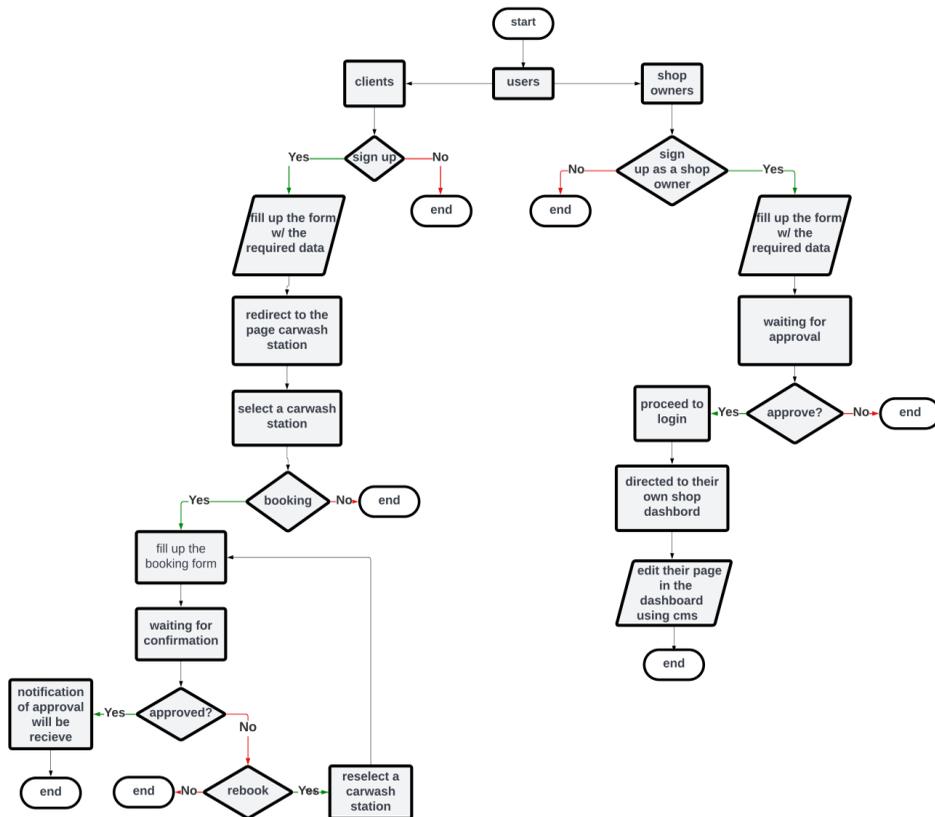


tables relates to one another. It also displays the main structure of the system.

### Flow Chart

Figure 4

Data flow diagram of Book2Shine web portal carwash booking system



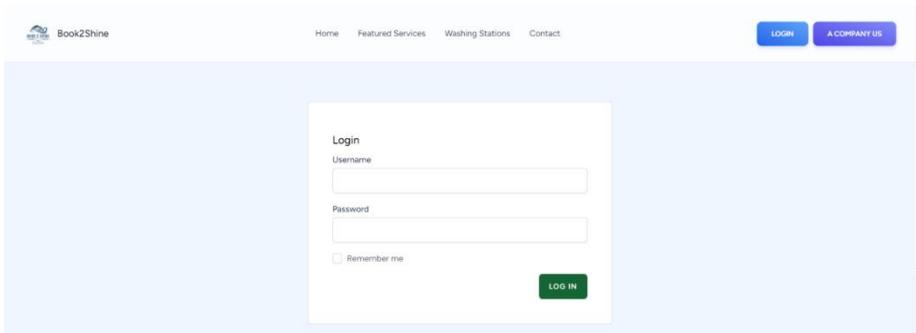
The flowchart diagram illustrates the overall process of how customers interact with the web portal and carwash stations, including the step-by-step booking process.

## System Design

*Log-in page for customers/admin.* This is the initial page displayed to both customers and administrators. To access the system, users must provide their username and password. The username serves as a unique identifier for each user, while the password ensures account security and protects user information.

**Figure 5**

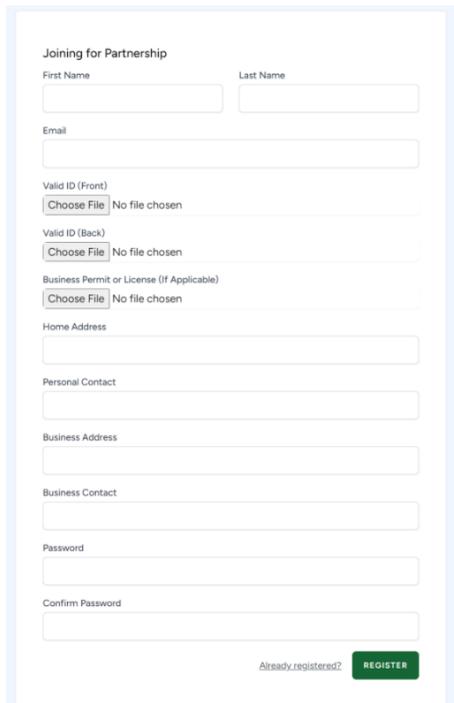
*Login page for customers*



The screenshot shows a web application interface. At the top left is the 'Book2Shine' logo. The navigation menu includes 'Home', 'Featured Services', 'Washing Stations', and 'Contact'. On the right side of the navigation bar are two buttons: 'LOGIN' and 'A COMPANY US'. The central focus is a 'Login' form with the following elements: a 'Username' input field, a 'Password' input field, a 'Remember me' checkbox, and a green 'LOG IN' button.

**Figure 6**

*Register form for carwash owner*



The screenshot displays a registration form titled 'Joining for Partnership'. The form contains the following fields: 'First Name' and 'Last Name' (text inputs), 'Email' (text input), 'Valid ID (Front)' and 'Valid ID (Back)' (file upload fields with 'Choose File' buttons and 'No file chosen' text), 'Business Permit or License (If Applicable)' (file upload field with 'Choose File' button and 'No file chosen' text), 'Home Address' (text input), 'Personal Contact' (text input), 'Business Address' (text input), 'Business Contact' (text input), 'Password' (text input), and 'Confirm Password' (text input). At the bottom right, there is a green 'REGISTER' button and a link for 'Already registered?'.

*Home page of client.* The home page serves as the front-end interface of the proposed system, providing users with easy navigation and access to key features. It includes the following menu options:

Home/About Us – Provides an overview of the system and information about the carwash services.

Featured Services – Highlights the main services offered by participating carwash stations.

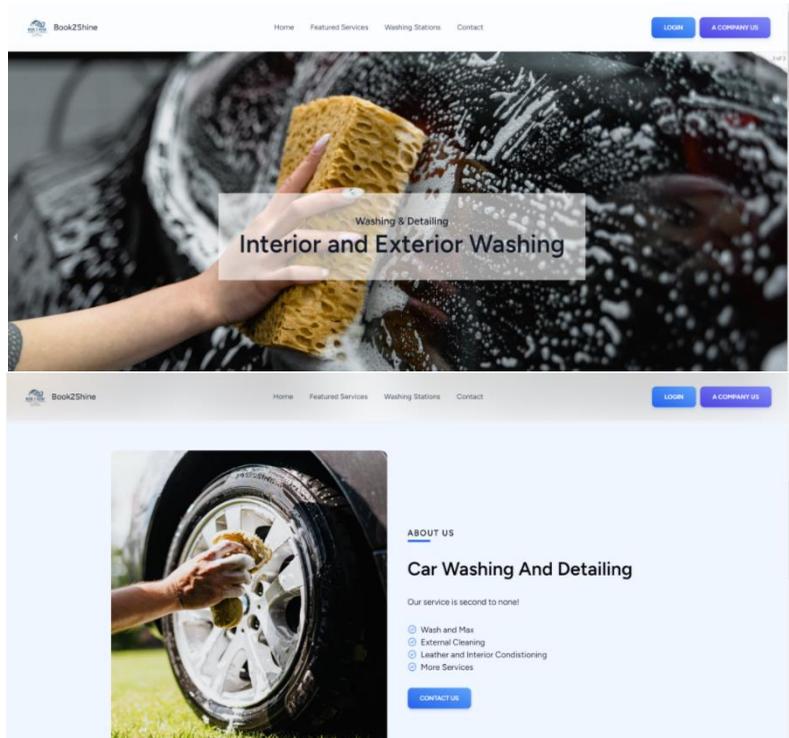
Washing Station – Allows customers to browse and select available carwash stations.

Contact – Displays contact information and channels for customer support or inquiries.

This page is designed to be user-friendly, ensuring that clients can quickly access essential functions of the booking system.

**Figure 7**

*Home page*



Visit the Book2Shine web portal, then go to car wash stations to choose the preferred stations to book an appointment.

**Figure 8**

*Making an appointment*

**Booking application in station Mr. Clean Carwash**

Select Services:

- Body Wash-₱400.00
- Back to Zero-₱500.00

Preferred Date:

Available Slots: **20 spots**

**June 2023**

Su	Mo	Tu	We	Th	Fr	Sa
28	29	30	31	1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	<b>21</b>	22	23	24
25	26	27	28	29	30	1

Total Services: 1  
Total Amount: ₱500.00

[CANCEL](#) [CONFIRM](#)

Figure 8 illustrates the appointment-making process, showing how the system allows customers to select their preferred date and time for a carwash service.

**Figure 9**

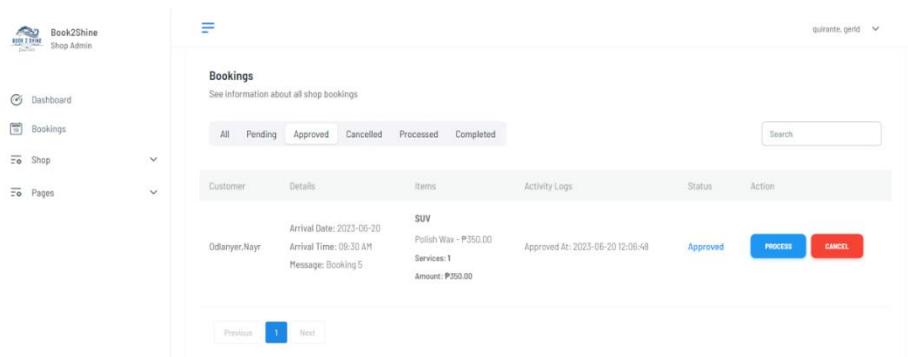
*Shop owner dashboard pending bookings*

Customer	Details	Items	Activity Log	Status	Action
Odyssey.Neyr	Arrival Date: 2023-06-20 Arrival Time: 08:00 AM Message: Booking 2	Grandia Body Wash - ₱400.00 Back to Zero - ₱500.00 Service: 2 Amount: ₱900.00		Pending	<a href="#">APPROVE</a> <a href="#">CANCEL</a>
Odyssey.Neyr	Arrival Date: 2023-06-20 Arrival Time: 08:30 AM Message: Booking 1	Grandia Back to Zero - ₱500.00 Body Wash - ₱400.00 Service: 2 Amount: ₱900.00		Pending	<a href="#">APPROVE</a> <a href="#">CANCEL</a>
Odyssey.Neyr	Arrival Date: 2023-06-20 Arrival Time: 07:30 AM Message: Booking 2	Grandia Back to Zero - ₱500.00 Service: 1 Amount: ₱500.00		Pending	<a href="#">APPROVE</a> <a href="#">CANCEL</a>

Figure 9 shows the shop owner dashboard, where the shop owner can approve pending bookings. Meanwhile, Figure 10 displays the approved bookings. Once the shop owner approves an appointment, the system sends an email notification to the customer containing their booking details.

**Figure 10**

*Approved Bookings*



**Figure 11**

*Completed bookings*

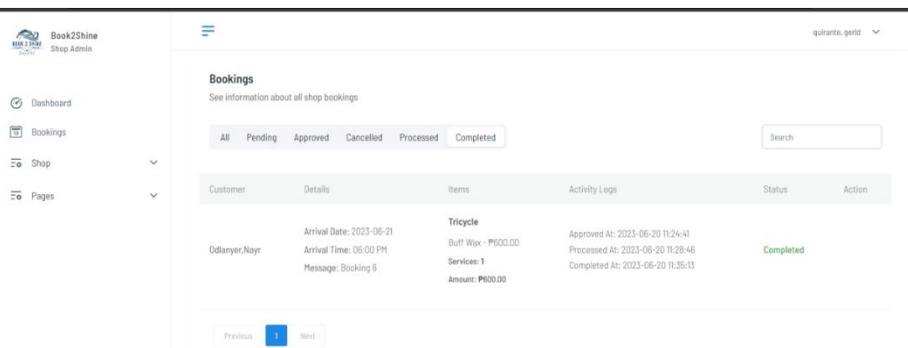
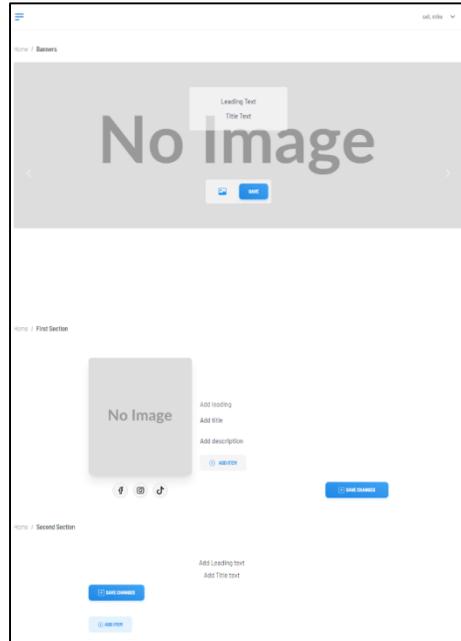


Figure 11 shows the complete bookings accessible to the shop owner.

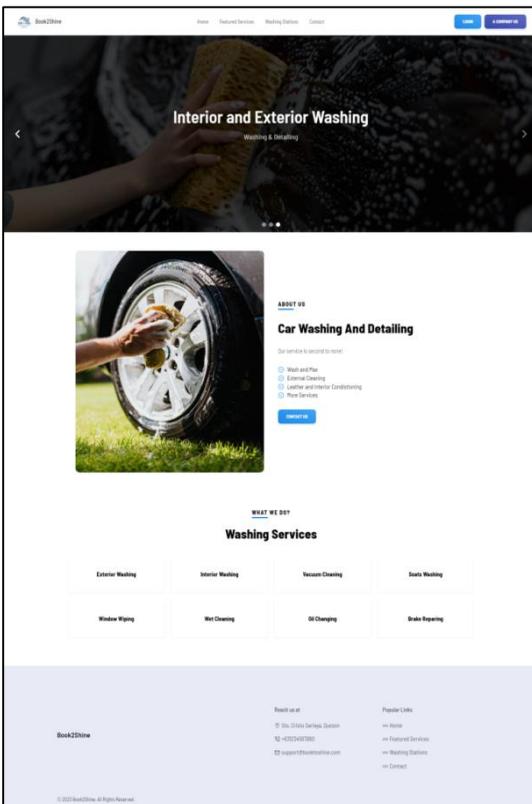
**Figure 12**

*Illustration Content Management System*



**Figure 13**

*The developed system*



## ***Development***

Creating an online platform that enables customers to conveniently book carwash services at their preferred time is the primary objective of developing a web-portal carwash booking system. This system offers several advantages over traditional appointment methods, such as phone calls or in-person visits, by saving time, reducing manual errors, and providing a more efficient service experience.

The design process typically begins with the development of a user-friendly interface that allows customers to easily navigate through the portal. The interface should clearly present information about the carwash station’s available services, pricing options, and additional offerings.

Customers can book an appointment by selecting their preferred date and time through the integrated booking system. To enhance usability, the system must display real-time availability, ensuring that customers can choose from up-to-date options without scheduling conflicts. This functionality improves customer satisfaction while also streamlining operations for carwash owners.

## ***Testing***

**Table 2**  
*Test case*

<b>Test Case</b>	<b>Precondition</b>	<b>Test Steps</b>	<b>Test Data</b>	<b>Expected Result</b>
Verify log-in with credentials	Admin should have an internet connection	1. Launch the URL 2. Enter valid username 3. Enter valid password 4. Click log-in	Username: <a href="mailto:renz@gmail.com">renz@gmail.com</a> Password: password	Admin is successfully log-in
Verify log-in with credentials	Admin should have an internet connection	1. Launch the URL 2. Enter invalid username 3. Enter valid password 4. Click log-in	Username: <a href="mailto:renz@gmail.com">renz@gmail.com</a> Password: password	Admin failed to log-in “invalid username”

### ***Deployment and Maintenance***

The study adopted a comprehensive testing approach, including functional testing, to validate the usability, reliability, and responsiveness of the web portal across different browsers and devices.

*Deployment:* Before going online, the researchers conducted manual testing of the booking system to immediately identify and correct any system errors, ensuring that all features work as intended. Once verified, the system was hosted online, allowing registered carwash owners to explore and understand its functionalities. Future customers will also be able to access the system through the web portal.

*Maintenance:* Maintaining a robust and efficient web portal requires ongoing effort. Administrators will have to generate regular reports to monitor system usage, track customer engagement, and identify potential issues. Updates will have to be performed periodically to improve functionality, add new features, and enhance user experience for both customers and carwash owners. The system will provide customers with booking confirmations and all relevant service information, while also communicating the availability of services and facilities clearly to users.

### ***Review and Evaluation***

The modernization of online booking software has simplified the appointment process for customers. The system allows users to specify their booking requirements, including location, preferred time, vehicle type, and access to star ratings and reviews. This flexibility enhances the customer experience and ensures the booking process aligns with company policies and procedures.

With rapid technological advancement, many booking systems are emerging to serve different business sectors. Implementing an online

booking system provides carwash stations with a competitive advantage, particularly those with larger operations, as it enables them to advertise online and reach a wider audience. Traditional booking methods often result in errors and inefficiencies, which this system aims to minimize.

The researchers designed and implemented the web-portal carwash booking system to help carwash owners adopt the latest technology and efficiently serve customers requiring quick service. The system also functions as a platform for carwash owners to advertise their services, attract new clients, and increase revenue. Customers benefit from a free, convenient, and accessible booking experience, enabling them to schedule appointments via mobile devices at any time, without the hassle of phone calls or in-person visits.

The Book2Shine, web portal car wash booking system, was developed using PHP and the Laravel Framework. The system serves as a platform for online advertising and includes a Content Management System (CMS) that allows shop owners to upload, edit, and manage their own websites.

Based on surveys conducted with respondents and IT experts, the system complies with ISO 2510 standards, demonstrating its adherence to established quality and usability benchmarks. Some respondents commented that the system has a clear and modern design, and that it is easy to access and navigate. These positive comments provided the researchers with a sense of satisfaction and reassurance that the system met user expectations.

Testing and validation results were also analyzed, providing insight into the system's performance and functionality. In addition to interpreting these results in relation to the study's objectives, the research focused on maintaining key system features, including the content management system,

shop owner websites, and the main website. These components ensure the system remains functional, user-friendly, and effective in supporting both carwash owners and customers.

### ***System Evaluation***

This section presents the results of the survey conducted involving a total of 45 respondents. The researchers used Raosoft to determine the appropriate sample size and employed a random sampling method to distribute the questionnaires. The questionnaire was designed based on ISO 2510 standards and evaluated the system across several key aspects, including functionality, maintainability, security, compatibility, reliability, performance efficiency, portability, and usability. These criteria provided a comprehensive assessment of the system’s quality and performance from the perspective of end-users. The study employed a Four-Point Likert Scale to gather respondents’ feedback, with the following categories: strongly agree, agree, disagree, and strongly disagree. Respondents selected one option for each questionnaire item based on their level of agreement.

**Table 3**

*Summary of system evaluation*

<b>Criteria</b>	<b>Weighted Mean</b>	<b>Interpretation</b>
Functionality	3.56	Strongly Agree
Usability	3.60	Strongly Agree
Security	3.55	Strongly Agree
Maintainability	3.46	Strongly Agree
Portability	3.62	Strongly Agree
Reliability	3.66	Strongly Agree
Compatibility	3.44	Strongly Agree
Performance Efficiency	3.53	Strongly Agree
<b>Average</b>	<b>3.56</b>	<b>Strongly Agree</b>

Table 3 presents the weighted mean results for each criterion based on ISO 2510, collected from 45 respondents. The overall system evaluation yielded an average weighted mean of 3.56, indicating that respondents rated the system as outstanding across the evaluated aspects: functional suitability, usability, security, maintainability, portability, reliability, compatibility, and performance efficiency. This suggests that the system is capable of performing its intended functions effectively.

*Functional suitability:* The system demonstrates strong functionality and is considered suitable for its purpose. Respondents agreed that the developed system could serve as a future business tool for carwash owners in Sariaya, with an average weighted mean of 3.56 and a remark of Strongly Agree.

*Usability:* The system is easy to operate, even for respondents with limited technical knowledge. Users reported that the interface is user-friendly and intuitive, with an average weighted mean of 3.60 and a remark of Strongly Agree.

*Security:* Respondents agreed that their data are secure within the system. The security features were rated highly, with an average weighted mean of 3.55 and a remark of Strongly Agree.

*Maintainability:* The system can be effectively maintained in the future, with respondents confirming its ease of updates and modifications. The average weighted mean for maintainability is 3.46, with a remark of Strongly Agree.

*Portability:* The system is accessible across different devices, including desktops and mobile phones. Respondents agreed on its

versatility, with an average weighted mean of 3.62 and a remark of Strongly Agree.

*Reliability:* The system provides accurate and consistent information, demonstrating high reliability. Respondents agreed on its dependability, with an average weighted mean of 3.66 and a remark of Strongly Agree.

*Compatibility:* The system performs well on various devices and platforms, with respondents confirming its responsiveness on both mobile phones and desktops. The average weighted mean is 3.44, with a remark of Strongly Agree.

*Performance efficiency:* The system can handle multiple users efficiently, demonstrating satisfactory performance under load. The average weighted mean is 3.53, with a remark of Strongly Agree.

Overall, the evaluation results indicate that the Book2Shine Web Portal Carwash Booking System meets ISO 2510 standards and is highly effective, user-friendly, and reliable for both customers and carwash owners.

*Economic feasibility.* An economic feasibility analysis was conducted using a cost-benefit approach to determine whether the expected advantages of the system outweigh its projected costs. Evaluating the website in terms of costs and benefits provides a precise comparison of its overall value. Feedback collected through the ISO 2510 questionnaire-based survey also contributed to assessing the system's economic feasibility and functionality, confirming that the benefits of implementing the system justify the investment.

***Technological feasibility.*** Upon successful development of the system, feedback indicated that it has a clear and modern design, is easy to use and understand, and is accessible across multiple devices. These attributes demonstrate that the system meets the technological requirements necessary for effective deployment.

***Operational feasibility.*** The developed system was found to be operationally feasible, as it is designed to be intuitive and easy to use. Survey results showed that both customers and carwash owners were satisfied with the system, and only a brief demonstration was needed for users to learn its functions. This confirms that the system can be efficiently adopted in real-world operations.

## **Conclusion**

The Book2Shine web portal carwash booking system is fully functional, allowing both carwash owners and customers to operate the system easily and efficiently, without bugs or errors. The system streamlines the process of booking appointments, reducing the effort and time required by customers to schedule vehicle cleaning services. It also ensures a smooth and organized flow of transactions across all carwash stations listed on the portal.

This web portal is designed to provide vehicle owners with convenient access to book appointments at their preferred carwash stations, allowing them to select locations closest to their current position. The system was developed using PHP and the Laravel Framework, providing a robust and scalable platform for online booking.

The system includes a Content Management System (CMS) for carwash owners, enabling them to customize their own websites easily. Shop owners can upload photos, edit text for banners, update their “About Us” section, and add social media links such as Facebook, Instagram, and TikTok. The CMS was designed to be intuitive and user-friendly, serving not only as a management tool but also as a medium for online advertisement to attract more customers.

After rigorous testing and evaluation, the system was found to comply with ISO/IEC 2510 standards, meeting criteria in functional suitability, maintainability, security, usability, portability, compatibility, reliability, and performance efficiency. These results indicate that the system is a viable alternative to traditional carwash booking methods, providing enhanced service delivery and improved customer assistance.

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# Pharmacy Management System with Online Ordering Data Visualization

*Mary Ann Item, John Jerick Magsino, Roberto Aquino Jr. & Marlon Atienza*

The widespread adoption of technology has transformed nearly every aspect of human life, delivering significant benefits to society, particularly in healthcare and business operations (Silberglitt & Antón, 2020). In inventory management, tracking the location and movement of products throughout the supply chain is essential. Technology ensures transparency and accountability, strengthening a company's competitive edge (Martínez-Peláez et al., 2023; Noor, 2022). Inventory management systems support this process by monitoring stock inflows and outflows, tracking product availability, and ensuring timely order fulfillment from selection to delivery. By applying best practices and leveraging advanced technology, warehouses can reduce losses, prevent product damage, and manage expiration dates more effectively (Adeodu et al., 2023; Rahman & Kirby, 2024; Khedr & Rani, 2024).

Data analytics further enhances operational decision-making. It encompasses tools and technologies for managing both qualitative and quantitative data to extract insights, support governance, and inform organizational strategies (Pancić et al., 2023; Pisoni et al., 2024). Within

business and healthcare contexts, analytics identifies trends in product use, consumer behavior, and operational inefficiencies, thereby facilitating more strategic management and targeted marketing decisions (Ahmed et al., 2024; Rosário & Dias, 2023). In e-commerce, customers must share sensitive financial and personal data, raising concerns about fraud, identity theft, and financial loss. Successful online payment processing typically involves three actors: the merchant, the payment platform, and the customer. Addressing security concerns and ensuring seamless transaction flows are crucial to building consumer trust and minimizing shopping cart abandonment.

Pharmacy management systems illustrate the advantages of technological integration in healthcare. These systems improve efficiency, accuracy, and patient care by automating routine processes. Meknassi et al. (2025) found that such systems significantly reduced both medication distribution times and errors, while Bialas et al. (2020) highlighted improvements in inventory management and the reduction of stockouts. Moreover, online ordering features increase convenience and customer satisfaction (Pabba et al., 2025; Bahamdan & Almanasef, 2024).

Pharmacies serve a critical role in ensuring proper medication administration and providing patient guidance, all while adhering to strict regulatory standards. The use of pharmacy management systems streamlines operations, reduces errors, and supports personalized care. Web-based platforms managed by licensed pharmacists also expand access to patients with mobility challenges, including nursing mothers and individuals requiring long-term medication. Features such as automated monitoring of fast-moving or soon-to-expire drugs further strengthen operational oversight and inventory management.

The pharmacy sector in Sariaya, Philippines, demonstrates a

pressing need for such technological intervention. Of 59 registered pharmacies, only 34 currently hold active licenses, and just six use sales and inventory systems. The majority still depend on manual recordkeeping, and none offer online ordering or delivery services (fda.gov.ph). This gap highlights the importance of adopting modern web-based pharmacy management systems to improve sales processes, strengthen inventory control, and enhance customer convenience. Hence, this study recognizes the potential benefits of transitioning to an online Pharmacy Management System. Such a system would allow customers to place orders conveniently online while enabling the pharmacy to optimize internal processes. It would also facilitate regular inventory updates, track medication flow, and provide real-time stock information for both staff and customers.

By addressing the operational limitations of pharmacies in Sariaya, the proposed system seeks to improve efficiency, ensure reliable client services, and enhance overall pharmaceutical operations. The study's primary objective is to design and develop a web-based pharmacy management system with online ordering and data visualization.

## **Theoretical Framework**

### ***The Role of Technology in Pharmacy Administration***

The evolution of technology has fundamentally reshaped pharmacy management, driving improvements in both operational efficiency and patient care. Bialas et al. (2020) underscore how integrated systems streamline workflows and boost productivity, enabling pharmacists to dedicate more time to high-quality patient care by automating tasks such as medication dispensing, stock management, and billing. Similarly, Mason et al. (2022) emphasize the importance of robust technological systems for

accurate stock monitoring and analysis, which ensure the timely availability of essential medications and support safer drug administration.

Alanazi et al. (2022) demonstrate that automated dispensing systems significantly reduce medication errors, thereby enhancing patient safety. Complementing this, Hamad and Bah (2022) highlight the role of electronic health records (EHRs) in improving medication reconciliation, strengthening communication among healthcare providers, and enabling personalized pharmaceutical care. Khare (2025) shows that telepharmacy services expand healthcare access in underserved areas, allowing pharmacists to provide consultations and dispense medications remotely. Furthermore, mobile health (mHealth) applications reinforce medication adherence by sending reminders and offering guidance, empowering patients to take an active role in managing their therapies (Peng et al., 2020). Porterfield et al. (2014) add that electronic prescribing systems reduce errors, improve inter-professional communication, and accelerate prescription processing.

These studies establish that technology not only improves medication safety and operational efficiency but also advances patient-centered care, positioning technological innovations as indispensable drivers of modern pharmacy administration.

### ***Electronic Commerce and Online Drugstores***

The rapid expansion of e-commerce has profoundly influenced the pharmaceutical sector, transforming how patients access medications and healthcare services. Houcheimi and Mezei (2024) highlight the convenience of online ordering and its potential to broaden market reach, stressing that secure payment methods are essential to building consumer trust. Varghese et al. (2025) identify perceived usefulness, ease of use, and platform

reliability as key determinants of consumers' willingness to adopt online pharmacy services. Likewise, Zacharia et al. (2024) emphasize e-commerce's role in accelerating healthcare innovation, enhancing patient engagement, and improving accessibility, while also underscoring the need for effective regulation and quality control.

Almeman (2024) demonstrates that online pharmacies not only facilitate access to essential medicines but also improve adherence and empower patients to participate more actively in healthcare decisions. Taken together, these findings underscore that while online pharmacies offer convenience, market expansion, and better patient outcomes, their sustainability relies heavily on trust, robust security, and strong regulatory compliance.

### ***Pharmaceutical Information Visualization and Analytics***

Pharmacy operations generate vast amounts of data, making data visualization and analytics critical for efficient decision-making. Eberhard (2023) argues that visual data representations enhance comprehension and inform actionable insights. Fatorachian and Pawar (2025) demonstrate that predictive modeling and demand forecasting optimize inventory management, reduce waste, and improve supply chain efficiency. Similarly, Babel et al. (2021) show how analytics can strengthen medication therapy management by detecting drug-related issues, improving adherence, and optimizing treatment outcomes.

Shahmoradi et al. (2021) further highlight that integrating clinical decision support systems with analytics enhances patient safety, minimizes prescription errors, and supports evidence-based decision-making in pharmaceutical practice. Collectively, these studies confirm that data visualization and analytics are powerful tools for improving inventory

control, medication management, and clinical outcomes in pharmacy administration.

### ***Designing and Deploying a System***

The design and deployment of pharmacy management information systems require careful attention to user requirements, system customization, and adequate staff training. Dopp et al. (2020) stress that aligning system design with user needs is critical to achieving successful implementation. Staras et al. (2021) add that clinical eHealth interventions streamline workflows, improve resource allocation, and enhance automation across healthcare facilities. Hence, there is a need to address technical, organizational, and usability challenges to secure user acceptance and system effectiveness.

Kroenert and Bertsche (2024) emphasize the importance of collaboration and the removal of implementation barriers to establish robust research and technological infrastructure in pharmacy settings. Moreover, Ezeamii et al. (2024) illustrate how pharmacy-led virtual clinics extend healthcare services through telemedicine, expanding access and improving patient outcomes. Collectively, these studies indicate that successful system deployment hinges on planning, collaboration, training, and a strong focus on usability.

### ***Security and Privacy in Online Pharmacy Systems***

As online pharmacy systems become increasingly widespread, ensuring security and privacy emerges as a critical concern. Kuzma (2011) highlights the risks inherent in online platforms, particularly regarding data protection, secure payments, and compliance with regulatory standards. Kumar et al. (2024) propose secure system architectures that protect

sensitive patient data through encryption, access controls, and audit trails. Similarly, Folorunso et al. (2024) advocate for strong authentication protocols, regular security audits, and operational safeguards to reduce the likelihood of breaches.

Alhuwail et al. (2021) present a comprehensive security framework for online pharmacies, emphasizing the prevention of cyberattacks, protection of personally identifiable health information, and secure communication channels. Collectively, these studies affirm that stringent security measures are essential for protecting patient confidentiality, ensuring system reliability, and fostering public trust in online pharmacy platforms.

## **Research Framework**

This section outlines the methodology used for developing and testing the proposed system.

### ***Data***

The following types of data were utilized in the development and testing of the pharmacy management system:

*Customer records:* Name, contact information, delivery address

*Product information:* Name, description, price, stock quantity

*Order data:* Order ID, customer ID, product ID, quantity, date, and time

*Payment information:* Payment method, transaction ID, amount

*Inventory data:* Stock levels, reorder points, supplier information

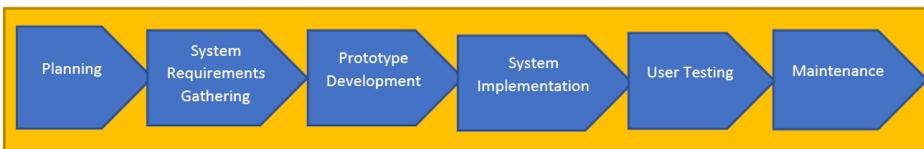
*Sales data:* Sales trends

*User accounts:* Pharmacy administrators, customers

Data collection was conducted through surveys, interviews, observations, and review of existing databases. Quantitative data were gathered via surveys from a representative sample, while qualitative insights were obtained through interviews with key stakeholders. Observations of pharmacy workflows identified inefficiencies, and historical data analysis supported informed decision-making. Data collection involved electronic questionnaires, interview notes, and field observations, with strict adherence to confidentiality and secure storage protocols. This data-driven approach ensured the system addressed stakeholder requirements and improved operational efficiency.

### ***Experimental Design***

Figure 1 illustrates the experimental design used to assess the Pharmacy Management System's effectiveness in improving operational efficiency and accuracy.



**Figure 1**

*Experimental design process*

The design involves several stages:

*Planning and definition:* Establish the system's objectives, goals, and overall scope.

*Requirements gathering:* Collect data from pharmacists, customers, and managers to identify key functionalities.

*Prototype development:* Construct a working prototype using software development tools such as UML diagrams to evaluate functionality and usability.

*User testing and feedback:* Conduct real-world testing and incorporate user feedback to refine the system.

*System evaluation:* Assess the system's accuracy, reliability, and scalability in operational settings, and report its impact on pharmacy operations and customer satisfaction.

*Maintenance:* Provide continuous technical support and implement periodic updates to meet evolving stakeholder requirements.

This experimental design ensures thorough testing, refinement, and optimization of the pharmacy management system.

### ***Procedures of the Different Phases***

The Agile methodology was employed for developing the pharmacy management system and online ordering system with data visualization due to its numerous advantages, including adaptability to changing requirements, responsiveness to feedback, early value delivery, risk reduction, enhanced collaboration, and transparency. Agile facilitates continuous development, enabling the system to evolve with user input and operational needs, thereby improving project success, customer satisfaction, and management efficiency.

The development process, following Agile methodology, involved iterative and cyclical stages:

*Requirements:* Engage stakeholders to gather, prioritize, and define system needs and functionalities.

*Design:* Develop architectural and user interface designs using diagrams, illustrations, and prototypes to ensure alignment with stakeholder expectations.

**Figure 2**

*Agile methodology*



*Development:* Implement the system’s modules and components based on design specifications.

*Testing:* Conduct comprehensive testing, including unit, integration, and user acceptance tests, to verify functionality and compliance with requirements.

*Deployment:* Install and configure the system, migrate data, and launch the system in a live environment.

*Review:* Evaluate system performance post-deployment, gather feedback from end users and stakeholders, and identify areas for improvement and future development.

The structured methodology ensures a robust, user-centered pharmacy management system that enhances efficiency, accuracy, and customer satisfaction.

## **Technical Framework**

### ***Materials***

The development of the pharmacy management system utilized three primary resources: software, hardware, and data.

*Software:* The selected software components provide essential functionalities and ensure a seamless and user-friendly experience for both pharmacy administrators and customers.

*Hardware:* System performance and accessibility depend on the hardware used in the local development environment as well as the HostGator web server infrastructure hosting the application.

*Data:* The integration of various data types facilitates efficient inventory management, secure transactions, and comprehensive data analysis within the system.

These resources collectively support the development, deployment, and operational efficiency of the pharmacy management system.

### ***Software***

A variety of software components were utilized in the development of the Pharmacy Management System to ensure functionality, usability, and a positive user experience. Key software resources include:

*Operating System:* Windows 11 was used for local development and testing, while the live system operates on HostGator's web server infrastructure.

*Web Server Software:* Apache HTTP Server version 2.4.48, deployed locally via XAMPP (which integrates Apache, MySQL, PHP, and other web development tools), and the Apache server provided by HostGator for online deployment.

*Database Management:* MySQL 8.0.21 served as the backend database for local development, while HostGator's MySQL server was used for live deployment.

*Programming Languages:* PHP (versions 7.4–8.0.7) and JavaScript were the primary languages. HTML and CSS were employed for front-end development, supporting dynamic and interactive functionality.

*Development Environment:* Visual Studio Code was used as the IDE, providing features such as code auto-completion, integrated debugging, and source control for efficient development.

*Web Browsers:* Google Chrome was the main testing target, with compatibility checks for Mozilla Firefox and Microsoft Edge.

*Payment Gateway Integration:* PayPal API was integrated for secure and reliable online transactions.

*Security Software:* Windows Defender Antivirus and Firewall secured the local environment, complemented by HostGator's web server security features for live deployment.

*Data Visualization:* Chart.js, a JavaScript framework, enabled interactive charts and graphs for sales, inventory, and other analytics.

*Image Editing:* Photoshop and Ibis Paint facilitated the customization and optimization of product images and graphical assets.

By leveraging this comprehensive suite of software tools, the development team ensured that the Pharmacy Management System supports efficient inventory management, online ordering, and data visualization while maintaining security and compatibility with various platforms.

## ***Hardware***

The pharmacy management system relies on both local development hardware and HostGator web server infrastructure to ensure functionality, reliability, and accessibility.

### *Local Development Environment:*

*Computers:* Desktop and laptop computers with Intel Core i5 processors, 8 GB RAM, and 512 GB SSD storage were used for system development and testing.

*Mobile devices:* Various smartphones and tablets were used to ensure responsive design and accessibility across platforms.

*Printers:* Standard printers facilitated printing invoices, reports, and labels.

### *HostGator Web Server Infrastructure:*

*Server:* A shared hosting architecture managed CPU, RAM, and storage resources to host the system reliably.

*Networking devices:* Network switches and routers were managed by HostGator to ensure stable internal and external connectivity.

*Storage devices:* Shared storage arrays provided sufficient space for hosting multiple applications, including the Pharmacy Management System.

*DNS servers:* HostGator-managed DNS servers (ns8641.hostgator.com and ns8642.hostgator.com) enable domain name resolution and system accessibility.

*Firewall:* HostGator's shared hosting firewall monitors and filters network traffic to enhance system security.

The combination of local development hardware and HostGator's hosting infrastructure ensured that the Pharmacy Management System is robust, scalable, and accessible, supporting seamless integration with the

software components to deliver a reliable and user-friendly experience.

**Table 1**

*Software, Hardware, and Data Tables of Materials Used*

<b>Category</b>	<b>Materials</b>
<b>Software</b>	
Operating System	Windows 11
Web Server	Apache HTTP Server version 2.4.48
Database	MySQL 8.0.21
Programming Languages	PHP (versions 7.4 to 8.0.7), JavaScript
Text Editor/IDE	Visual Studio Code
Web Browser	Google Chrome
Payment Gateway	PayPal API
Security	Windows Defender Antivirus and Firewall
Data Visualization Tools	Chart.js
Photo Editor	Photoshop, Ibis Paint
<b>Hardware</b>	
Computers	Desktop and portable computers (Intel Core i5, 8GB RAM, 512GB SSD)
Mobile Devices	Smartphones, tablets
Printer	Standard printer
Web Server	HostGator shared server architecture
Networking Devices	Network switches, routers
Storage Devices	Hard drives, shared storage arrays
DNS Server	HostGator DNS servers (ns8641.hostgator.com, ns8642.hostgator.com)
Firewall	HostGator shared hosting firewall
<b>Data</b>	
Customer Records	Name, contact information, delivery address
Product Information	Name, description, price, stock quantity
Order Data	Order ID, customer ID, product ID, quantity, date, and time
Payment Information	Payment method, transaction ID, amount
Inventory Data	Stock levels reorder points, supplier information
Sales Data	Sales trends
User Accounts	Pharmacy administrators, customers

## ***Modeling***

The development of the pharmacy management system relied extensively on modeling, which provides a clear representation of the

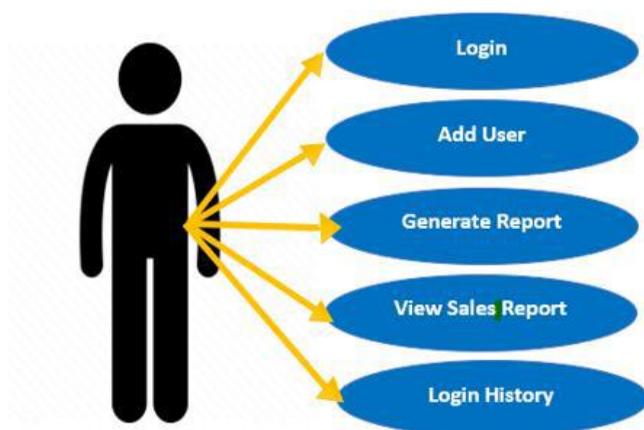
system's structure, behavior, and interconnections. During development, various modeling techniques were employed to capture and communicate the system's components effectively. These included use case diagrams, database design/schema and relationship tables, and data flow diagrams. By leveraging these modeling approaches, the system's features, database architecture, process flows, and overall behavior were clearly defined. The models ensured a shared understanding of the system architecture among stakeholders, improved communication between team members, and guided the development team throughout the implementation process. The following sections detail how these modeling techniques were applied in the development of the pharmacy management system.

### *USE Case*

Figure 3 presents the administrator use case, showing how the system is managed by the admin. The administrator has full control and can perform essential functions such as viewing, recording, and updating product information, as well as managing customer records.

**Figure 3**

*Admin use case*



**Figure 4**

*Customer use case*

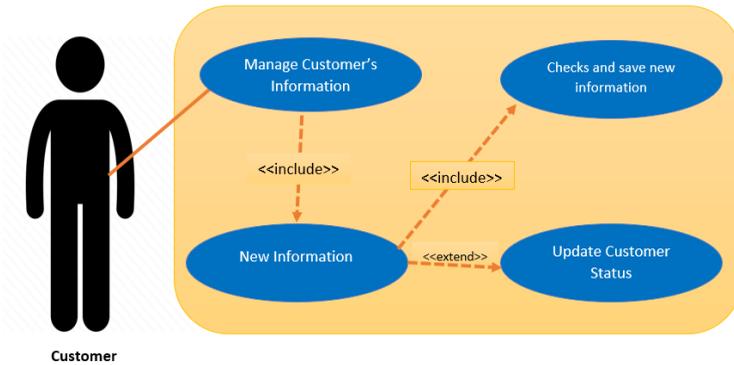
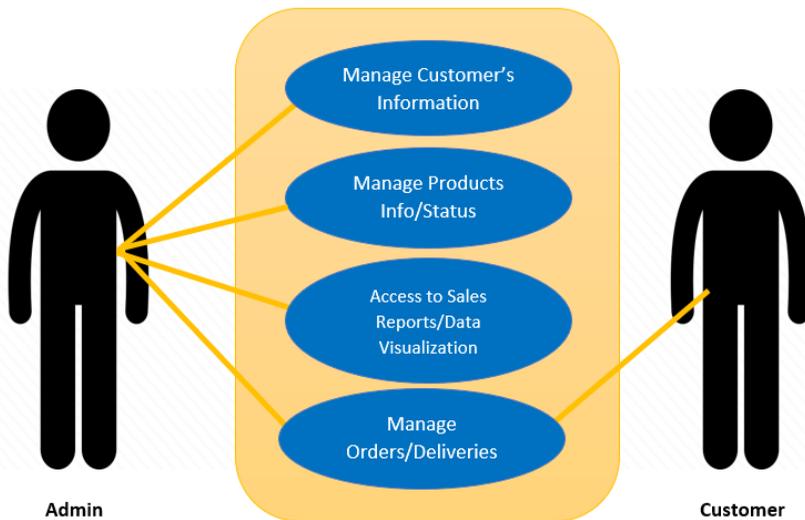


Figure 4 illustrates the system's overall operations and functionalities, which differ according to the actions performed by administrators, users, and customers.

**Figure 5**

*Manage users' information*



The primary focus of this use case is “Manage User Information.” It covers all functions and support required to efficiently handle and update user information within the system.

**Figure 6**  
*Manage orders*

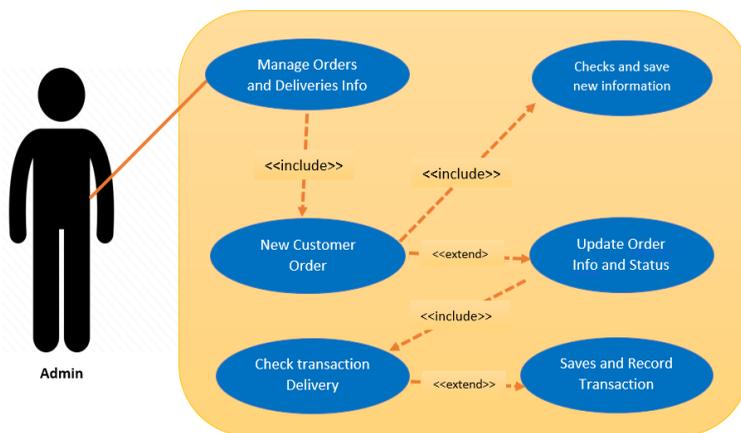


Figure 6 illustrates the data flow from customer requests and orders to final delivery. The tracked information includes the reservation or order date, item quantities, individual prices, total payment, and delivery status updates.

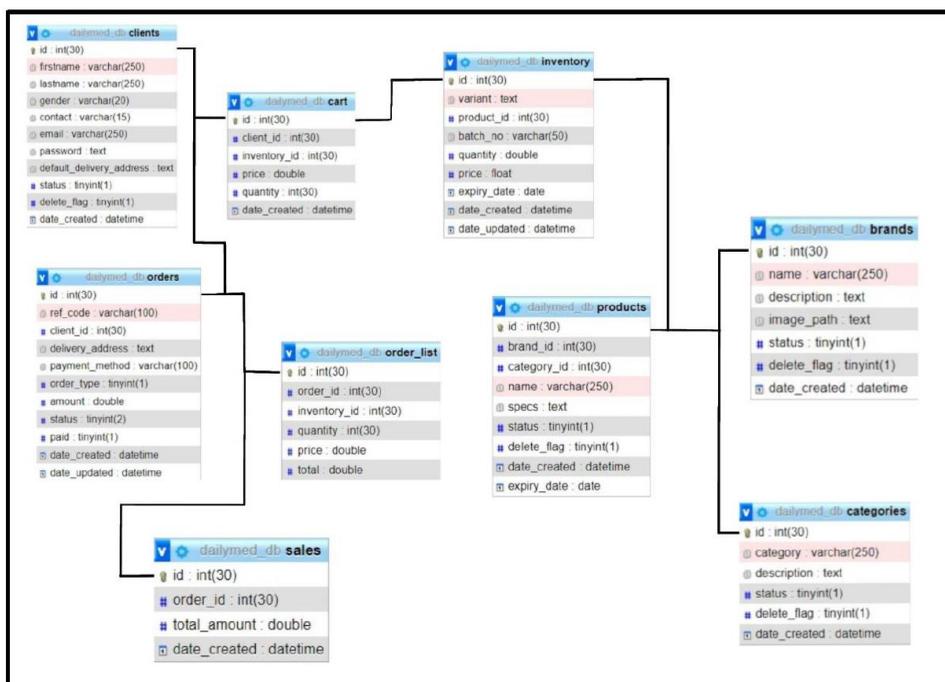
### ***Database Design/ Schema and Relationship Table***

Figure 7 illustrates the organization and interconnection of database tables through a schema and defined relationships. Entities such as Users, Customers, Orders, Order\_List, Inventory, Sales, Products, Brands, and Categories are represented as tables within the sample database. Relationships are established using foreign keys; for instance, the Orders table may reference the Customers table to link each order to a specific customer. This structured approach streamlines data storage and retrieval,

ensuring information is efficiently organized and reliably managed. A well-designed database with clearly defined relationships strengthens system operations and facilitates seamless information access.

**Figure 7**

*Database design/ schema and relationship*



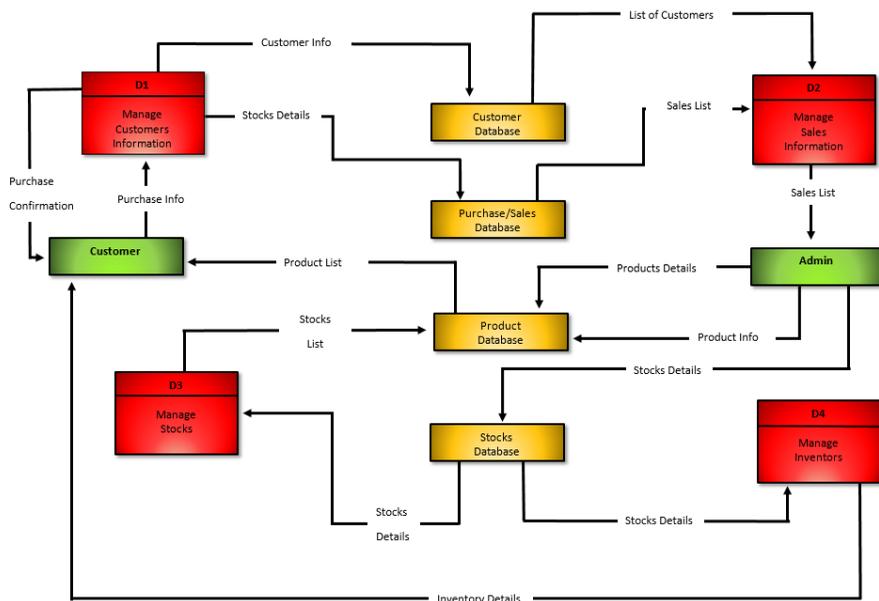
### **Data Flow Diagram**

The Data Flow Diagram (DFD) in Figure 8 provides a visual representation that supports system understanding, analysis, and modeling. It illustrates how information flows and how different components of the Pharmacy Management System interact. The DFD shows the movement of data between major components and their associated databases. The Customer component manages customer information and purchase transactions, which are stored in the Customer Database and Purchase/Sales

Database. The Admin component oversees product information and stock levels, recorded in the Product Database and Inventory List. By mapping these data flows, the DFD highlights how the system enables efficient customer management, sales tracking, and inventory control.

**Figure 8**

*Data flow diagram within system*



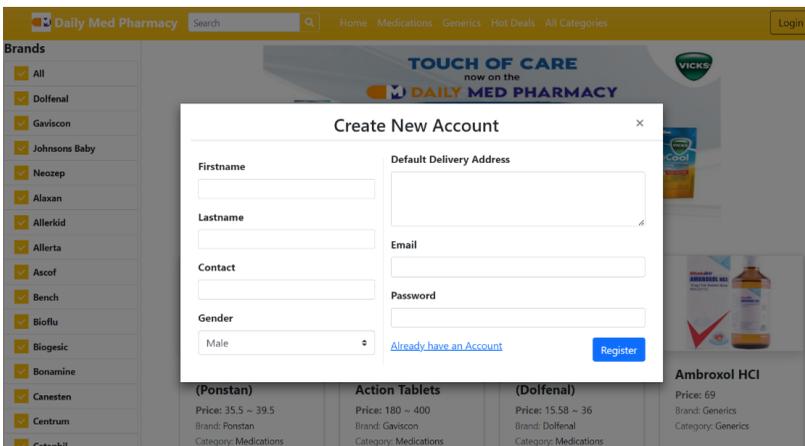
**System Design**

This section presents the graphical user interface (GUI) design for system users, emphasizing visual elements, user interaction, responsiveness, and overall usability. The design is guided by the goal of providing an intuitive and efficient interface that meets the needs and preferences of system users.

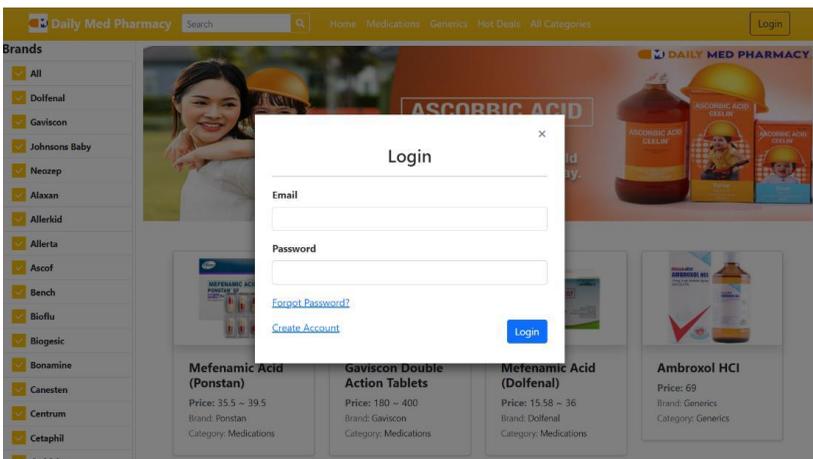
New users can register using the “Customer Create Account” option by providing essential details such as their name, email, password, and

contact information, as shown in Figure 9. Once registered, they gain access to personalized features and services, including placing orders, viewing order histories, and securely managing personal data. This functionality ensures a seamless onboarding experience while enabling customers to interact with the system safely and efficiently.

**Figure 9**  
*Customer create account*



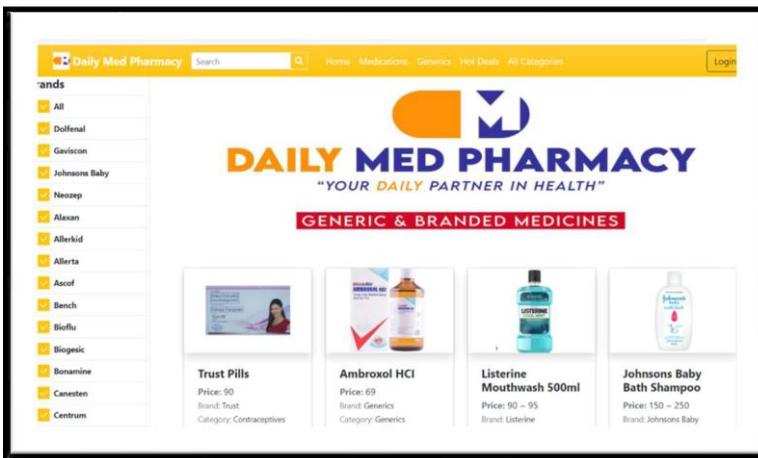
**Figure 10**  
*Customer log in*



Registered users can securely access their accounts through the “Customer Login” option (Figure 10). By entering their credentials, such as a username and password, they can access personalized features, review purchase history, and manage account settings. This functionality ensures secure interaction with the system while allowing users to maintain full control over their data.

**Figure 11**

*Homepage*

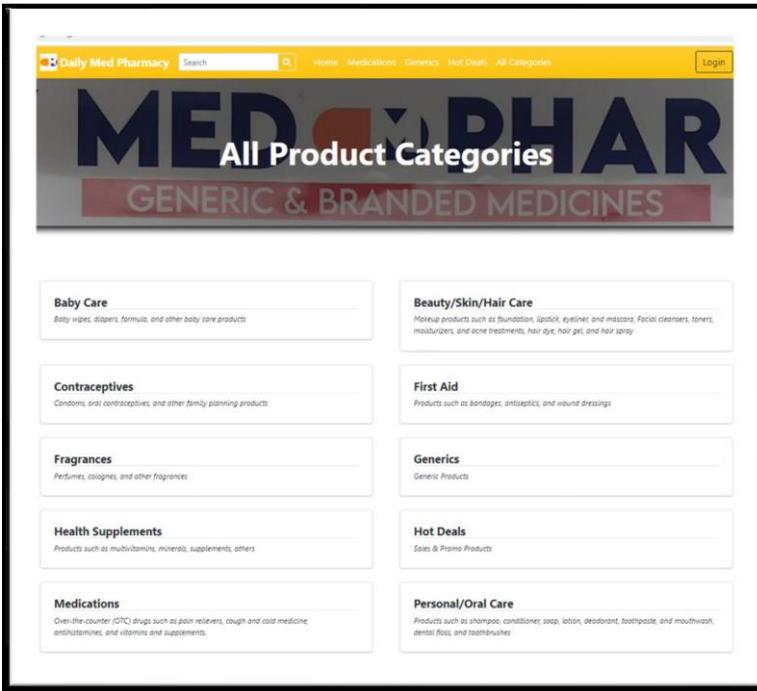


Upon successful login, users are directed to the “Homepage,” which serves as the main interface of the system (Figure 11). The homepage provides a structured overview of available features and guides users in accessing them. Acting as a central hub, it enables seamless navigation to the various subsystems and modules of the Pharmacy Management System.

As illustrated in Figure 12, the “All Categories” option allows customers to browse and explore all available product categories. It presents a comprehensive list or menu, enabling users to view the full range of products offered by the system.

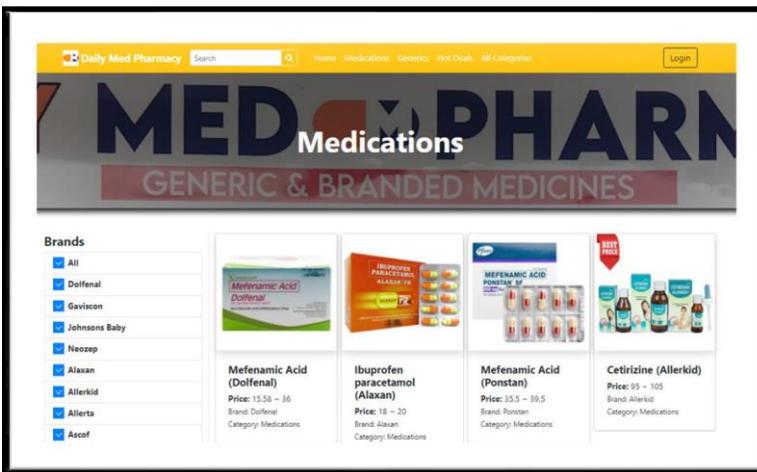
**Figure 12**

*All categories*



**Figure 13**

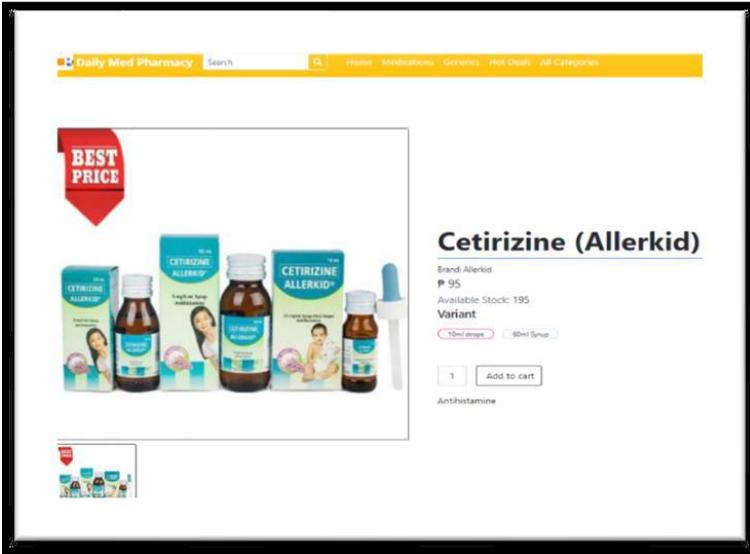
*Medications category*



The “Medications Category” is a subcategory that organizes pharmaceutical products, including over-the-counter (OTC) medications for a variety of treatments, as illustrated in Figure 13.

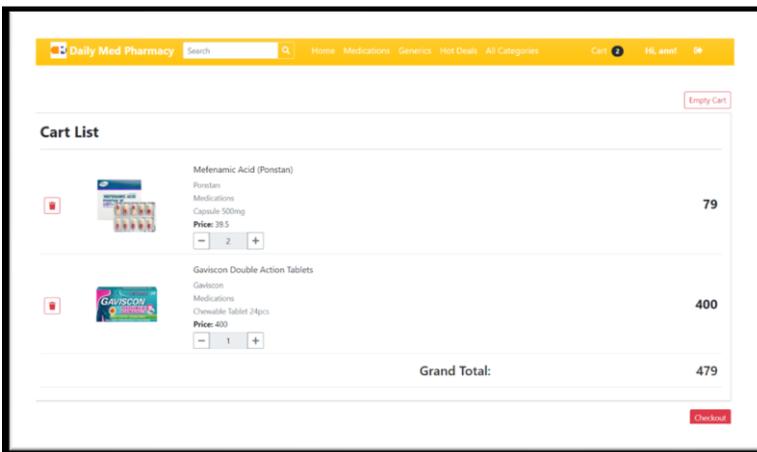
**Figure 14**

*Add to cart*



**Figure 15**

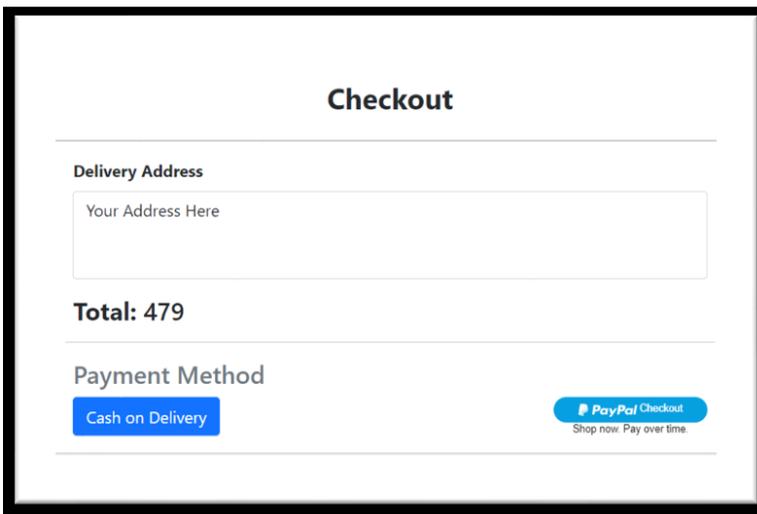
*View cart list*



As shown in Figure 14, when a user selects a product from a category, they can click the “Add to Cart” button to place the item in their virtual shopping cart. This feature allows customers to conveniently gather and organize their selected products before proceeding to checkout. Items remain in the cart while users continue browsing or make modifications to their selections. Meanwhile, the “View Cart List” option in Figure 15 provides customers with a clear summary of all items in their virtual shopping cart. It displays the selected products, their quantities, and prices, allowing users to review and verify their choices before proceeding to checkout.

**Figure 16**

*Checkout*



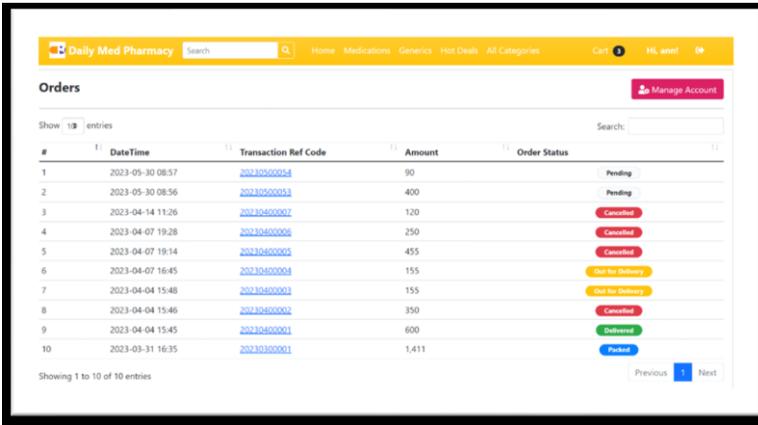
The screenshot displays a checkout interface with the following elements:

- Checkout** (Section Header)
- Delivery Address** (Section Header)
- (Text Input Field)
- Total: 479** (Total Amount)
- Payment Method** (Section Header)
- (Payment Option)
- (Payment Option) with subtext: "Shop now. Pay over time."

The “Checkout” feature in Figure 16 allows customers to complete their purchases by providing the necessary information and selecting a preferred payment method. Users can securely finalize their orders using either PayPal or Cash on Delivery (COD), ensuring a convenient transaction process.

**Figure 17**

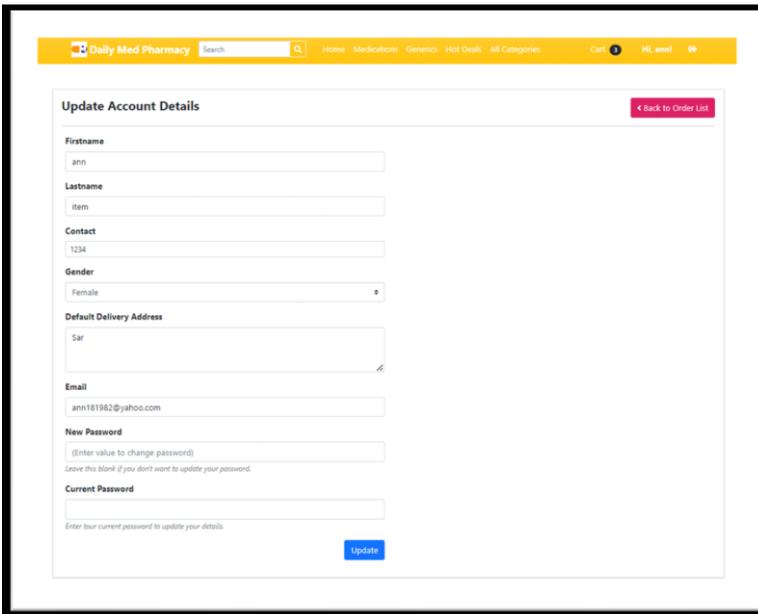
*View order*



The “View Orders” feature enables customers to access and review their past orders, facilitating the tracking of order history and monitoring of previous purchases.

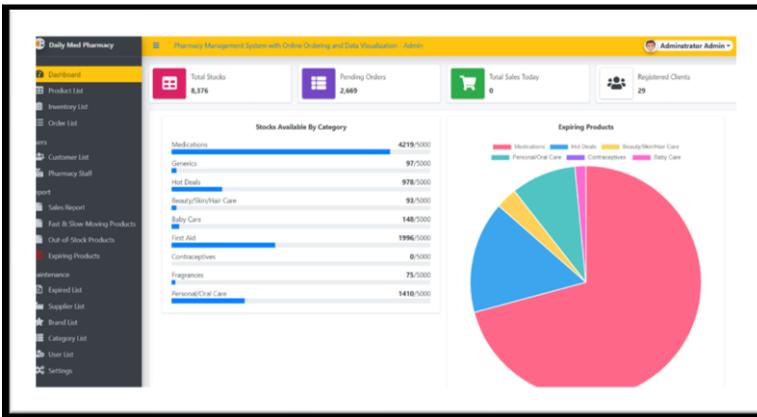
**Figure 18**

*Manage account*



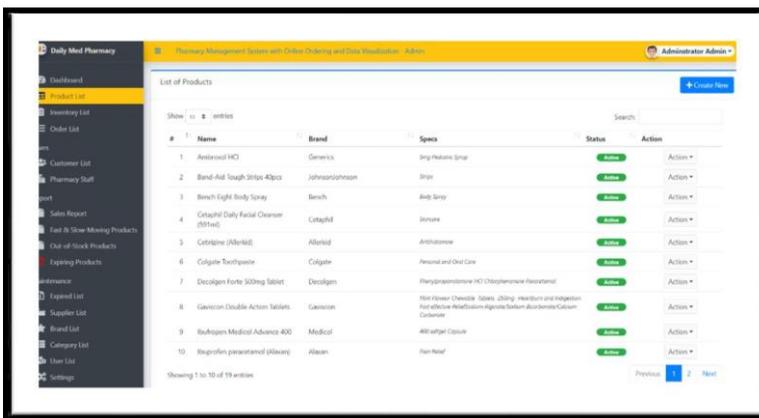
The “Manage Account” feature allows users to update their personal account information, ensuring secure access and a personalized experience.

**Figure 19**  
*Admin dashboard*



The “Admin Dashboard” serves as a centralized platform for pharmacy administrators, offering a comprehensive interface to efficiently monitor, manage, and oversee all pharmacy operations.

**Figure 20**  
*Product list*

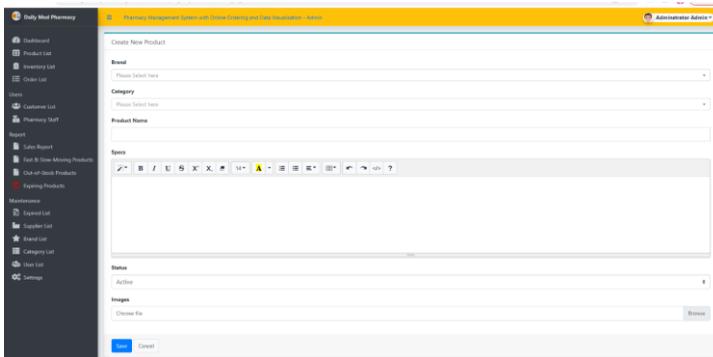


The “Product List” displays detailed information for all products in the system, including brand, name, and specifications. Administrators and

users can efficiently search and filter items by name, brand, or specifications, facilitating easier management and retrieval.

**Figure 21**

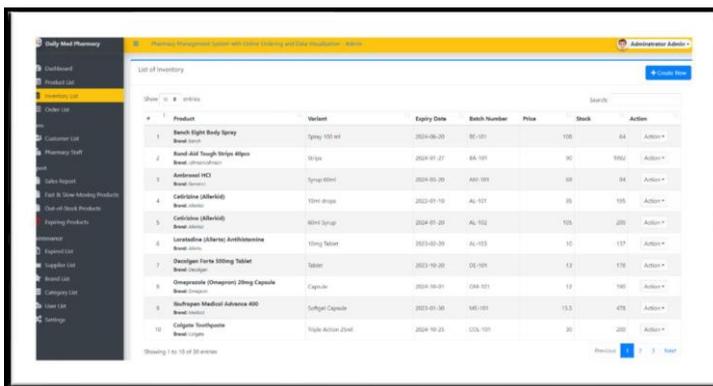
*Create new product*



The “Create New Product” feature allows pharmacy administrators to add new items to the system’s database, updating and expanding the product catalog. This ensures that all products are accurately recorded and readily accessible for both management and customer interactions.

**Figure 22**

*Inventory list*

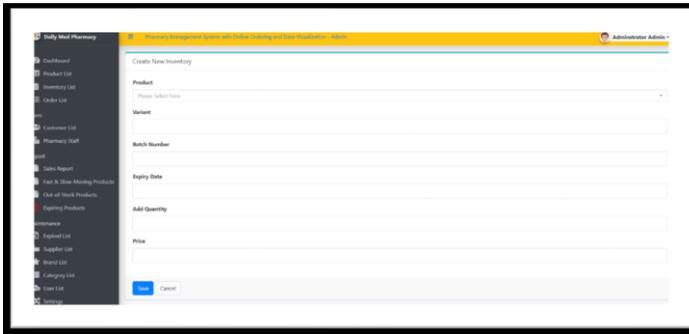


The “Inventory List” feature provides a structured view of the pharmacy’s stock. For each product, it displays key details such as the name,

variation, expiry date, batch number, price, and available quantity. This functionality enables administrators to efficiently monitor and manage inventory levels.

**Figure 23**

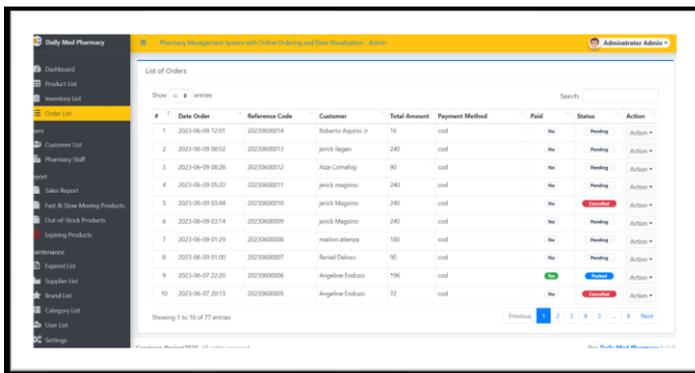
*Create new inventory*



The “Create New Inventory” function enables authorized users, such as pharmacy administrators or staff, to add new inventory records for products. This ensures the system maintains an accurate and up-to-date representation of product availability and stock levels.

**Figure 24**

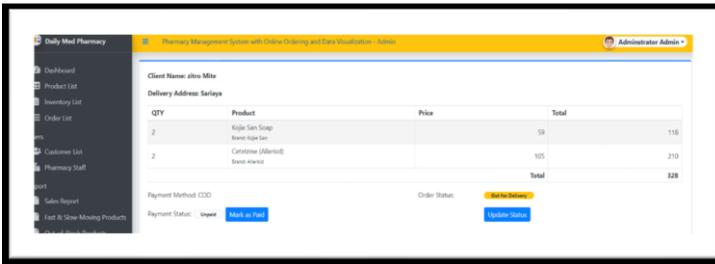
*Order list*



The “Order List” functionality provides a comprehensive overview of customer orders, enabling pharmacy administrators and staff to monitor and manage order statuses, ensuring a smooth and efficient order fulfillment process.

**Figure 25**

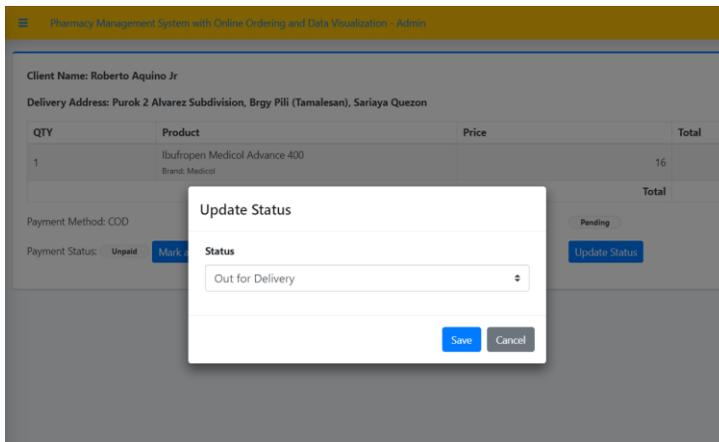
*View customer’s order*



The “View Customer’s Order” feature allows pharmacy administrators and staff to access and review specific order details. Beyond viewing standard order information, users can mark orders as paid and update their status, ensuring accurate tracking and efficient order management.

**Figure 26**

*Update status*



The “View Customer’s Order” feature enables administrators and staff to monitor and update order statuses as needed. Status options include Pending, Packed, Out for Delivery, Delivered, and Canceled. This functionality supports efficient order management while providing customers with clear, real-time updates, thereby enhancing satisfaction and communication.

**Figure 27**  
*Customer list*

#	Date Created	Name	Email	Contact	Status	Action
1	2023-09-09 09:26	Alice Canahay	alicecanahay1997@gmail.com	09481120270	Active	Action *
2	2023-09-07 20:07	Angeline Endaco	angelinemebaco1996@gmail.com	09971361702	Active	Action *
3	2023-09-31 16:34	Ann Item	ann181982@yahoo.com	1234	Active	Action *
4	2023-09-07 02:08	Ann Item	anna@phoo.com	156899976	Active	Action *
5	2023-09-25 21:58	Ann Item	ann@sample.com	111111111111111	Active	Action *
6	2023-09-26 00:56	Anna Item	anna@sample.com	12345678	Active	Action *
7	2023-09-31 00:41	Anna Mei	mayamemey.cui@gmail.com	234567890	Active	Action *
8	2023-09-09 10:23	Angeline Endaco	angelinemebaco@gmail.com	09971361702	Active	Action *
9	2023-06-08 08:21	Jenavia Magasin	jenaviamagasin7@gmail.com	09483972632	Active	Action *
10	2023-06-09 06:05	Jenick Magasin	jenickmagasin2@gmail.com	09123456677	Active	Action *

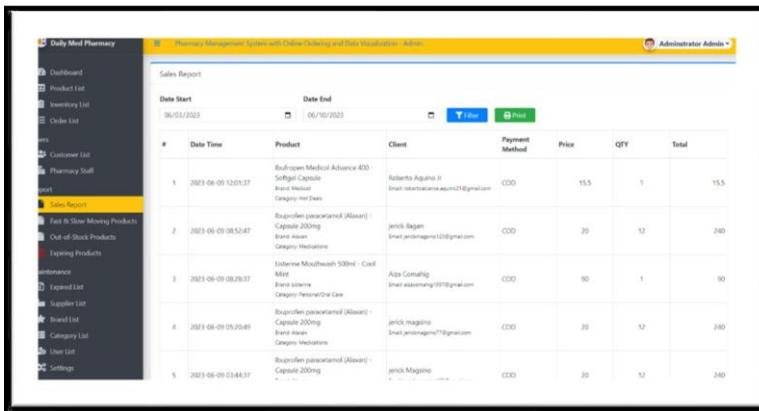
The “Customer List” feature displays a detailed record of all registered customers. It includes each customer’s name, contact information, and other relevant data, enabling administrators to manage customer information efficiently.

**Figure 28**  
*Pharmacy Staff*

#	Product	Variant	Price	Stock	Action
1	Stash Eight Study	Stary 100 ml	100	84	Quantity Add
2	Stash Eight Study	Stary 100 ml	100	84	Quantity Add
3	Stash Eight Study	Stary 100 ml	100	84	Quantity Add
4	Stash Eight Study	Stary 100 ml	100	84	Quantity Add
5	Stash Eight Study	Stary 100 ml	100	84	Quantity Add

The “Pharmacy Staff” feature allows administrators to manage walk-in orders, catering to customers who prefer purchasing medications in person rather than through the online system.

**Figure 29**  
*Sales report*



#	Date Time	Product	Client	Payment Method	Price	QTY	Total
1	2023-06-09 12:01:37	Buclupren Medical Advance 400 Softgel Capsule Brand: Mileon Category: Hot Deals	Roberto Aquino Jr Email: roberto.aquino.ajr@gmail.com	COD	15.5	1	15.5
2	2023-06-09 08:52:47	Ibuprofen paracetamol (Mileon) Capsule 200mg Brand: Mileon Category: Medications	jenck Bagas Email: jenckbagas12@gmail.com	COD	20	12	240
3	2023-06-09 08:28:37	Estimote Mouthwash 500ml - Cool Mint Brand: Liberte Category: Personal Care	Alice Comalig Email: alicecomalig19@gmail.com	COD	90	1	90
4	2023-06-09 05:20:49	Ibuprofen paracetamol (Mileon) Capsule 200mg Brand: Mileon Category: Medications	jenck megasni Email: jenckmegasni17@gmail.com	COD	20	12	240
5	2023-06-09 03:48:37	Ibuprofen paracetamol (Mileon) Capsule 200mg	jenck Megasni	COD	20	12	240

The “Sales Report” feature generates detailed reports for a specified period, enabling users to analyze sales performance by date, product category, or customer segment. Reports can be printed or exported as PDFs for further analysis or sharing. This functionality supports data-driven decision-making, financial assessment, and overall business evaluation within the pharmacy.

The “Fast & Slow-Moving Products” feature in Figure 30 allows users to assess product sales based on turnover rates. It filters items by time periods, tracks sales, and identifies fast- and slow-moving products. Reports can be printed or exported for further analysis. This functionality supports informed decision-making related to inventory management, marketing strategies, stock levels, and areas for operational improvement.

**Figure 30**

*Fast and slow-moving product*

The screenshot shows a web application interface for a pharmacy management system. The main content area displays a report titled "Fast & Slow-Moving Products". The report includes a date range filter set to 06/03/2023 to 06/10/2023, with "Filter" and "Print" buttons. Below the filter is a table with the following data:

#	Product	Brand	Total Quantity Sold
1	Colgate Toothpaste	Colgate	152
2	Ibuprofen paracetamol (Alaxan)	Alaxan	53
3	Listerine Mouthwash 500ml	Listerine	3
4	Mefenamic Acid (Difenal)	Difenal	2
5	Lorazepam (Allerta) Anesthetamine	Allerta	2
6	Cetaphil Daily Facial Cleanser (Cetfil)	Cetaphil	1
7	Band Aid Tough Strips 40pcs	Johnson&Johnson	1
8	Decolgen Forte 500mg Tablet	Decolgen	1
9	Bull-Open Medical Advance 400	Medical	1

**Figure 31**

*Out-of-stock products*

The screenshot shows a web application interface for a pharmacy management system. The main content area displays a report titled "Out-of-Stock Products". The report includes a date range filter set to 06/03/2023 to 06/10/2023, with "Filter" and "Print" buttons. Below the filter is a table with the following data:

#	Product	Brand	Available Quantity
1	Trust Pills	Trust	0

The “Out of Stock Products” feature in Figure 31 allows users to quickly identify items that are currently unavailable due to depleted inventory. This function helps pharmacy staff monitor stock levels and restock products as needed. By providing a clear and organized list of out-of-stock items, it supports efficient inventory management, ensuring customer needs are met while minimizing potential sales loss.

**Figure 32**

*Expiring products*

#	Product	Quantity	Brand	Category	Expiry Date	Batch Number	Action
1	Cetirizine (Alerkid)	198	Alerkid	Medications	2023-01-10	AL-101	Confirm
1	Loratadine (Alertra) Antihistamine	169	Alertra	Medications	2023-02-20	AL-103	Confirm
1	Bupropion Medical Advance 400	409	Medical	Hot Deals	2023-01-30	ME-101	Confirm
1	Cetaphil Daily Facial Cleanser (S914e)	93	Cetaphil	Beauty/Skin/Hair Care	2023-03-30	CE-101	Confirm
1	Listerine Mouthwash 500ml	200	Listerine	Personal/Oral Care	2022-12-31	LIS-101	Confirm
1	Listerine Mouthwash 500ml	86	Listerine	Personal/Oral Care	2023-04-30	LIS-102	Confirm
1	Mefenamic Acid (Ponstan)	498	Ponstan	Medications	2023-03-20	PO-101	Confirm
1	Trust Pills	0	Trust	Contraceptives	2023-03-26	TR-101	Confirm
1	Johnson's Baby Bath Shampoo	48	Johnson's Baby	Baby Care	2023-01-10	MR-101	Confirm

The “Expiring Products” feature allows users to quickly identify and manage items nearing their expiration dates. This tool helps pharmacists stay organized and proactively ensure product quality and patient safety. By providing a list of expiring items along with a confirmation function, it simplifies expiry tracking and verification. Pharmacies can efficiently remove outdated products and implement timely disposal procedures, reducing risks and maintaining regulatory compliance.

**Figure 33**

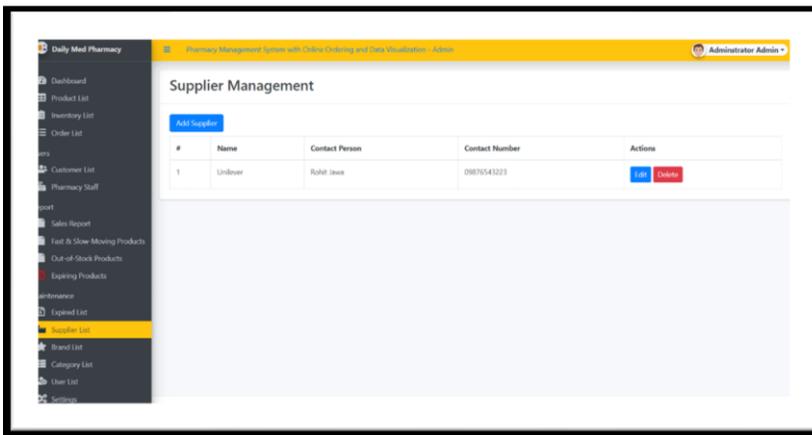
*Expired list*

#	Product	Quantity	Brand	Category	Expiry Date	Batch Number	Action
1	Listerine Mouthwash 500ml	86	Listerine	Personal/Oral Care	2023-04-30	LIS-102	—
2	Cetaphil Daily Facial Cleanser (S914e)	93	Cetaphil	Beauty/Skin/Hair Care	2023-03-30	CE-101	—
3	Trust Pills	0	Trust	Contraceptives	2023-03-26	TR-101	—
4	Mefenamic Acid (Ponstan)	498	Ponstan	Medications	2023-03-20	PO-101	—
5	Ibuprofen paracetamol (Alean)	116	Alean	Medications	2023-02-26	ALA-102	—
6	Loratadine (Alertra) Antihistamine	169	Alertra	Medications	2023-02-20	AL-103	—
7	Bupropion Medical Advance 400	409	Medical	Hot Deals	2023-01-30	ME-101	—
8	Johnson's Baby Bath Shampoo	48	Johnson's Baby	Baby Care	2023-01-10	MR-101	—
9	Cetirizine (Alerkid)	198	Alerkid	Medications	2023-01-10	AL-101	—
10	Listerine Mouthwash 500ml	200	Listerine	Personal/Oral Care	2022-12-31	LIS-101	—
11	Mefenamic Acid (Dolfinal)	243	Dolfinal	Medications	2022-10-30	DOX-102	—

The “Expired List” feature enables pharmacies to efficiently manage products that have passed their expiration dates. It organizes expired items by name, quantity, and expiry date, allowing for quick identification. Pharmacies can then remove these products from shelves, dispose of them properly, or process returns and reimbursements as needed. This functionality ensures product quality, regulatory compliance, and the safe and effective use of medications by customers.

**Figure 34**

*Supplier list*

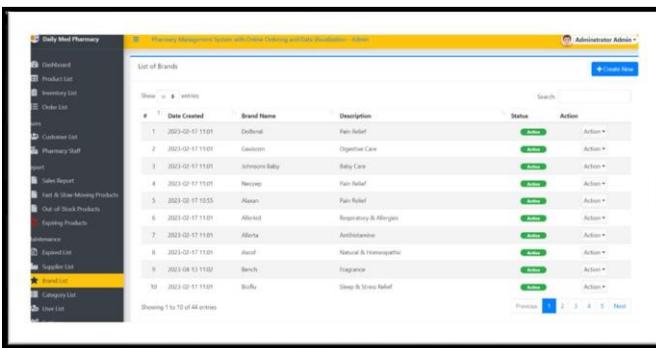


The “Supplier List” feature in the Pharmacy Management System enables pharmacies to maintain a centralized record of their suppliers. It provides essential details for each supplier, including contact information, allowing efficient management of supplier relationships. While it does not support online ordering, this feature is a valuable tool for monitoring supplier information, ensuring effective communication, and supporting informed decision-making in inventory procurement.

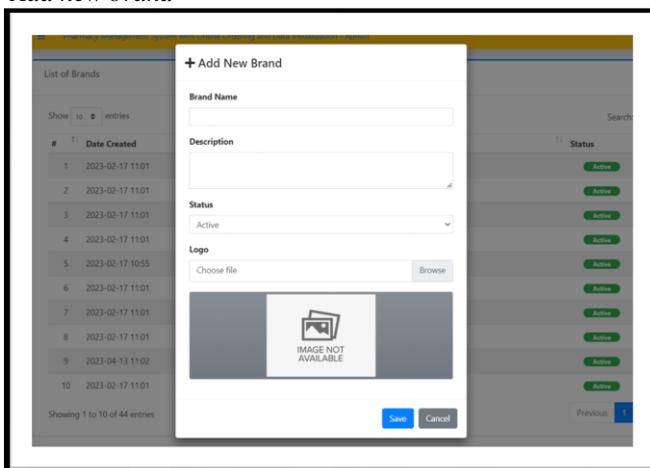
The “Brand List” feature (Figure 35) provides concise information about each drug brand. It allows pharmacy staff and customers to quickly

access details about brands and their associated medications. This functionality supports accurate dispensing and efficient inventory management by enabling the identification and selection of specific brands. Maintaining an up-to-date brand list helps the pharmacy meet customer needs and provide comprehensive drug information.

**Figure 35**  
*Brand list*



**Figure 36**  
*Add new brand*

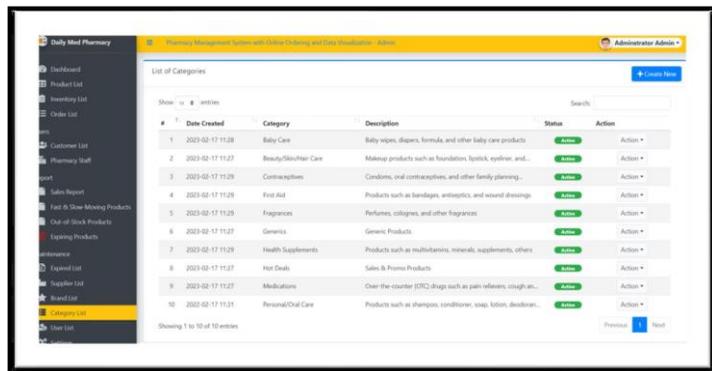


The “Add New Brand” feature allows pharmacists to add new drug brands to the system. Users can input brand names and relevant details,

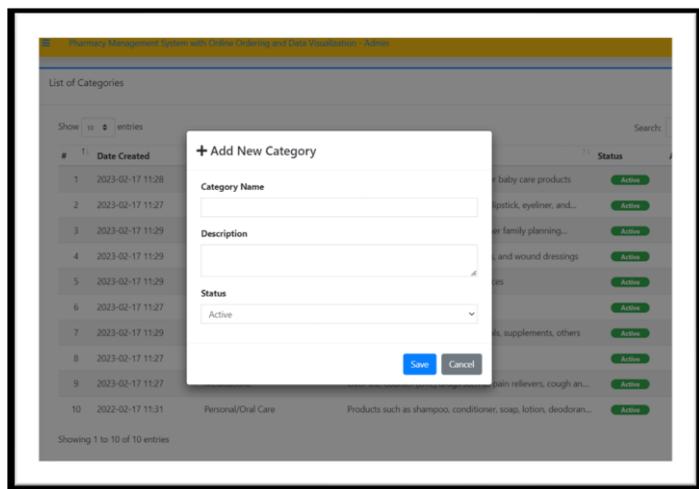
ensuring the database remains current for accurate medication identification and inventory management. This functionality enhances the pharmacy’s product variety and supports improved customer service.

The “Category List” feature (Figure 37) displays the pharmacy’s therapeutic classifications and drug categories. It enables pharmacists and customers to quickly locate medications by category, streamlining retrieval and distribution. Maintaining an organized category list enhances inventory management, facilitates efficient medicine selection, and improves satisfaction for both staff and customers.

**Figure 37**  
*Category list*



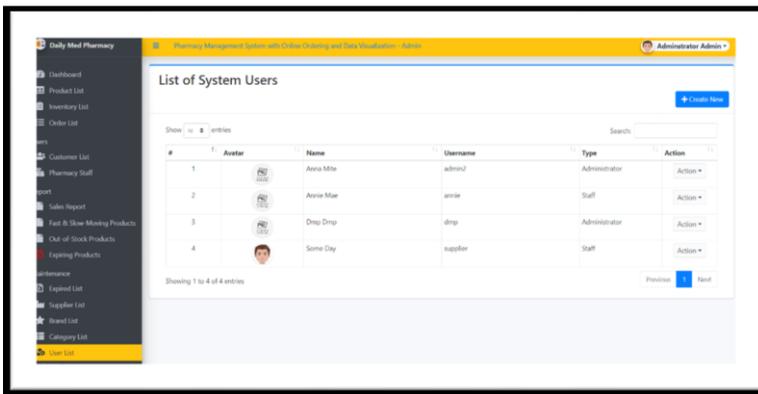
**Figure 38**  
*Add New Category*



The “Add New Category” feature (Figure 38) of the Pharmacy Management System allows pharmacists to create new pharmaceutical categories or therapeutic classes. Staff can organize medications within the system by specifying the category name and description. This functionality enhances the efficiency of drug selection for both staff and customers. By expanding the category list, the pharmacy can better respond to changing medicine inventories and offer a wider range of options to clients.

**Figure 39**

*User list*



The “User List” feature displays all registered users, assisting administrators and staff in managing user accounts. It provides essential information such as username, email, role, and contact details. Administrators can create, update, activate, deactivate, and reset user passwords directly from the User List. This functionality ensures secure and effective management of accounts and access control within the Pharmacy Management System.

### ***System Evaluation and Testing***

User feedback and evaluations were collected from 20 participants, including 5 IT specialists, 3 pharmacy owners, and 12 customers. The

evaluation aimed to assess system effectiveness, usability, and overall user satisfaction. Questionnaires were designed based on ISO 25010, the standard for software product quality. Responses were analyzed using the weighted mean formula, calculating an overall score for each quality characteristic while considering the assigned weight of each criterion.

Figure 40 shows that the pharmacy management system was well-received by participants. It demonstrated strong performance across functionality, efficiency, compatibility, usability, reliability, maintainability, security, and portability. The system’s stable, secure, and user-friendly design aligns with user needs.

**Figure 40**

*Summary of evaluation of the developed system*



Average ratings indicate that most respondents either agreed or strongly agreed with the system’s features and capabilities. Overall, the system is well-designed, efficient, and suitable for varied contexts. It is user-friendly, dependable, secure, and easy to maintain. Areas for improvement include performance efficiency and security, where average ratings suggested agreement rather than strong agreement. These results

indicate that the system fulfills its intended purpose and provides useful insights for further enhancements.

*Compatibility:* Respondents agreed or strongly agreed that the system is compatible with multiple platforms, operating systems, and software components. The average score of 4.21 demonstrates high compatibility, indicating seamless integration with various technologies and consistent user experience across environments.

*Usability:* Most respondents agreed or strongly agreed that the system is easy to learn and use. With an average usability score of 4.22, the system is considered highly usable. Intuitive navigation and simple features enable users to maximize system benefits and promote a positive experience.

*Reliability:* Respondents indicated that the system is reliable, functioning without errors or downtime. An average score of 4.32 confirms high reliability. The system handles data accurately, processes transactions correctly, and maintains consistent performance, instilling user confidence.

*Security:* Respondents agreed that the system provides adequate security to protect sensitive data. The average security score of 4.16 suggests room for improvement. This evaluation highlights potential areas to strengthen system and data security.

*Maintainability:* Most respondents agreed or strongly agreed that the system is easy to update, enhance, and fix. With an average score of 4.23, the system's modular code, clear documentation, and design flexibility support effective maintenance, ensuring long-term viability.

*Portability:* Respondents agreed or strongly agreed that the system is adaptable across platforms. With a portability score of 4.17, the system demonstrates compatibility with multiple devices and operating systems, ensuring mobility and accessibility.

Economic feasibility was evaluated by analyzing costs and benefits of system implementation:

*Costs:* Development, hardware and software procurement, training, and ongoing maintenance were carefully estimated.

*Benefits:* Increased operational efficiency, streamlined processes, improved data accuracy, reduced documentation, and enhanced customer satisfaction were quantified.

Additional considerations included market demand, competitive advantage, and strategic alignment. The analysis concluded that implementation is economically feasible, with anticipated benefits exceeding costs and providing a positive return on investment.

Technology feasibility assessed whether the proposed technological infrastructure could support system implementation, considering:

*Compatibility:* Integration with existing hardware, software, and network infrastructure.

*Availability:* Access to required servers, databases, frameworks, and development tools within the desired timeframe.

*Suitability:* Ability of the technology to meet performance, scalability, security, and support requirements.

The evaluation confirmed that the proposed technology stack is viable and capable of supporting the system's functionality, performance, and long-term sustainability.

Operational feasibility examined whether the system could integrate smoothly with existing processes and workflows. Key factors included infrastructure compatibility, availability of resources, and impact on daily operations. The analysis confirmed that the system can be successfully implemented without significant disruption to organizational activities.

## **Conclusion**

The web-based pharmacy management system with online ordering and data visualization has achieved its objectives. The system's positive attributes demonstrate its effectiveness in meeting the expectations of both the pharmacy owner/manager and customers. While security enhancements are recommended, the overall evaluation confirms the system is a robust, efficient, and practical solution for modern pharmacy management.

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# Web-based SMS Notification Appointment and Records Management System

*Cristine Rebullo, Pamela Rogelio, Jennifer Venus & Jennifer Reynaldo*

Effective records management plays a pivotal role in ensuring the smooth operation of health clinics, as it guarantees that patient files and administrative documents are systematically preserved and easily retrievable (Amin et al., 2020; Bali et al., 2011). Traditional manual record-keeping, which involves storing piles of paper in folders, cabinets, or boxes, often poses challenges such as misplacement, delayed retrieval, and susceptibility to physical damage. In contrast, a digital records management system streamlines these processes, offering quick and accurate access to specific information when needed (Vos et al., 2020; Julaihi et al., 2024; Putri and Yulianti, 2024). As Chopade and Pachghare (2021) explain, the core benefits of implementing such systems include the elimination of redundant data, faster and simpler retrieval, and enhanced security of sensitive information. These advantages are particularly critical for hospitals and clinics, where daily operations involve managing large volumes of confidential medical records. Without a proper digital system, retrieving files can be not only cumbersome but also time-consuming, potentially leading to service delays and inefficiencies.

Beyond records management, clinics also face the challenge of ensuring patients comply with scheduled appointments. An SMS notification appointment system emerges as an effective solution to this problem. In the fast-paced lifestyle of today, patients often forget medical appointments due to personal or professional commitments. Study revealed that approximately 30% of patients require reminders for follow-up visits, and as many as 70% end up missing their schedules altogether (Alkomos et al., 2020). This high no-show rate can disrupt clinic operations, reduce service efficiency, and even result in financial losses. Research highlights that SMS messages have a 98% open rate (Sumrak et al., 2025), making them a reliable communication channel. By integrating SMS notifications, clinics can significantly reduce missed appointments, improve patient turnout, enhance continuity of care, and ultimately optimize their operational workflow.

Javaid et al. (2024) further underscore how the integration of computer-based management systems has revolutionized organizational practices across various industries, including healthcare. Both small-scale and large-scale clinics now rely on electronic systems to automate data processing, from storing patients' case histories to monitoring their treatment progress. Such advancements not only minimize the risk of human error but also enhance decision-making, resource allocation, and patient satisfaction. Modern information systems, therefore, serve as valuable tools that support both administrators and patients in achieving more organized and reliable healthcare management.

For clinic administrators, digital systems streamline appointment scheduling, patient registration, and record monitoring, thereby reducing clerical workload and increasing efficiency. For patients, the SMS notification system provides timely and convenient reminders, often sent at

least one day before their scheduled check-up or consultation. This proactive approach encourages patient compliance with treatment schedules, reduces instances of missed visits, and strengthens the overall provider-patient relationship.

The main objective of this study is to minimize the clinic's dependence on paperwork by introducing a comprehensive solution: the web-based SMS notification appointment and records management system. The system is designed not only to save time spent on manual data recording but also to evaluate and enhance the overall efficiency and effectiveness of healthcare service delivery. By integrating records management with automated appointment reminders, the system seeks to foster a more reliable, patient-centered, and technologically advanced approach to clinic management.

## **Theoretical Framework**

### ***The Importance of Maternal Record Management***

Maternal records play a critical role in ensuring the health and safety of expecting mothers, particularly first-time mothers, as they provide a comprehensive and organized account of prenatal care (Joseph et al., 2022). These records allow healthcare providers to track and monitor potential risks or complications during pregnancy, enabling timely interventions that can significantly improve maternal and fetal outcomes. Traditionally, maternal records have been maintained on paper and stored in physical cabinets or filing systems. While paper-based records may allow straightforward retrieval in some cases, they are prone to human error, such as inaccurate data entry, misplaced files, or duplication of information. Such inefficiencies can delay the provision of care and complicate patient

management, potentially affecting pregnancy outcomes.

In the Philippines, the healthcare system has largely relied on manual record-keeping, especially in hospitals and clinics (De Mesa et al., 2024; Elepaño et al., 2025). However, challenges associated with paper records, such as limited storage capacity, difficulty in updating information, and risk of data loss, underscore the need for more efficient solutions. Implementing a digital record management system offers a practical alternative, providing accurate, organized, and secure storage for patient information while enabling quick retrieval of critical data when needed. Electronic record systems not only reduce administrative workload but also ensure that maternal information is consistently reliable, supporting better clinical decision-making and improving overall maternal healthcare management.

### ***Integration of Electronic Records with SMS Notification Systems***

Electronic record management systems become even more effective when paired with patient communication tools, such as SMS notification systems (Quinn et al., 2019). These systems serve as reminders for patients regarding their scheduled appointments, helping reduce late arrivals and missed visits, which are common in traditional healthcare delivery models. Timely notifications enhance patient adherence, encourage engagement, and improve punctuality, ultimately leading to a more streamlined and efficient healthcare service.

Research has consistently demonstrated that electronic record systems are more accurate and reliable than manual systems. The 2015 Maternity Care Patients Study found that authorized healthcare personnel could retrieve specific patient information quickly and efficiently, which is vital for monitoring pregnancy progress and responding to potential

complications. When combined with SMS reminders, these systems ensure that patients are consistently reminded of upcoming check-ups, fostering compliance with prenatal care schedules. This integration contributes to improved maternal health outcomes by minimizing missed appointments, reducing administrative errors, and supporting continuity of care.

### ***System Usability and Operational Efficiency***

Beyond accuracy and patient communication, the usability of digital systems is a key factor in their effectiveness. A system that is intuitive, user-friendly, and easy to navigate can significantly reduce training time for clinic staff, allowing them to focus more on patient care rather than administrative tasks. Operational efficiency is enhanced when users can quickly perform tasks such as updating patient records, generating reports, and tracking appointments.

The developed system demonstrates that ease of use directly impacts adoption and satisfaction. Even staff members who were initially unfamiliar with digital tools were able to operate the system with minimal guidance. This efficiency reduces workflow bottlenecks, minimizes errors, and ensures that patient care processes are streamlined. Consequently, usability not only benefits staff productivity but also indirectly improves patient experience by ensuring timely service delivery and accurate record-keeping. The system thus represents a practical solution that enhances both operational efficiency and user satisfaction in maternity care settings.

## **Research Framework**

### ***Data***

This phase presents the evaluation of data collected from

respondents of the web-based SMS notification appointment and records management system. The data provides insights into system effectiveness, usability, and user satisfaction.

This study involved 50 participants who completed the survey. The total number of respondents was determined using Slovin's formula, and a random sampling method was applied to distribute the questionnaires, ensuring a representative sample of the population.

Data for this project were collected using questionnaires. A questionnaire is a set of carefully standardized questions designed for selected respondents to answer, allowing the systematic collection of relevant information. The survey instrument was designed to gather factual information from respondents and was classified according to ISO 25010 into four categories: performance efficiency, maintainability, suitability, and usability. A Four-Point Likert Scale was employed to capture participants' responses, with categories of Strongly Agree, Agree, Disagree, and Strongly Disagree. Each scale was assigned a corresponding mean range to facilitate the interpretation of evaluation results for each survey item.

The study employed the weighted mean to evaluate the overall responses, providing a quantitative assessment of how well the developed system maintains its performance, reliability, suitability, and usability. The objectives of the study, along with the outcomes of validation and testing, were reported and analyzed to measure the effectiveness of the developed system.

### ***Experimental Design***

In the design phase, the proponents developed a system to transition manual patient records into an electronic maternity management system.

Once the system design and features were finalized, programmers began the actual creation and integration of the system.

Figure 1 illustrates the experimental design of the study. The process begins with the admin, who manages the system, logging in using a verified username and password. Upon successful authentication, the admin gains access to the admin dashboard, which provides an overview of the maternity clinic's services, billing statements, and inventory management system.

**Figure 1**

*Experimental design of the study*



**Figure 2**

*Design of patient interaction*

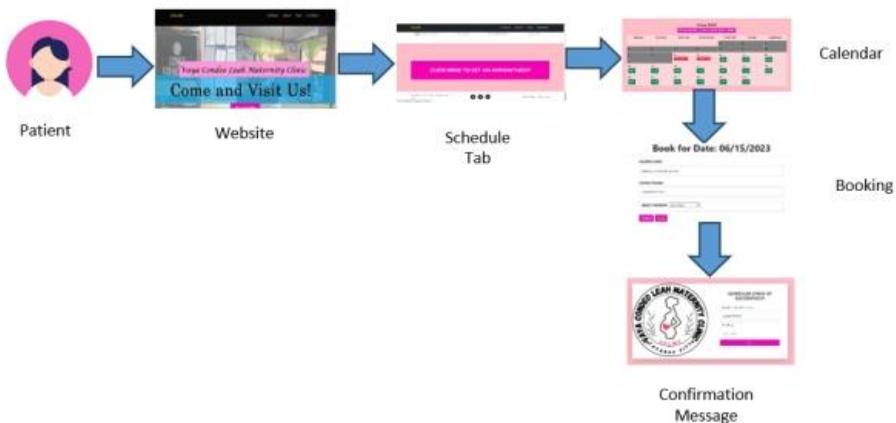


Figure 2 illustrates the experimental design for patient interactions with the system. The process begins with the patient accessing the website and navigating to the schedule tab. Using the calendar, the patient selects a

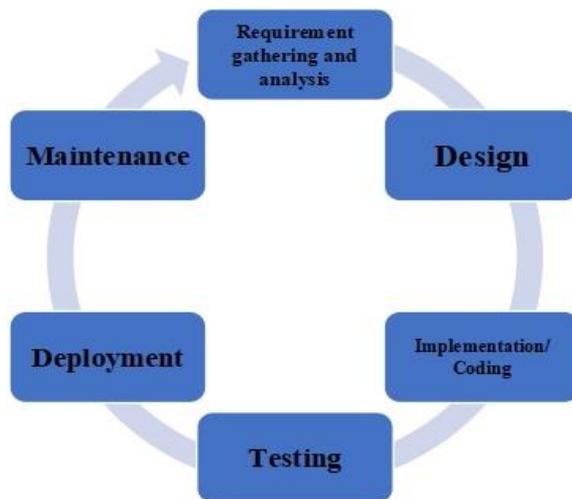
preferred date based on their availability. Next, the patient proceeds to the booking form, where they enter their name, contact information, and select a preferred midwife as their attending caregiver. Finally, a confirmation message is displayed, indicating that the appointment has been successfully booked.

### ***Procedures of the Different Phases***

Before beginning system development, it is essential for developers to understand the operations and requirements of the maternity clinic. Familiarity with the institution allows developers to identify the needs of stakeholders, outline system requirements, and plan the development sprints effectively.

Understanding the business requirements prior to development is crucial; however, the adaptability of the Agile methodology allows for adjustments as new insights or changes arise. This ensures that the software solution is both effective and aligned with the clinic’s needs. Thorough project planning before development not only prepares the team for upcoming sprints but also increases the likelihood of project success.

**Figure 3**  
*Agile model*



*System users.* Patients have access to the website to book appointments, while administrators can access the full system, including patient profiles, medical histories, doctor prescriptions, schedules or appointments, staff information, and reports.

*Implementation/Coding.* During the implementation phase, programmers use various languages such as PHP and JavaScript. They also utilize technologies and tools including Visual Studio Code, HTML, the CodeIgniter framework, Bootstrap, CSS, XAMPP, and MySQL to build a robust and effective system tailored to the client's needs.

*Testing.* At this stage, the system becomes available to users, and the development team conducts comprehensive testing to ensure full functionality. Any bugs or issues identified are promptly addressed. User feedback is also gathered to guide refinements and improvements.

*Deployment.* Once successfully installed, clients can access the software. The development team provides ongoing support to ensure smooth system operation and to address any irregularities. Further iterations may be implemented to enhance the system or add new features.

*Maintenance.* During the maintenance phase, programmers continue to update and improve the system. A well-designed system should be accessible, reliable, and easy to maintain. Maintenance ensures that the clinical management system continues to process data effectively and meets the operational needs of the maternity clinic.

Before diving into the progression of system development, it is important for developers to thoroughly understand the institution where the project will be implemented. In this case, researchers and developers alike need to familiarize themselves with the specific context, operations, and needs of the maternity clinic. This foundational knowledge allows developers to make informed decisions, identify challenges, and propose

solutions that genuinely address the clinic's requirements. By engaging with stakeholders early on, developers can outline clear project requirements and prepare well-structured development sprints.

Understanding the business demands before initiating development is a critical step that ensures alignment between the clinic's needs and the system's capabilities. At the same time, the use of Agile methodology provides the flexibility to adapt to changes that may arise during the process. Agile allows teams to refine features, address unforeseen issues, and continuously improve the system throughout its development cycle. This adaptability is essential in healthcare environments, where patient needs, administrative practices, or technological requirements may evolve.

Careful project planning prior to actual development increases the likelihood of project success. It equips the development team with a roadmap to follow, establishes clear goals, and ensures that resources are efficiently allocated. Moreover, it fosters preparedness for the upcoming sprints, enabling the team to work systematically while maintaining the capacity to adjust as necessary. Ultimately, combining thorough institutional understanding with Agile's flexibility ensures that the software solution is not only well-designed but also effective in supporting the maternity clinic's operations.

## **Technical Framework**

This section presents the materials used in developing the system. In addition, it presents the overview and evaluation of the system.

### ***Materials***

#### ***Software***

Visual Studio Code was used as the primary text editor for coding

the web-based SMS notification appointment and records management system. The system was developed using JavaScript, PHP, MySQLi, the CodeIgniter framework, Bootstrap, and CSS. Visual Studio Code provides a streamlined environment for debugging, task execution, and version control, offering developers the essential tools for a rapid code-build-debug cycle. More complex workflows can be handled by full-featured IDEs, such as Visual Studio IDE, if needed.

**Table 1**

*Software specifications and software platform*

System Type	x64-based PC
Operating System	Windows 10 Pro
System Model	2OAU030JP
Language	Php, JavaScript
System Directory	Xampp localhost, MySQLi
Text Editor	Visual Studio
Designing	HTML, CSS, JavaScript

### ***Hardware***

The successful implementation of the proposed system requires specific hardware components that will support its development and operation. These hardware requirements are essential to ensure that the system functions efficiently, processes data effectively, and delivers reliable performance for both administrators and patients. The details of the necessary hardware specifications are presented in Table 2, which outlines the minimum and recommended requirements needed for the development and deployment of the system. By meeting these requirements, the clinic can guarantee smooth execution of tasks such as records management,

appointment scheduling, and SMS notifications, while also ensuring system scalability and long-term usability.

**Table 2**

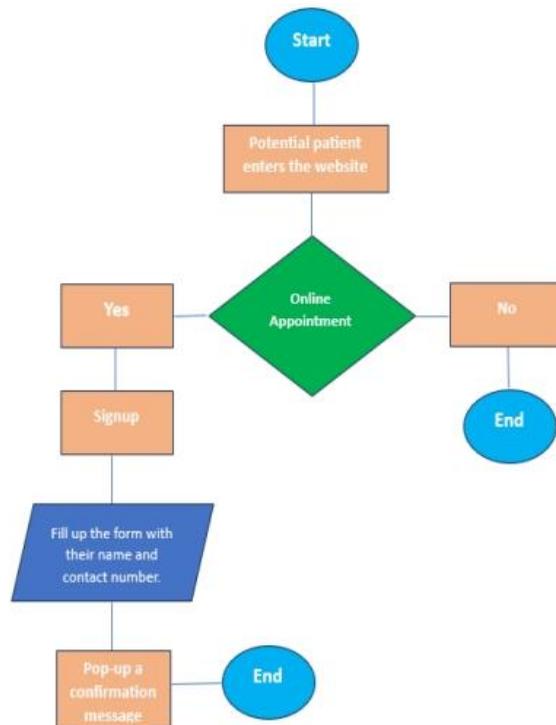
*Hardware specifications*

Laptop	Hp, ASUS, Dell, MacBook, or any kind of laptop
Mouse	Wireless or wired type
External Keyboard	Wireless or cable
WIFI	Pocket Wifi, piso wifi, mobile hotspot
Processor	Intel ® Core™ i5-4200M CPU @ 2.50GHz, 2494 Mhz
RAM	4.00 GB
Hard Disk Space	20 GB (x6 Bit)

**Flowchart Diagram**

**Figure 4**

*Process of online appointment through website*



The flowchart in Figure 4 illustrates how patients interact with the clinic’s website and the appointment booking system. It visually represents the sequence of steps from accessing the website to successfully scheduling an appointment, helping to clarify the system’s workflow and user interactions.

### ***ERD Case Diagram***

**Figure 5**  
*ERD case diagram for admin*

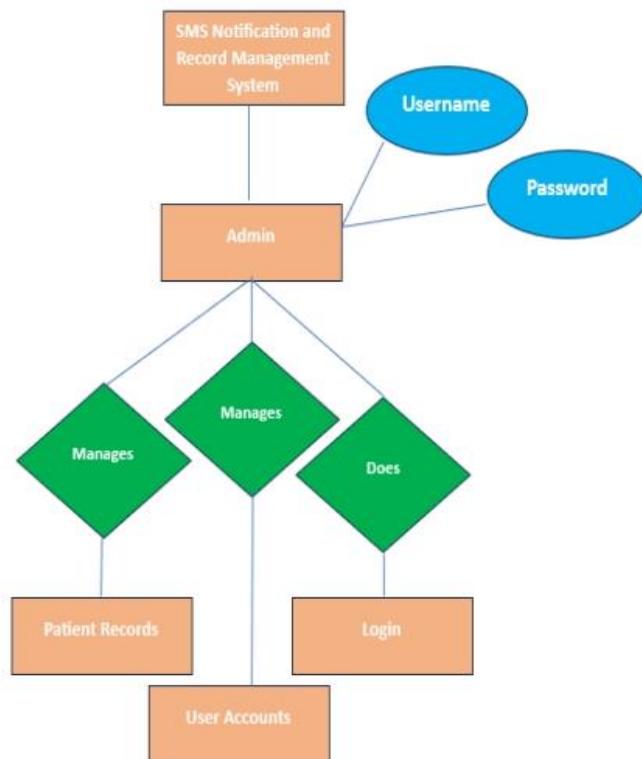
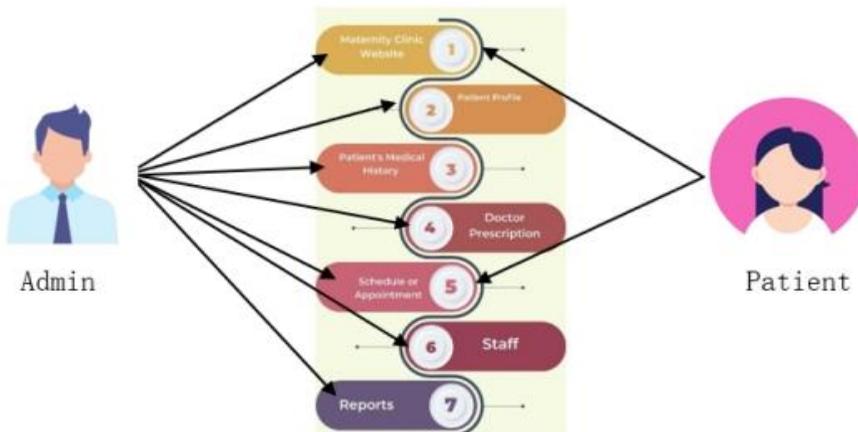


Figure 5 shows that the system is managed by the admin. First, the admin must enter a verified username and password to log in. Once authenticated, the admin can access and manage all data stored within the system.

**Figure 6**

*Design of the developed system*

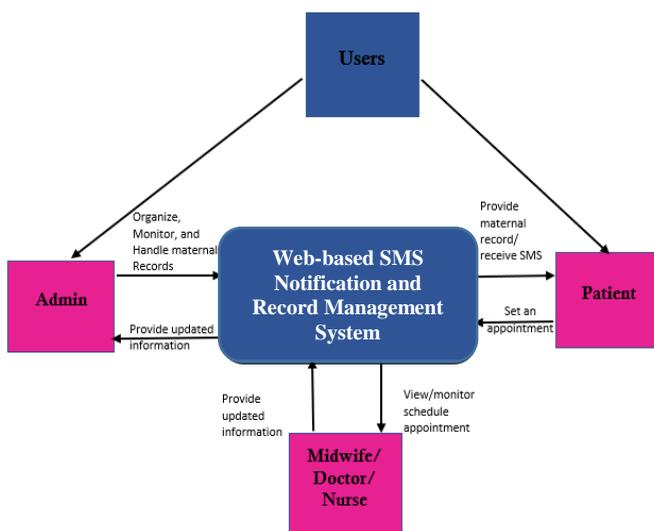


### **Modeling**

System modeling is a technique used to organize and define the structure and flow of data within a system, as well as the logic, procedures, and rules implemented by system processes.

**Figure 7**

*The context data flow diagram of the developed system*

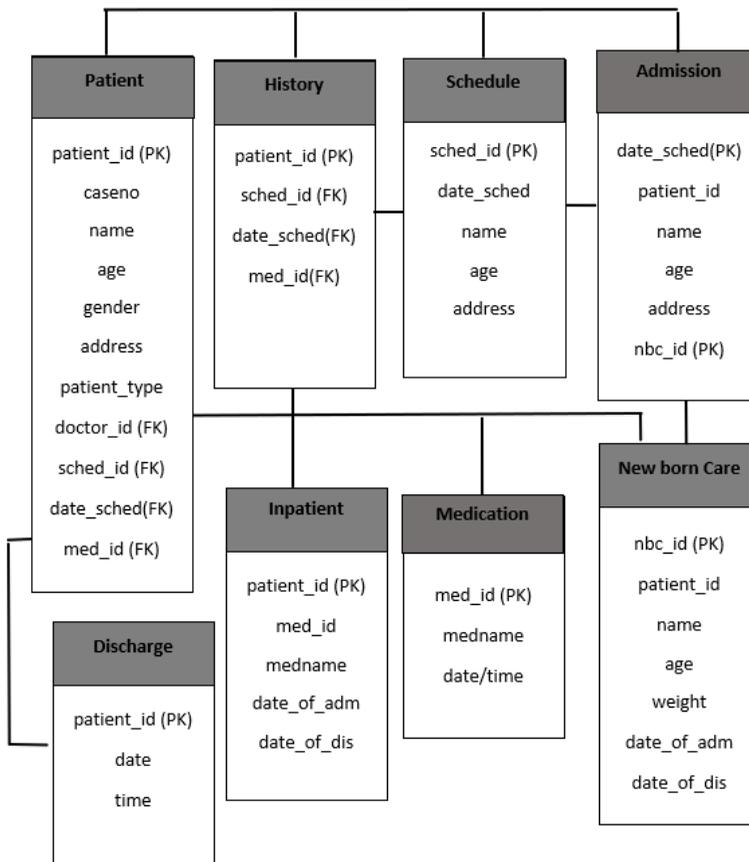


The study illustrates the system’s logical design using a context-level Data Flow Diagram (DFD). A context DFD provides a high-level view of the system, showing its boundaries and scope. The central element in the diagram is the web-based SMS notification and records management system. The system interacts with three external agents: administration, midwives and clinic personnel, and expectant women. Figure 8 presents the developed context DFD for the system.

### Database Schema

**Figure 8**

*Database schema of the system*



## ***Database Tables***

The clinic management system comprises eight tables:

*Patient table* – Manages all patient records, including patient ID, name, age, address, patient type, doctor ID, and schedule ID.

*History table* – Contains patient history information, including patient ID, schedule ID, scheduled date, and medication ID.

*Schedule table* – Stores schedule records, including schedule ID, scheduled date, name, age, and address.

*Admission table* – Maintains patient admission records, including patient ID, scheduled date, name, age, address, and NBC ID.

*Medication table* – Contains records of medications assigned to patients.

*Inpatient table* – Manages patient ID, medication ID, medication name, date of admission, and date of discharge.

*Newborn care table* – Maintains records of newborns, including name, weight, date of admission, and date of discharge.

*Discharge table* – Stores patient ID, discharge date, and time information.

## **Figure 9**

### *Website design*



Figure 9 shows the design of the website while Figure 10 shows the

style of the calendar in booking a check-up date with the clinic.

**Figure 10**

*Calendar*



Figure 11 shows the fields in booking an appointment.

**Figure 11**

*Booking appointment*

**Book for Date: 06/15/2023**

MAIDEN NAME  
REBULLO CRISTINE ESTILA

Contact Number  
091736101515

SELECT MIDWIFE: Lilia Linoq

Submit Back

Figure 12 shows the confirmation message indicating successful

booking.

**Figure 12**

*Confirmation message*



The following figures illustrate how the system operates. First, the patient visits the website. If they wish to schedule an online appointment, they can navigate to the Schedule tab and click the square button to begin the process. Next, they select their preferred date and sign up for an appointment. Finally, a confirmation message will appear, indicating that the appointment has been successfully booked.

The admin logs in by entering their username and password.

**Figure 13**

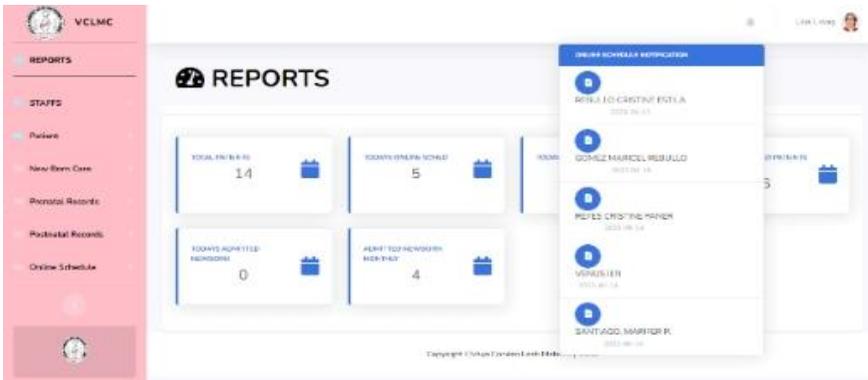
*Admin's login*



After logging in, the dashboard will appear, displaying reports and a summary of the system's information.

**Figure 14**

*Dashboard / Reports*



Under the Newborn Care section, the admin can view records.

**Figure 15**

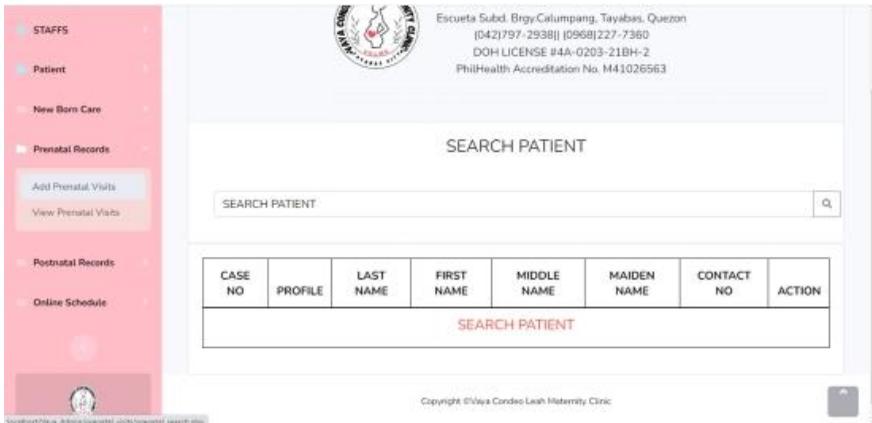
*View records*



To retrieve patient information, the user must go to the search bar and type the name of the patient to be retrieved.

**Figure 16**

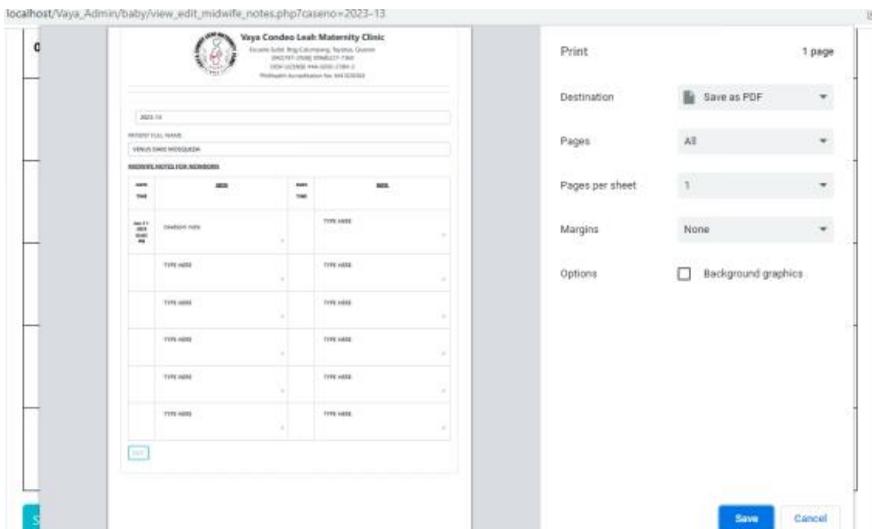
*Search patient*



The system also allows documents to be printed.

**Figure 17**

*Printable documents*



### ***Cost Benefit Analysis***

Operational cost-benefit analysis evaluates and quantifies the monetary value of the system's benefits and costs to determine whether the

investment is justified. The system’s operational costs are summarized, including details on duration, monthly expenses, and the total overall cost of using the system.

**Table 3**

*Operational cost analysis*

<b>Operational Cost</b>	<b>Units</b>	<b>Months</b>	<b>Cost</b>	<b>Total</b>
Electricity (Computer and Printer)	4	7	Php 450.00	Php 3,150.00
Internet Fee	4	7	Php 400.00	Php 11,200.00
Maintenance Fee	4	3	Php 500.00	Php 6,000.00
<b>Subtotal</b>				<b>Php 20,350.00</b>

**Table 4**

*Developmental cost analysis*

<b>Development Cost</b>	<b>Units</b>	<b>Months</b>	<b>Cost</b>	<b>Total</b>
Programmers	1	1	Php 17,578.00	Php 17,578.00
System Analyst	1	1	Php 30, 954.00	Php 30, 954.00
Internet Fee	1	12	Php 1,299.00	Php 15, 588.00
Researcher	2	12	Php 22, 992.00	Php 45,984.00
<b>Subtotal</b>				<b>Php 110,104.00</b>

Table 3 and Table 4 present the estimated cost-benefit analysis to determine whether the system provides a worthwhile investment.

### ***System Evaluation/Testing***

This section presents the survey results based on responses from 50 participants. The questionnaire was developed using the ISO 25010 standard, focusing on four key aspects of system quality: performance efficiency, maintainability, suitability, and usability.

**Table 5***Weighted mean distribution of the criteria for the developed system*

<b>Criteria</b>	<b>Weighted Mean</b>	<b>Remarks</b>
Performance Efficiency	3.76	Strongly Agree
Maintainability	3.78	Strongly Agree
Suitability	3.64	Strongly Agree
Usability	3.76	Strongly Agree
<b>Average</b>	<b>3.74</b>	<b>Strongly Agree</b>

Table 5 shows that the overall system evaluation survey yielded an average weighted mean of 3.74, indicating that respondents rated the system as outstanding in terms of performance efficiency, maintainability, suitability, and usability. This demonstrates that the system effectively meets the specified requirements.

For Performance Efficiency, the system was found to be easy to understand, with an average weighted mean of 3.76 and a remark of Strongly Agree, reflecting respondents' satisfaction with the system's performance.

Regarding Maintainability, the system was perceived as easy to maintain and cost-effective, with an average weighted mean of 3.78 and a remark of Strongly Agree, indicating that respondents are satisfied with its maintainability.

In terms of Functional Suitability, respondents agreed that the system functions well and could serve as a valuable tool for their community. The average weighted mean for this attribute was 3.64, with a remark of Strongly Agree, confirming that the system meets its intended functional requirements.

For Usability, respondents who were initially unfamiliar with the system indicated that they were able to quickly learn its controls within a

few minutes. The average weighted mean for Usability was 3.76, with a remark of Strongly Agree, highlighting that the system is user-friendly and easy to operate.

*Economic feasibility.* Economic feasibility assesses whether the anticipated benefits of the system outweigh or justify its projected costs. A cost-benefit analysis was conducted to evaluate the application. By examining the system's advantages and potential drawbacks, feedback on the overall costs and benefits was obtained, providing an accurate comparison. The ISO 25010-based questionnaire survey also contributed to evaluating the economic feasibility, confirming that the system delivers value relative to its cost.

*Technological feasibility.* The technological feasibility of the system was confirmed through successful project completion and positive feedback from respondents. Many highlighted that the system is particularly useful for generating monthly reports and performing routine tasks efficiently.

*Operational feasibility.* The developed system is operationally feasible, as it is easy to manage and requires minimal training for users. Survey results indicate that clients were satisfied with the system's functionality and found it intuitive, requiring only a brief demonstration to understand its operations.

## **Conclusion**

The developed system is a web-based application with features that facilitate patient appointment booking through the website. For administrative users, the system allows accurate storage, updating,

archiving, and retrieval of patient information. The system effectively addresses the challenges faced by some clinics in managing patient records. It also sends SMS notifications to patients, reminding them of their appointments, thereby reducing the likelihood of late arrivals or no-shows. Additionally, it supports the creation of electronic documentation for in-clinic stays.

Evaluation results indicate that the system is functional, reliable, and valuable. Respondents unanimously agreed that the system is user-friendly, enabling clients to perform tasks efficiently and accurately. The system successfully met ISO 25010 standards for performance efficiency, maintainability, functional suitability, and usability.

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# Web-based Online Reservation Utilizing Reinforcement Learning Algorithm

*Shaneen Delfin, Marie U. Vergara, Reymark R. Vergara & Guiller I. Yenna*

The growing demand for hotels and resorts has created significant opportunities for the adoption and expansion of technology (Somera & Petrova, 2024; Amirulloh et al., 2024; Zahidi et al., 2024). One notable development is the rise of online booking systems in the hospitality industry, including hotels, resorts, airlines, and other service-oriented businesses. In line with this trend, hotels and resorts require an efficient system to streamline and enhance its booking and reservation processes. To meet customer needs, the resort's system must be both user-friendly and tailored to its specific operational requirements.

Implementing a web-based reservation system alleviates the complexity of traditional booking procedures, reducing the need for manual processing and minimizing errors (Park et al., 2018; Sahara et al., 2025). Such systems can estimate total reservation costs and significantly reduce the time required for staff to complete bookings. As technology continues to advance, customers increasingly expect faster and more efficient services. A well-designed online reservation system allows customers to select and reserve their preferred rooms quickly, enhancing overall

satisfaction.

This paper seeks to address these needs. The system features two main components: a back-end dashboard for administrative use and a customer-facing front end. The back-end allows resort staff to manage, monitor, and verify bookings efficiently, consolidating all user data in one location and reducing reliance on multiple spreadsheets. The customer-facing interface is intuitive, enabling seamless booking and payment. First-time users will provide their information through a registration form, while subsequent bookings will be faster due to stored data.

A key feature of the system is the Reinforcement Learning Algorithm (RLA). RLA enables the system to learn optimal decision-making strategies by evaluating the correctness of user commands, rewarding accurate actions, and providing consequences for incorrect ones (Gao et al., 2025; Taherdoost, 2023). This algorithm is critical for optimizing system processes and ensuring efficient, step-by-step decision flows based on user interactions.

In the hotel and resort industry, booking systems are central to operational efficiency and business success. Resorts must manage room availability, amenities, and customer inquiries effectively. Without a dedicated booking system, they rely on personal phone calls or social media messages, which is time-consuming and prone to errors. Implementing an online booking system will streamline operations, enhance customer service, and support marketing efforts by providing visual advertisements and detailed information online, thereby attracting more guests.

The use of management information systems (MIS) within the resort supports effective inventory and reservation management. The inventory system, a crucial component of MIS, tracks available resources and updates in real-time whenever a booking occurs. This allows the resort to anticipate

demand, prepare accommodations, and maintain necessary supplies, ensuring seamless guest experiences. MIS also helps identify booking trends, guiding decisions on purchasing and maintaining inventory (Ali, 2019; Hamdat et al., 2024).

Reinforcement learning is designed to maximize rewards through trial-and-error learning. Unlike traditional machine learning methods, it does not provide explicit instructions for each action (Sutton & Barto, 2015). The agent observes the current state, selects actions based on exploration and exploitation strategies (Terven, 2025), and receives a reward ( $r_{t+1}$ ), updating its knowledge of the environment for future decisions. Q-learning, a model-free reinforcement learning technique, divides operations into discrete episodes, updating Q-values based on actions taken and rewards received (Premakumari et al., 2025; Alavizadeh et al., 2022)). This approach allows the system to learn optimal policies, balancing short-term and long-term rewards.

An online booking system replaces manual spreadsheets and data entry, automating processes such as payment, scheduling, availability tracking, and notifications. It enables 24/7 bookings, accommodating customer preferences such as partial or full payments. Automated features also support reporting and resource management, benefiting both customers and resort staff. Hence, this system ensures that customers can make bookings at any time without being constrained by operating hours. It enhances accessibility, convenience, and overall customer satisfaction. Additionally, the system safeguards personal information through a dedicated data privacy interface, preventing fraud, identity theft, and other security risks associated with online reservations.

## Theoretical Framework

### *Technological Innovations in Booking Systems*

In today's competitive hospitality industry, technological innovations play a central role in shaping how resorts and hotels manage their reservations and deliver services to guests. The introduction of online booking platforms transformed the traditional process by eliminating the reliance on manual spreadsheets and phone inquiries. This shift allowed businesses to accommodate bookings 24/7, giving customers the convenience of securing reservations at any time, regardless of business hours. More advanced systems now integrate artificial intelligence (AI) and machine learning techniques to further optimize booking efficiency (Sousa et al., 2024; Grieco et al., 2025; López-Naranjo et al., 2025).

One notable innovation is the RLA, which equips booking systems with the ability to learn and adapt based on user interactions. Unlike rule-based systems, RLA applies a trial-and-error approach to determine the most effective response to user commands. When customers input correct information, the system confirms and processes the request. Incorrect inputs, on the other hand, are met with programmed feedback or corrective actions, allowing the system to guide users toward successful bookings. This creates a dynamic feedback loop where the system continuously improves its performance over time.

The implication of this technology is significant: it reduces human intervention in repetitive tasks, minimizes booking errors, and enhances the responsiveness of the system to different customer behaviors. By integrating RLA, resorts can offer a more personalized booking experience, where the system “learns” preferences and provides tailored suggestions (Chen et al., 2022; Leka et al., 2025). This not only boosts efficiency but

also increases customer satisfaction, as users perceive the system as intuitive and user-friendly. Ultimately, these innovations highlight how automation and AI-driven systems are becoming indispensable tools for modern resorts and hotels.

### ***Role of MIS and Inventory Management***

While booking systems focus on the customer-facing aspect of reservations, MIS provide the backbone for internal operations. MIS refers to the computer-based systems that collect, store, and analyze data to support decision-making in an organization. In the context of resorts and hotels, MIS plays a critical role in managing inventory, resource allocation, and scheduling, ensuring that the business operates smoothly behind the scenes.

The inventory subsystem of MIS is particularly vital. Each time a reservation is made, the system automatically updates the records of available rooms, amenities, and consumable resources. This ensures that managers and staff have real-time insights into the current status of accommodations, dining facilities, pools, and other entertainment areas. Such real-time monitoring reduces the risk of overbooking, which is a common challenge in manual systems. It also allows management to prepare accommodations and services ahead of guest arrivals, contributing to a seamless experience.

Moreover, MIS enables data-driven decision-making by identifying patterns and trends in customer reservations (Chen et al., 2012). For example, managers can analyze seasonal peaks, determine which facilities are in high demand, and forecast supply needs. This helps the resort plan purchases, schedule staff, and maintain facilities proactively. In addition, MIS supports long-term strategic decisions, such as expanding certain

amenities or launching targeted promotions, based on historical booking data.

By combining operational efficiency with strategic foresight, MIS and its inventory component provide resorts and hotels with a competitive advantage. They not only support daily operations but also ensure that the business is adaptable to fluctuations in demand and capable of delivering consistent service quality.

### ***Existing Studies on Reservation Systems in Resorts and Hotels***

A number of studies and system designs highlight the growing reliance on computerization in the hospitality industry. These works serve as evidence that both small-scale resorts and large hotels benefit significantly from adopting automated reservation systems.

Lagman (2018) introduced a LAN-Based Reservation with Billing System for Hacienda Gracia Resort and Hotel, designed to improve reservation management and billing accuracy. The system minimized manual errors, reduced delays, and streamlined the handling of customer bookings. Importantly, the study demonstrated how computerization could bridge the gap between guest expectations and operational limitations, particularly in resorts that previously relied on face-to-face or social media-based bookings.

Similarly, Adegboye and Akingbade (2023) designed a website for Atican beach resort for booking and reservation using HTML, PHP and MySQL. This system provided instant booking confirmations and allowed customers to modify their arrangements with minimal hassle. By maximizing the resort's online presence, the system also improved visibility, attracted more potential customers, and offered competitive rates. The study highlighted how direct online booking systems not only reduce

reliance on third-party platforms but also strengthen customer relations through convenience and transparency.

Together, these studies reflect a broader trend: the hospitality industry is steadily moving toward automation and digitalization to remain competitive. Resorts and hotels that adapt to technological innovations in reservations position themselves to achieve higher efficiency, increase customer satisfaction, and expand their market reach. These findings emphasize that computerization is not merely a luxury but a necessity in ensuring business sustainability in a fast-evolving industry.

## **Research Framework**

### *Data*

This study gathered data from the survey results from 20 respondents. The sample size was determined using Slovin's formula, and a random sampling method was employed to distribute the questionnaires. The questionnaire was designed based on ISO/IEC 25010 standards, covering the following aspects: functionality and performance efficiency, maintainability, usability, accessibility and compatibility, and security. The four-point Likert scale was used to evaluate each criterion. Respondents selected from the following categories: strongly agree, agree, disagree, and strongly disagree. Each response category corresponds to a mean range, which determines the interpretation of the evaluation results. To analyze the responses, the weighted mean formula was applied.

### *Experimental Design*

Figure 1 illustrates the experimental design of the study. The process begins with the admin, who manages the system, logging in with a valid

username and password. Upon successful login, the admin accesses the dashboard, which displays the services offered by the resort and provides tools to manage reservations efficiently.

**Figure 1**

*Experimental design of the study*



The system will process client information throughout its operations, from input to output. Data will be collected directly from the forms completed by customers during the booking process on the website. This information will then be stored, processed, and used to manage reservations efficiently.

### ***Ethical Considerations***

Online reservation systems can raise several ethical concerns that must be addressed to ensure responsible and equitable use. Key considerations include:

*Privacy:* Online reservation systems collect and store users' personal information. It is essential to ensure that this data is kept secure and used solely for the purposes for which it was collected.

*Accessibility:* The system should be accessible to all users, including individuals with disabilities. This requires designing the website or application to comply with accessibility standards and ensuring that information is easy to access for everyone.

*Fairness:* The system must provide equal access to all users. This includes implementing anti-discrimination policies and ensuring that the system does not favor certain users over others.

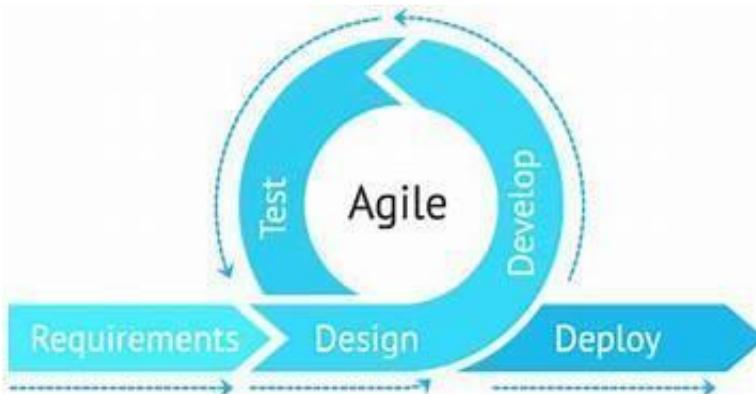
*Transparency:* The reservation system should operate transparently, allowing users to understand how decisions are made. This includes disclosing any algorithms or biases that may influence recommendations or other system outputs.

*Responsibility:* The system’s owners and operators are accountable for maintaining system security, protecting users’ data, and ensuring ethical use. They must take appropriate measures to prevent and address any unethical or harmful practices associated with the system.

### ***Agile Software Development and Client Interaction***

**Figure 2**

*Agile methodology model*



Agile software development emphasizes flexibility and encourages modifications from clients and other stakeholders throughout the project lifecycle. The development team actively seeks feedback by creating joint releases and iterating the software in successive cycles. Changes in

customer requirements are not considered challenges; rather, they are integral to the development process. Incorporating client feedback and interaction is critical to Agile methodologies, as it ensures the software product aligns with the evolving needs of the users.

### ***Procedures of the Different Phases***

Scientific applications and experimental facilities generate massive datasets, which often need to be transferred to remote sites for collaboration, processing, and long-term storage. To support increasingly data-intensive research, Software-Defined Networks (SDNs) are used to facilitate high-speed and reliable data transfer between participating institutions. Next-generation research networks leverage SDN technologies to provide high-bandwidth, on-demand access. In this context, the system for online data scheduling coordinates bandwidth reservations and data transfer nodes to ensure that approved jobs are completed within user-specified time windows, improving upon existing systems by enabling more advanced and efficient data handling.

For the operational phase of the online booking system, the process follows these steps:

*Search for an online booking app or website.* Customers begin by searching online for resorts and tour locations that meet their preferences. The internet serves as the platform for identifying legitimate and suitable options.

*Search for resort information.* While browsing, customers gather detailed information about the resort, including itineraries and available services. This allows them to assess the resort's offerings and suitability for their needs.

*Check availability and initiate booking.* Once satisfied with the

information, customers begin the booking process. They may reserve a room or an entertainment area through the website, depending on their requirements.

*Fill out required details and documents.* Customers complete the online booking form, providing all necessary personal and reservation information. They can review their submitted data to ensure accuracy.

*G-Cash payment.* To prevent scams and ghost bookings, the resort requires a half-payment per reservation. This policy protects against revenue loss and ensures that resources are properly allocated.

*Booking confirmation via SMS verification.* After payment, customers receive a confirmation notification on the website. They are advised to save a screenshot of the receipt. Additionally, an SMS verification is sent to the customer's phone to confirm the booking, providing an added layer of security.

## **Technical Framework**

### ***Materials***

The materials used in developing the system include both software and hardware requirements.

### ***Software***

The system was developed using a variety of software tools and platforms essential for design, implementation, and coordination of the project. These technologies were selected to support the development, deployment, and maintenance of the online reservation system, ensuring that all components function efficiently and integrate seamlessly.

**Table 1***Software specifications and software platforms*

System Type	x64-based PC
Operating System	WINDOWS
System Directory	Cloud Server, Render, Vercel, PostgreSQL
Designing	Angular and FastAPI
Text Editor	VS CODE
Languages	Typescript and Python

The following outlines the software specifications and platforms used in developing the system, including system type, operating system, development environment, text editors, and programming languages.

*Visual Studio Code (VS Code).* Visual Studio Code is a free, open-source text editor developed by Microsoft. It is supported on Linux, macOS, and Windows. Despite its lightweight design, VS Code offers robust functionality and has become one of the most widely used development environment tools.

*PostgreSQL (Postgres).* PostgreSQL is a free, open-source relational database management system (RDBMS) that emphasizes extensibility and SQL compliance, making it suitable for handling complex data operations.

*Cloud Server.* Cloud servers function similarly to physical servers, providing data storage, running applications, and supporting system operations.

*Render Hosting.* Render is a unified cloud platform for building and running applications and websites. It provides free TLS certificates, a global CDN, DDoS protection, private networks, and auto deployments from Git.

*Vercel Hosting.* Vercel is a platform designed for front-end developers, offering speed, reliability, and seamless deployment to enable

rapid application and website development.

*Angular.* Angular is a TypeScript-based, open-source framework for building single-page web applications (SPA). It is maintained by Google and a community of developers.

*FastAPI.* FastAPI is a modern, high-performance Python web framework for building APIs, utilizing standard type hints for improved development efficiency.

*TypeScript.* TypeScript is a free, open-source, high-level programming language developed by Microsoft that extends JavaScript by adding static typing with optional type annotations.

*Python.* Python is a high-level, general-purpose programming language known for its simplicity, readability, and wide range of applications in web development, data analysis, and automation.

## ***Hardware***

**Table 2**

*Hardware resources*

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Device Name:	DESKTOP-TAPTENL
Processor:	Intel(R) Core(TM) i5-4210H CPU @ 2.90GHz 2.90 GHz
Installed RAM:	8.00 GB
System Type:	64-bit operating system, x64-based processor
Edition:	Windows 10 Pro

---

These specifications ensure that the system runs efficiently and supports all development and operational processes.

## ***Modeling***

System modeling is a method used to organize and represent the structure and flow of data within a system, as well as the logic, procedures,

and rules that govern its processes. This study illustrates the logical design of the system using a Data Flow Diagram (DFD) context, providing a visual representation of how data moves through the system and how processes interact.

**Figure 3**

*The system's developed context data flow diagram*

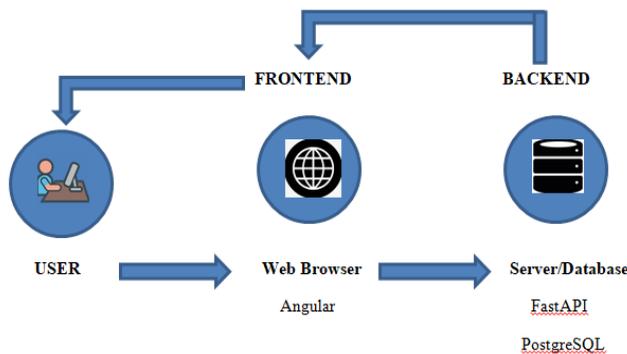


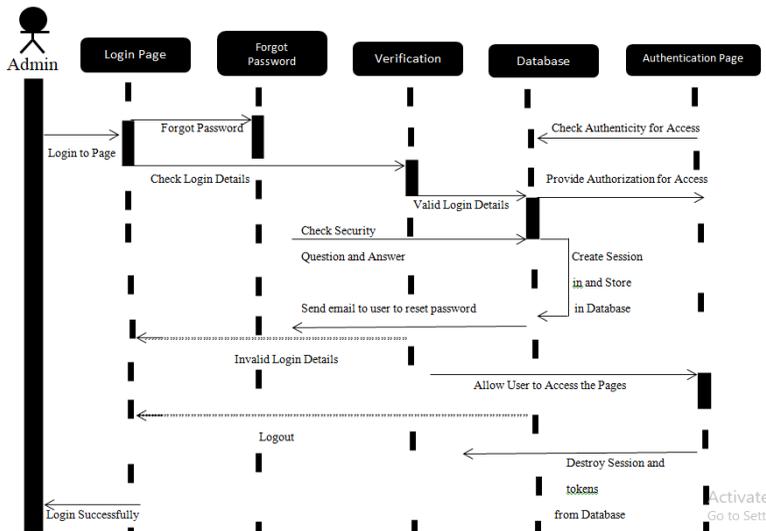
Figure 3 illustrates the context-level DFD of the developed system. A context DFD provides a high-level view of the system, highlighting its boundaries and scope. At the center of the diagram is the resort online reservation system, while the two external agents are Administration and Guests. This diagram visually represents the interactions between users and the system, emphasizing data exchanges and system functionality at a conceptual level.

### ***System Design***

Figure 4 illustrates the UML sequence diagram of the system, showing the overall design and workflow for processing online reservations at the resort. The system is designed so that only the admin and staff can log in, ensuring controlled access to sensitive operations.

**Figure 4**

*UML sequence design of system*



The protection of sensitive client data, such as login credentials, credit card information, reservation records, and financial reports, is critical. Loss or compromise of such data can have severe legal and reputational consequences. The following best practices were implemented to safeguard client information:

*Limiting access to sensitive information.* Critical client data should only be accessible to authorized personnel. Restricting access reduces the risk of accidental or malicious data leaks, thereby enhancing system security and minimizing potential human errors.

*Intelligent password security measures.* Strong, complex passwords are required to prevent unauthorized access. Additionally, multi-factor authentication (MFA) is implemented, notifying users if login attempts are made from unknown devices. This provides an added layer of protection against unauthorized access.

*Use of dedicated servers.* While shared servers may reduce costs,

they pose security risks because multiple websites share the same infrastructure. Dedicated servers, though more expensive, provide enhanced security for both the business and its customers.

*Firewall and antivirus protection.* Firewalls block unauthorized access, while antivirus software detects, prevents, and removes malware. These measures protect the system from external threats and reduce vulnerabilities that could compromise client data.

*Regular security updates.* Security patches and updates are critical for preventing exploitation of known vulnerabilities. For example, attacks like the WannaCry ransomware exploited unpatched systems. Regular updates ensure the system remains protected against emerging threats.

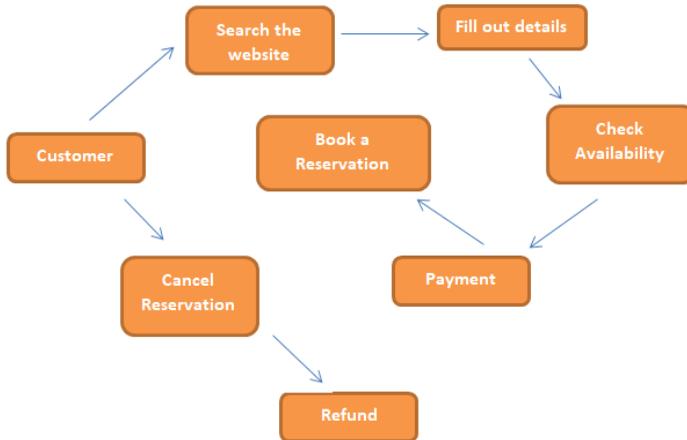
Maintaining client data security is a top priority. The system is designed to safeguard sensitive information through access control, strong authentication, dedicated servers, protective software, and continuous monitoring. Regular security assessments and updates, combined with contingency planning, ensure the system remains robust and secure against potential threats.

## ***USE Case***

Figure 5 illustrates the use case diagram for customers, depicting how customers interact with the online reservation system at the resort. The diagram highlights the steps involved in making a reservation online, from accessing the system to completing the booking process. This visual representation clarifies the customer workflow and the interactions required to successfully reserve accommodations or services at the resort.

**Figure 5**

*Use case diagram for customer*



**Figure 6**

*Use case diagram for admin*

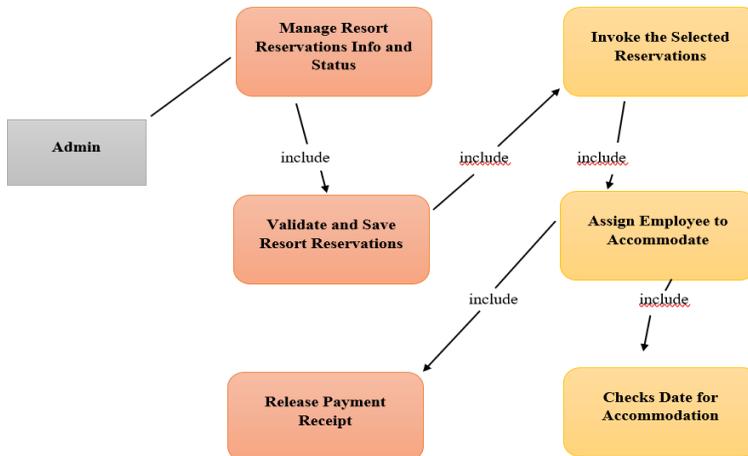


Figure 6 illustrates the use case diagram for the admin, showing how the admin manages resort reservations within the system. The admin can validate and save reservations, invoke selected bookings, assign employees to handle specific reservations, and issue payment receipts. This diagram provides a clear overview of the administrative responsibilities and

interactions necessary to efficiently manage the resort's online reservation system.

**Figure 7**

*Data flow diagram*

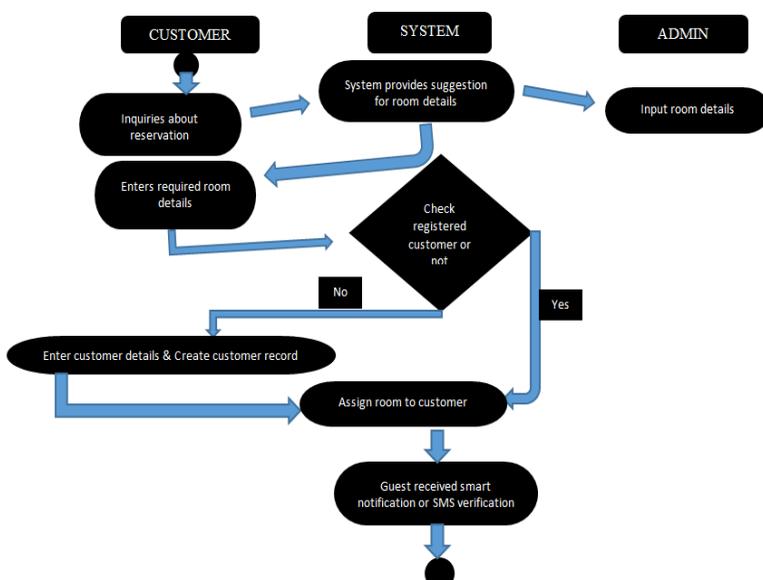


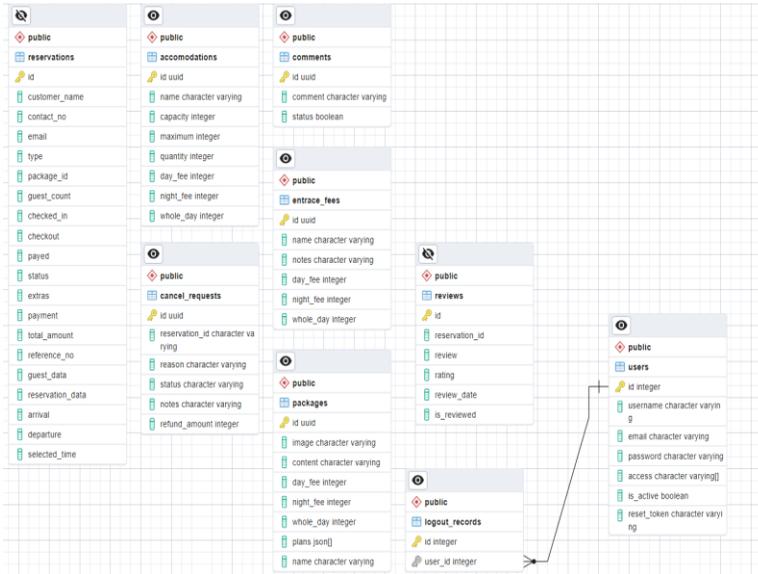
Figure 7 presents the DFD illustrating the interactions among the customer, the system, and the admin. The process begins when the customer inquires about a reservation. The system provides suggestions for available room details, while the admin inputs room information into the system. Next, the customer enters the required reservation details, and the system verifies whether the customer is registered. If the customer is confirmed as registered, the system assigns a room and sends a notification to the customer, confirming the reservation. This DFD clearly represents the flow of data and the interactions between users and the system during the reservation process.

Figure 8 illustrates the database schema / Entity-Relationship (ER) diagram of the developed system. It demonstrates the relationships between

different entities within the database and how they are conceptually linked to support system operations. This schema ensures data integrity and proper organization of information within the online reservation system.

**Figure 8**

*Database schema / ER diagram of the system*



During the development phase, the programmers utilized multiple programming languages, including TypeScript and Python, to build a robust and efficient system tailored to the client’s requirements. The development process also incorporated various technologies and tools, such as Visual Studio Code, the CodeIgniter framework, Bootstrap, Angular, FastAPI, Cloud Server, and PostgreSQL Database, along with appropriate styling formats. These technologies collectively ensure the system is functional, scalable, and user-friendly.

### **System Evaluation**

The system was evaluated using a survey conducted with 20

respondents. The questionnaire was developed based on ISO 25010 standards, covering the following aspects: functionality and performance, efficiency, maintainability, usability, accessibility and compatibility, and security. Data were analyzed using the weighted mean formula, and responses were recorded using a four-point Likert scale.

**Table 4**

*Weighted mean distribution of the criteria for the developed system*

<b>Criteria</b>	<b>Weighted Mean</b>	<b>Remarks</b>
Functionality and Performance Efficiency	3.46	Strongly Agree
Maintainability	3.53	Strongly Agree
Usability	3.59	Strongly Agree
Accessibility and Compatibility	3.47	Strongly Agree
Security	3.48	Strongly Agree
<b>Average</b>	<b>3.51</b>	<b>Strongly Agree</b>

Table 4 presents the overall weighted mean and remarks from the researchers' survey evaluating the system. The total average weighted mean of the system is 3.51, with a remark of Strongly Agree, indicating that the system successfully meets the specified requirements and is well-received by respondents.

*Functionality and Performance Efficiency:* The system is easy to access from any location and performs efficiently. The average weighted mean is 3.46, with a remark of Strongly Agree, demonstrating that respondents are satisfied with its performance.

*Maintainability:* The system is easy to maintain and incurs low operational costs. The average weighted mean for maintainability is 3.53, with a remark of Strongly Agree.

*Usability:* The system is user-friendly and easy to navigate. Even

respondents with limited computer experience were able to learn the system's controls within minutes. The average weighted mean for usability is 3.59, with a remark of Strongly Agree.

*Accessibility and Compatibility:* The system is compatible with all major web browsers and accessible to a wide range of users. The average weighted mean is 3.47, with a remark of Strongly Agree.

*Security:* The system ensures secure usage for all users. The average weighted mean for security is 3.48, with a remark of Strongly Agree.

These results indicate that the developed system is highly effective, user-friendly, secure, and reliable, meeting both user and operational requirements.

## **Conclusion**

The primary objective of this project was successfully achieved through the development of a system capable of pre-emptively detecting booking conflicts and verifying whether a reservation already exists for a specific date. In addition, the system provides comprehensive management tools for handling accommodations, packages, and entrance fees, which can be easily updated if the business modifies its offerings. The system also includes automated email notifications to inform customers about the status of their reservations, ensuring clear and timely communication.

Following testing and evaluation, the system met the ISO/IEC 25010 standard for system evaluation, excelling in functionality and performance efficiency, maintainability, usability, accessibility and compatibility, and security. These results indicate that the developed system is reliable, user-friendly, and well-suited for the long-term operational needs.

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# Web-based Household Sanitary Facility Data

*Jayrald M. Babao, John Paolo F. Caballero, Reniel M. Deloso & Wilfredo B. Empreñado*

Nowadays, safely managed sanitation, access to safe water, and good hygiene are essential to public health. According to the World Health Organization (WHO) (2023), sanitation is one of the most fundamental aspects of community well-being, as it safeguards human health and contributes to longer life spans. Similarly, Blom (2015) emphasizes that sanitation also pertains to maintaining germ-free conditions through services such as wastewater disposal and garbage collection.

The WHO (2010) identifies sanitation as a basic human right and an essential component for ensuring improved health outcomes. Globally, access to safe drinking water, proper sanitation, and good hygiene remain vital to human survival. However, many regions still face limited water supply, poor water quality, and inadequate accessibility (VanDerslice, 2011; Outreach International, 2023; UNICEF, 2021). Proper excreta disposal and solid waste management are also persistent challenges that require urgent solutions (Schrecongost & Evans, 2017; Clasen et al., 2010).

Globally, sanitation issues remain widespread (Centers for Disease Control and Prevention, 2024; World Bank, 2022; WHO, 2025; United

Nations, 2019). In 1990, WHO and UNICEF's Joint Monitoring Programme reported that 2.4 billion people lacked access to basic sanitation, with 946 million individuals practicing open defecation in public spaces such as street gutters, bushes, or water bodies. By 2015, approximately 68% of the global population had access to improved sanitation facilities, up from 54% in 1990 (WHO, 2022). Despite this progress, more than 2.4 billion people still lacked access, and nearly 946 million continued to defecate in open areas (WHO, 2015). By 2020, 54% of the world's population used hygienic sanitation facilities, with 34% connected to sewers and 20% using latrines with proper disposal of human excreta. Meanwhile, 78% of the global population (6.1 billion people) had access to at least basic sanitation. Although open defecation has decreased globally from 24% to 13%, it continues to affect millions of people worldwide (WHO, 2022).

Poor sanitation remains a significant driver of disease. It is estimated that 10% of the world's population consumes food irrigated with wastewater, increasing the risk of waterborne illnesses (WHO, 2023). Diseases such as dysentery, cholera, diarrhea, polio, trachoma, and intestinal worm infections are directly linked to unsafe sanitation and hygiene practices. Each year, poor sanitation contributes to the deaths of approximately 280,000 people from gastrointestinal illnesses (WHO, 2022). Additionally, the lack of clean sanitation has been associated with malnutrition and poor health outcomes.

The Department of Health (DOH) and the WHO have stated that all nations must work toward achieving sustainable sanitation by 2030. Unfortunately, the Philippines still struggles with this issue. It is estimated that around 10 million Filipinos lack access to safe and proper sanitation facilities, with many relying on unimproved toilets and latrines (UNICEF

Philippines, 2023). Safely managed sanitation is defined as the use of improved toilet facilities where human waste is properly collected and treated.

The primary objective of this study is to develop a system that can monitor water quality, excreta disposal, and solid waste management in households within the municipality of Sariaya. By addressing these issues, the system aims to promote better sanitation practices, improve public health, and contribute to the achievement of sustainable sanitation goals.

## **Theoretical Framework**

### ***Government Responsibility and Definition of Sanitation***

One of the main obligations of the government is to provide basic necessities for individuals within the community, ensuring that environmental concerns such as sanitation, clean water, and waste management are addressed. Sanitation is one of the most essential needs of human beings, crucial for both well-being and health. Despite this, a large number of people worldwide still lack access to proper sanitation facilities. The rising demand for safe and clean water is driven by population growth and increasing requirements in agriculture, industry, and energy (Ingrao et al., 2023).

According to Kabir et al. (2021), preventing infections and controlling pathogen transmission requires continuous improvements in hygiene and sanitation practices, particularly in educational settings. Naughton and Mihelcic (2017) further emphasize that improved sanitation not only benefits human health but also plays a significant role in social and economic development, especially in low-income countries. Proper sanitation reduces disease and morbidity rates, thereby enhancing quality of

life, particularly for children. Similarly, McGill University (2023), in *Improving Sanitation in Coastal Communities*, highlights that sanitation promotes healthy living, environmental quality, and overall community well-being by ensuring proper waste collection (Abanyie et al., 2022). Aboah and Miyitta (2022) also note that improvements in water quality, sanitation, and hygiene have positive impacts on health, social development, and economic growth. However, global progress in ensuring universal access to safe water and sanitation remains limited.

### ***Importance of Sanitation and Hygiene***

The importance of proper sanitation and hygiene has been widely recognized. Humanitarian Global (2022) outlines six key reasons why sanitation and hygiene are vital:

*Disease prevention* – Lack of sanitation, poor water quality, and malnutrition are leading causes of death in underdeveloped countries. Proper waste disposal and clean water are fundamental to reducing illness and mortality.

*Mental health* – Clean environments and proper sanitation reduce anxiety and psychological problems linked to poor living conditions, supporting holistic health.

*Confidence and self-esteem* – Good sanitation contributes to self-perception, confidence, and empowerment by promoting a clean and healthy lifestyle.

*Community status* – Proper sanitation enhances social interactions and social status, as individuals with good hygiene are perceived more positively within communities.

*Productivity and concentration* – Clean environments support better focus and productivity, allowing individuals to achieve continuous

development and personal growth.

*Quality of life* – Ultimately, sanitation and hygiene improve overall quality of life by fostering healthier homes and communities.

### ***Challenges in Sanitation***

Despite its importance, sanitation faces significant challenges. Many communities, particularly in developing countries, lack adequate facilities for excreta disposal. For instance, almost seven million Filipinos still practice open defecation, particularly in rural areas (Naughton & Mihelcic, 2017). This practice poses serious health risks, as human waste is often disposed of in open areas or connected directly to rivers, seas, and canals.

WHO (2023) reports that approximately 2.6 billion people worldwide lack access to proper sanitation, contributing significantly to the spread of diarrheal and other diseases. McGill University (2023) further explains that poor sanitation disproportionately affects urban poor communities living in overcrowded settlements with limited financial capacity and knowledge to improve conditions (Adugna, 2023; Kitole et al., 2024; Okesanya et al., 2024; Anthonj et al., 2024). The World Health Organization (2022) stresses that inadequate sanitation and hygiene are contributing factors to tropical diseases such as intestinal parasites, schistosomiasis, and trachoma. Annually, around 890,000 people in low- and middle-income countries die due to unsafe water, poor sanitation, and inadequate hygiene, which account for nearly 60% of gastroenteritis-related deaths.

### ***Web-Based Systems for Addressing Sanitation Challenges***

Several systems have been developed to address sanitation-related

challenges. One example is the Sanitation Management System (SMS), a web-based application developed using PHP and MySQL. The system provides functionalities for both administrators and users, featuring login and logout options, service management, inquiries, and dashboards. Administrators can manage requests and user data, while staff and public users can browse services, read descriptions, and submit inquiries (Montero, 2022). The system utilizes tools such as Google Chrome, XAMPP, PHP, HTML, CSS, JavaScript, and MySQL for development and deployment.

The relevance of SMS lies in its similarity to the proposed system, as both provide separate user and administrator interfaces with user-friendly features. However, unlike SMS, the proposed system incorporates enhanced login credentials for both public and management users, ensuring greater data confidentiality. The developed web-based household sanitary facility data system aims to address these challenges. The system will provide data on excreta disposal, water surveillance, and solid waste management. Local officials can encode survey data from their barangays into the system, enabling the municipality to identify areas most in need of facilities such as water systems, garbage segregation areas, and public comfort rooms. This initiative will help ensure that sanitation needs are systematically addressed, contributing to healthier and more sustainable communities.

## **Research Framework**

### ***Data***

The data for this study were gathered through a survey conducted to the IT expert, office staff and barangay sanitation auxiliary with a total of thirty-six (36) respondents. The researcher used Slovin's formula to determine the total number of respondents and utilized a purposive

sampling method of distributing questionnaires. The questionnaires are based on ISO 25010 that contains the following criteria: functionality, reliability, usability, efficiency, maintainability, portability, compatibility and security.

**Table 1**

*Distribution of respondents*

<b>Profession/Expertise</b>	<b>No. Of respondents</b>	<b>Percentage</b>
Sanitation Office Staff and Admin	10	27.78%
IT Expert	5	13.89%
Barangay Representative	21	58.33%
<b>Total</b>	<b>36</b>	<b>100%</b>

Table 1 presents the distribution of respondents who evaluated the system. The respondents included 10 sanitation office staff and administrators, 5 IT experts, and 21 barangay representatives, for a total of 36 participants.

A five-point Likert scale was utilized to allow respondents to provide their ratings. The categories were outstanding, good, satisfactory, poor, and unsatisfactory. Each category was assigned a specific mean range to guide the interpretation of results and ensure accurate analysis. To assess the system, the researchers employed the Weighted Average Mean (WAM), which was used to evaluate its functionality, usability, reliability, efficiency, portability, maintainability, compatibility, and security.

### ***Data Privacy***

Every firm should have a written data security policy, particularly because most organizations are now subject to increasingly strict information confidentiality legislation. A data security policy typically

addresses issues such as password security, data encryption, and access control. Beyond simply outlining precautionary measures, the policy demonstrates management's commitment to comply with legal obligations. In particular, it should ensure organizational protection for sensitive and confidential data, such as personal information.

The policy must clearly define the roles and responsibilities of all parties involved in safeguarding data, including the Data Protection Officer (DPO) in ensuring compliance with GDPR. Furthermore, access control guidelines are established to ensure that users can only access information necessary for their role. In this study, the researchers provide a data policy to secure the information submitted by system users.

To prevent unfavorable effects on clients, the company treats data confidentiality as a priority, ensuring that information is not lost or mishandled. While the policy cannot fully prevent malicious attempts to steal private information, its main purpose is to raise awareness among users and prevent accidental data loss or breaches. The data security policy applies to all personal information classified as sensitive under the organization's data classification guidelines.

This policy extends to servers, databases, and IT systems designed to handle collected data, as well as all devices used for email, web access, and related activities. Every user interacting with the organization's services is subject to this policy. The system guarantees that all user-provided information remains secure and confidential.

*User responsibilities.* Administrators should maintain a clear workspace, free from sensitive information. They must keep their passwords confidential. c. Residents must provide only accurate information required by the system and they should review their information before final submission.

*Application and information access.* Administrators are granted access permissions and are responsible for record management. Sanitation office representatives may only access the survey forms. Access to sensitive information is restricted to authorized personnel and isolated for enhanced security.

*Confidentiality and information restriction.* Confidentiality and restricted access are granted solely to authorized personnel for purposes aligned with their job responsibilities. The IT Security Department is responsible for enforcing access restrictions.

### ***Verification, Validation, and Testing Plans***

The researchers conducted a series of evaluations to determine whether the system meets its objectives and intended purpose. In addition, barangay representatives are required to visit households and complete a survey form regarding household sanitation. Once submitted, administrators validated and analyzed the encoded data to prevent the

### ***Development Model***

It is a development tool that guided the researchers in pursuing a structured system. The proponents adopted the Rapid Application Development (RAD) model for developing the web-based household sanitary facility data system.

**Figure 1**

*Rapid application development model*

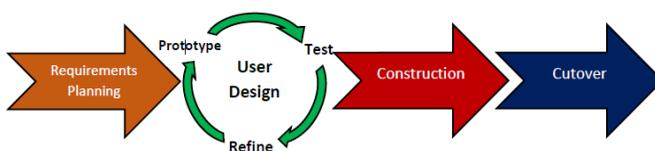


Figure 1 illustrates how the proposed system was built on the basis of the development model used.

*Requirements planning.* This phase involves identifying and organizing the details necessary for the project. It emphasizes collaboration between the research team and the client, focusing on current issues that need to be addressed in system development. The goals and objectives of the program are established, and project assumptions are analyzed by all stakeholders. Input from each significant team member and developer is gathered to secure agreement and avoid future misunderstandings or costly changes. At this stage, the researchers plan the system to be developed and collect requirements as provided by the client.

*User design.* In this phase, developers and team members begin working on the project by producing user designs through various prototypes. This is the core component of RAD that distinguishes it from other development approaches. Developers collaborate with clients to ensure that requirements are addressed at every stage of the design process. Users evaluate each prototype to confirm alignment with project goals. Errors and bugs are identified and resolved through an iterative process. The developer creates prototypes for user testing, and both parties work together to determine necessary adjustments. This iterative feedback loop allows modifications until the design meets expectations.

*Rapid construction.* At this stage, prototypes and beta versions evolve into working models. The development team collaborates to build the final functioning system, using iterative processes to resolve problems identified earlier. Client input remains crucial during this stage, as users can provide insights, adjustments, suggestions for improvement, or new concepts that contribute to system refinement. Collaboration ensures that the system functions properly and meets the goals and requirements defined

by the client.

*Cutover.* This is the execution phase, where the fully developed system is prepared for implementation. Activities in this stage include data conversion, system testing, final adjustments, and user training. Programmers and clients continue monitoring the system to detect and resolve any issues. The researchers conduct multiple tests to ensure that the system operates effectively and achieves its intended purpose.

## **Technical Framework**

### ***Materials***

This section outlines the specifications that the researchers used in designing the project.

### ***Software***

Table 2 shows the software programming tools and specifications that were used in the project.

**Table 2**

*Software specification*

<b>Software</b>	<b>Specification</b>
Database	MySQL
Server/UI testing	Google Chrome, XAMPP
IDE Platform	VS code
Operating System	Windows 10
Android Operating System	Android 10

### ***Hardware***

Table 3 shows the hardware tools and specifications that were used in the project.

**Table 3***Hardware specifications*

Hardware	Specification	
	Minimum	Recommended
Internal Memory	4GB of disk space	8GB of disk space
Memory	4GB RAM	8GB RAM
Processor	12	17
Resolution	1280x81500 screen display	
Internal memory (Smartphone)	100MB of disk space	250MB of disk space
Memory (Smartphone)	1GB RAM	2GB RAM

### ***Development Approach***

The goal of the development approach is to identify how the system will be developed and implemented. For this study, the chosen development model is the RAD model, complemented by the top-down approach. The top-down method begins with a general principle and breaks it down into smaller components. Using this approach, the researchers analyzed how the system could be efficiently applied, ensuring that the basic concepts were gradually decomposed to quickly understand the system's flow.

To build the system, the proponents integrated various software and tools. By combining these technologies, the design and implementation of the system became feasible. The tools used include:

*PHP (Hypertext Preprocessor)*. A widely used, open-source, general-purpose scripting language chosen for system development. PHP served as the primary programming language for building the system.

*MySQL (My Structured Query Language)*. A widely adopted database management system. MySQL was employed as the storage location for information and data entries. Data was created, stored, and

managed in the MySQL database, with PHP facilitating database interactions.

*XAMPP (Cross-Platform, Apache, MySQL, PHP, and Perl).* Used for server and user interface testing, XAMPP provided an integrated platform to connect the website with the MySQL database.

*Microsoft Word.* Utilized for documentation purposes, particularly in creating and typing project-related reports.

*Figma.* A collaborative web-based application for interface design, offering additional offline functionality through desktop versions for macOS and Windows. Figma was used to design and edit the system's interface.

*HTML (Hypertext Markup Language).* Used to define the structure of web pages. HTML served as the backbone of the system's front-end, providing the essential framework for content display.

*CSS (Cascading Style Sheets).* Applied to format text, tables, and overall web page layouts. CSS allowed the researchers to define styles, enhance readability, and ensure a structured presentation of web content.

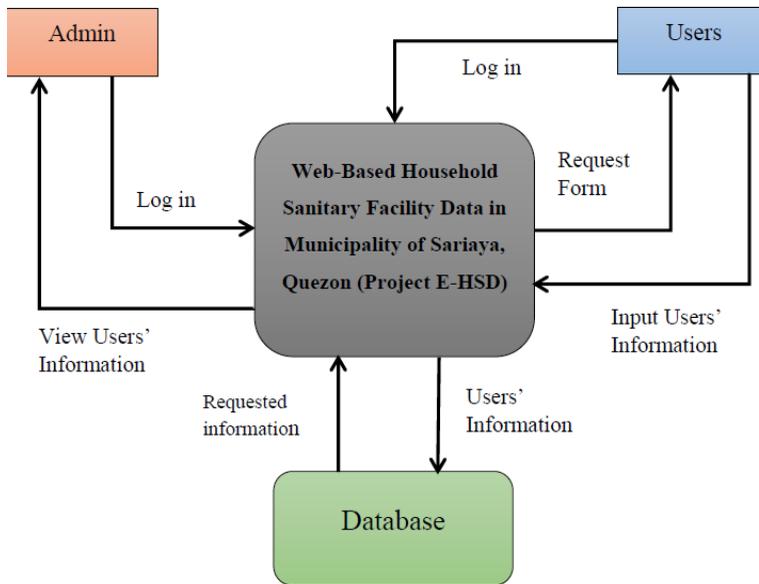
*JavaScript.* Employed as the programming language to add dynamic and interactive elements to the website. JavaScript enhanced user interaction and improved system usability.

### ***Analysis of the System***

Figure 2 presents the system context diagram. The diagram displays the process of the monitoring the household sanitary facility data between the system and the users. Admin will add, edit, delete and manage records to the software and system admin will view the residents' information. The user sends request form to the system. System will give form to be filled out by the users.

**Figure 2**

*Context diagram of the developed system*



**Figure 3**

*Data flow diagram of the developed system for inputting and storing users' information*

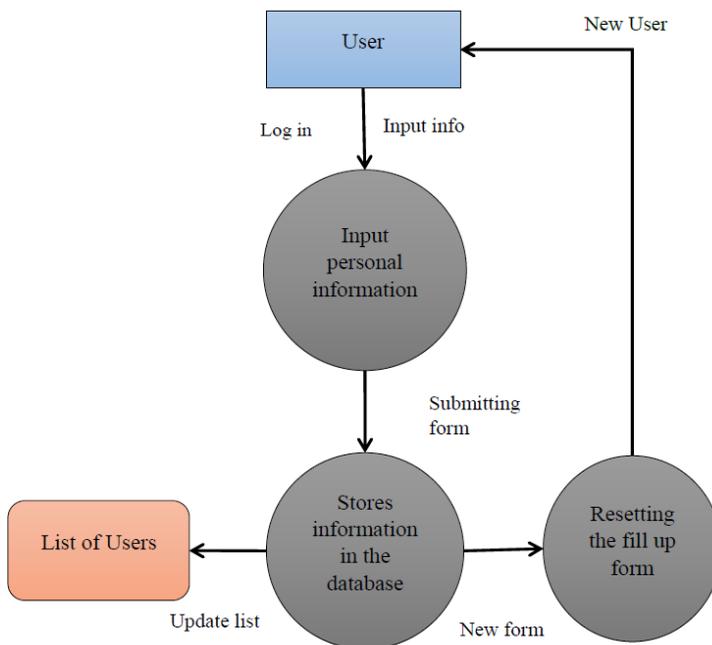


Figure 3 illustrates the user's DFD. In this process, users log in to the system, input the collected personal information, and the system directly stores the data in its database.

**Figure 4**

*Data flow diagram of the developed system for the admin accessing the users' list*

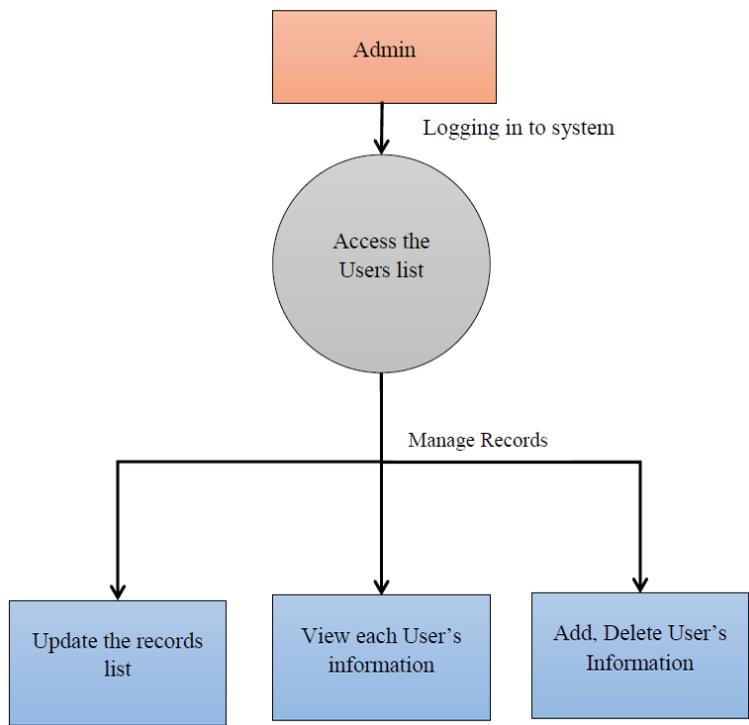


Figure 4 presents the DFD for administrators. In this process, the administrator logs in to the system using a designated username and password to access the users' list. The system then displays all user information, allowing the administrator to view and manage the details submitted by each user.

### ***Design***

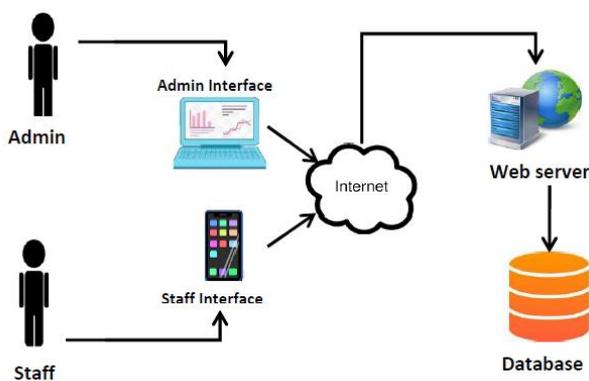
System design is a step in which system engineers evaluate and

understand the function of the proposed system by reviewing the user specifications text. They define the possibilities and strategies by which the specifications of the user can be implemented. On the other hand, system development is an approach to establishing or modifying structures along with the methods, processes, designs, and methodologies used to produce them. System design is the method of determining the constituent elements, modules, interfaces, and data for an application to satisfy particular requirements.

### ***System Architecture***

Figure 5 illustrates how users access the developed system. The diagram shows the flow of data encoded by the administrator and staff. Users connect to the system via the internet, enabling their information to be stored in the database. The administrator, represented by a computer interface in the diagram, has full access to all system functions. In contrast, staff members, represented by a mobile device interface, have limited access restricted to the survey form. The use of mobile devices allows staff to conveniently conduct surveys in the field.

**Figure 5**  
*System architecture*



## Use Case

Figure 6 presents the use case model of the system, illustrating how administrators and users interact with and manage system functions. The administrator can manage user accounts, generate reports, and handle record information, while users interact with the system to submit and access their personal data as permitted.

**Figure 6**

*Use case model of the system for admin*

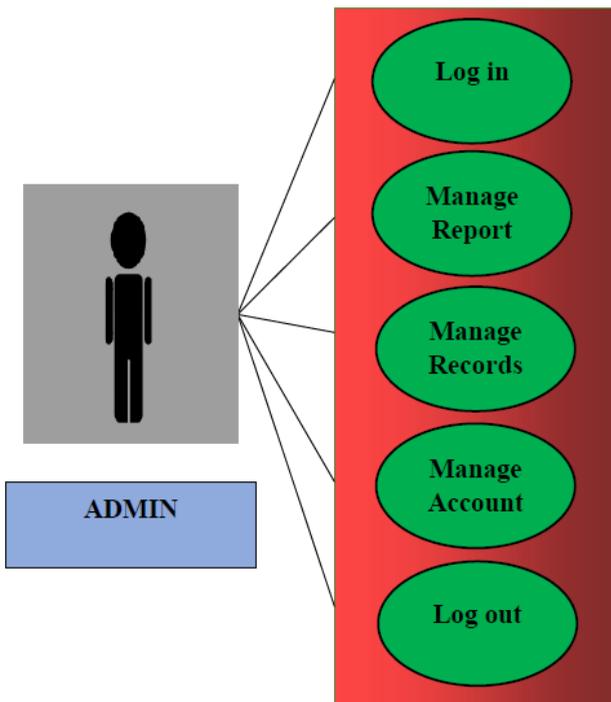
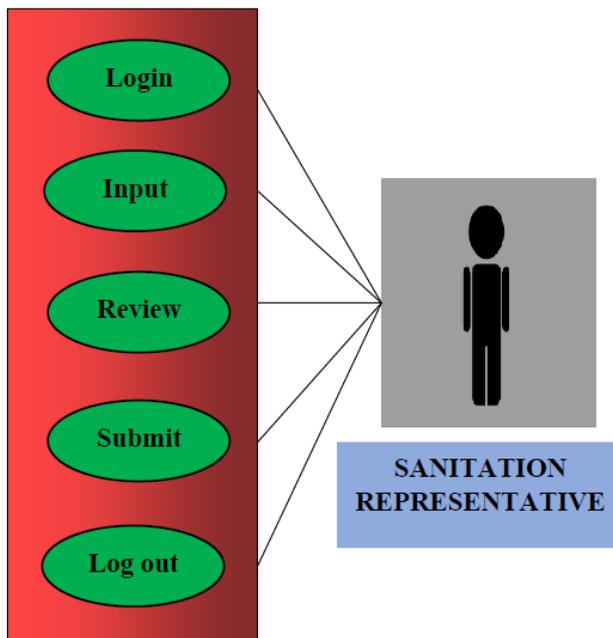


Figure 7 presents the use case model of the system for the Sanitation Representative. It illustrates how the representative interacts with the system by inputting residents' information, reviewing it, and submitting it for storage and processing within the system.

**Figure 7**

*Use case model of the system for sanitation representative*



### *User GUI*

A Graphical User Interface (GUI) is a type of interface that allows users to interact with electronic devices through graphical icons and visual elements. Users engage with the system using graphical components such as windows, icons, and buttons. Navigation is primarily performed using a mouse and keyboard, which are best suited for desktop computers; these input devices may not function as effectively on portable gadgets.

**Figure 8**

*Homepage*

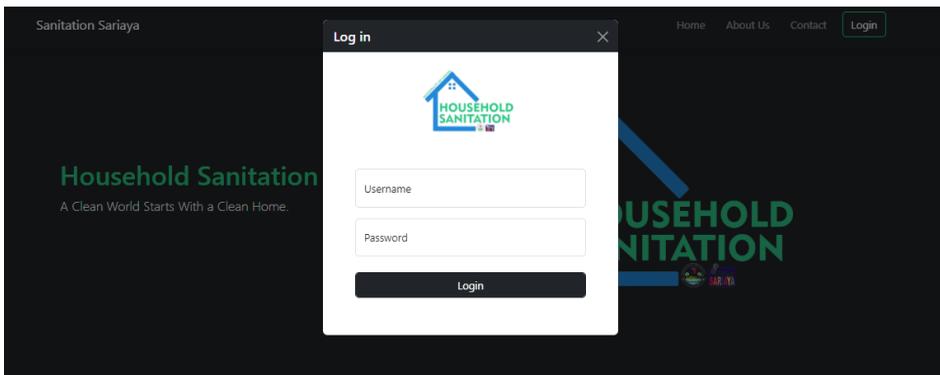


The Home Page serves as the main screen of the system and contains buttons for “Home,” “About Us,” “Contact,” and “Login.”

Figure 9 shows the Login Page for Admin/Barangay Representative/Staff. It is designed for administrators, barangay representatives, and staff members. Users are required to enter a username, which serves as a unique identifier, and a password to securely access the system.

**Figure 9**

*Login page*



**Figure 10**

*Dashboard*

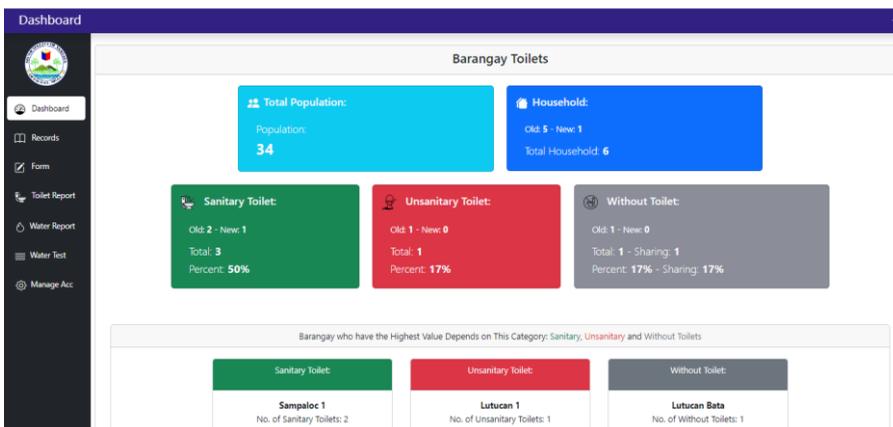


Figure 10 shows the dashboard. It provides an overview for the admin, displaying the total number of populations, households, sanitary toilets, unsanitary toilets, and households without toilets.

**Figure 11**

*Record page*

Status	Household Head Name	Purok	Barangay	Water Source	Toilet	No. of Occupants	No. of Family
Old	John Paulo	Purok 3	Lutucan Bata	Level II	Sanitary Toilet	5	6
Old	Wilfredo Empremiado	Purok 3	Balubal	Level III	Sanitary Toilet	5	6
Old	John Jerick	Purok 1	Sampaloc 1	Level I	Sanitary Toilet	6	1
Old	Jayrald Babao	Purok 3	Limbon	Level I	Without Toilet	5	1
Old	Jhon Carlo	Purok 4	Lutucan Bata	Level I	Without Toilet	6	2
Old	Kara deloso	Purok 1	Lutucan 1	Level I	Unsanitary Toilet	6	1
New	Reniel Deloso	Purok 1	Sampaloc 1	Level I	Sanitary Toilet	6	1

Figure 11 shows the record page. On the Record Page, the admin can view, edit, and delete existing records.

**Figure 12**

*Importing data*

Status	Household Head Name	Purok	Barangay	Water Source	Toilet	No. of Occupants	No. of Family
Old	John Paulo	Purok 3	Lutucan Bata	Level II	Sanitary Toilet	5	6
Old	Wilfredo Empremiado	Purok 3	Balubal	Level III	Sanitary Toilet	5	6
Old	John Jerick	Purok 1	Sampaloc 1	Level I	Sanitary Toilet	6	1
Old	Jayrald Babao	Purok 3	Limbon	Level I	Without Toilet	5	1
Old	Jhon Carlo	Purok 4	Lutucan Bata	Level I	Without Toilet	6	2
Old	Kara deloso	Purok 1	Lutucan 1	Level I	Unsanitary Toilet	6	1
New	Reniel Deloso	Purok 1	Sampaloc 1	Level I	Sanitary Toilet	6	1

Figure 12 shows the importing of data. The Importing Data screen allows the admin to import data files into the system’s records.

Figure 13 shows the survey form. The survey form screen enables both the admin and barangay representatives to fill out household surveys.

**Figure 13**  
*Survey form*

**Figure 14**  
*Toilet report*

Barangay	Population	Household	Sanitary Toilet			Unsanitary Toilet			Without Toilet			Total HH with access toilet facility	% of total HH with toilet facility
			No.	H.H. Served	%	No.	H.H. Served	%	No.	H.H. Served	%		
Antipolo	0	0	0	0	0	0	0	0	0	0	0	0	0
Balubal	5	1	1	1	100%	0	0	0%	0	0	0%	1	100%
Bignay 1	0	0	0	0	0	0	0	0	0	0	0	0	0
Bignay 2	0	0	0	0	0	0	0	0	0	0	0	0	0
Bucal	0	0	0	0	0	0	0	0	0	0	0	0	0
Canda	0	0	0	0	0	0	0	0	0	0	0	0	0
Castafas	0	0	0	0	0	0	0	0	0	0	0	0	0
Con Barahaw	0	0	0	0	0	0	0	0	0	0	0	0	0
Con Palasan	0	0	0	0	0	0	0	0	0	0	0	0	0
Con Pinagbakuran	0	0	0	0	0	0	0	0	0	0	0	0	0
Conception 1	0	0	0	0	0	0	0	0	0	0	0	0	0
Gibanga	0	0	0	0	0	0	0	0	0	0	0	0	0
Guilguis San Roque	0	0	0	0	0	0	0	0	0	0	0	0	0
Guilguis Talon	0	0	0	0	0	0	0	0	0	0	0	0	0

**Figure 15**  
*Water supply report*

Barangay	Population	Household	LEVEL I			LEVEL II			LEVEL III			Doubtful Sources		
			No.	H.H. Served	%	No.	H.H. Served	%	No.	H.H. Served	%	No.	H.H. Served	%
Antipolo	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Balubal	5	1	1	1	100%	0	0	0%	0	0	0%	1	100%	0
Bignay 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bignay 2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bucal	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Canda	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Castafas	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Con Barahaw	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Con Palasan	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Con Pinagbakuran	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Conception 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gibanga	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Guilguis San Roque	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Guilguis Talon	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Janagdong 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Janakoven 2	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure 14 shows the toilet Report screen displaying a report on the sanitary, unsanitary, and households without toilets. On the other hand, Figure 15 shows the water supply report, providing a report on water surveillance, indicating sources categorized as Level 1, Level 2, Level 3, or doubtful sources.

**Figure 16**

*Water supply test report*

Barangay	LEVEL I			LEVEL II			LEVEL III		
	Total No.	Total No. Tested Microbio.	Total No. Passed P. Microbio.	Total No.	Total No. Tested Microbio.	Total No. Passed P. Microbio.	Total No.	Total No. Tested Microbio.	Total No. Passed P. Microbio.
Antipolo	0	0	0	0	0	0	0	0	0
Balubal	0	0	0	0	0	0	1	1	1
Bignay 1	0	0	0	0	0	0	0	0	0
Bignay 2	0	0	0	0	0	0	0	0	0
Bucal	0	0	0	0	0	0	0	0	0
Canda	0	0	0	0	0	0	0	0	0
Castillas	0	0	0	0	0	0	0	0	0
Con Banahaw	0	0	0	0	0	0	0	0	0
Con Palasan	0	0	0	0	0	0	0	0	0
Con Pinaglakuran	0	0	0	0	0	0	0	0	0
Conception 1	0	0	0	0	0	0	0	0	0
Gubang San Roque	0	0	0	0	0	0	0	0	0

Figure 16 shows the water supply test report. This report presents findings from microbiological and physico-chemical testing of different water sources.

**Figure 17**

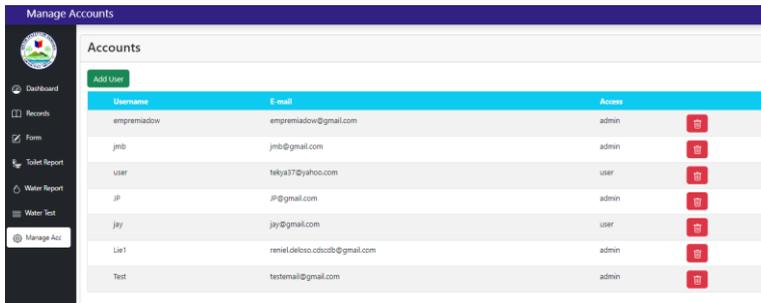
*Generated report*

Barangay	Population	Household	No.	H.H. Served	%	No.	H.H. Served	%	No.	H.H. Served	%	Total HH with access to toilet facility	% of total HH with toilet facility
Antipolo		0	0	0	0	0	0	0	0	0	0	0	
Balubal	5	1	1	1	100%	0	0	0%	0	0	0%	1	100%
Bignay 1		0	0	0	0	0	0	0	0	0	0	0	
Bignay 2	5	1	1	1	100%	0	0	0%	0	0	0%	1	100%
Bucal		0	0	0	0	0	0	0	0	0	0	0	
Canda		0	0	0	0	0	0	0	0	0	0	0	
Castillas		0	0	0	0	0	0	0	0	0	0	0	
Con Banahaw		0	0	0	0	0	0	0	0	0	0	0	
Con Palasan		0	0	0	0	0	0	0	0	0	0	0	
Con Pinaglakuran		0	0	0	0	0	0	0	0	0	0	0	
Conception 1		0	0	0	0	0	0	0	0	0	0	0	
Gubang		0	0	0	0	0	0	0	0	0	0	0	

Figure 17 shows the generated report. It consolidates data on water surveillance, excreta disposal, and solid waste management, allowing the admin to generate and print comprehensive reports.

**Figure 18**

*Manage accounts*



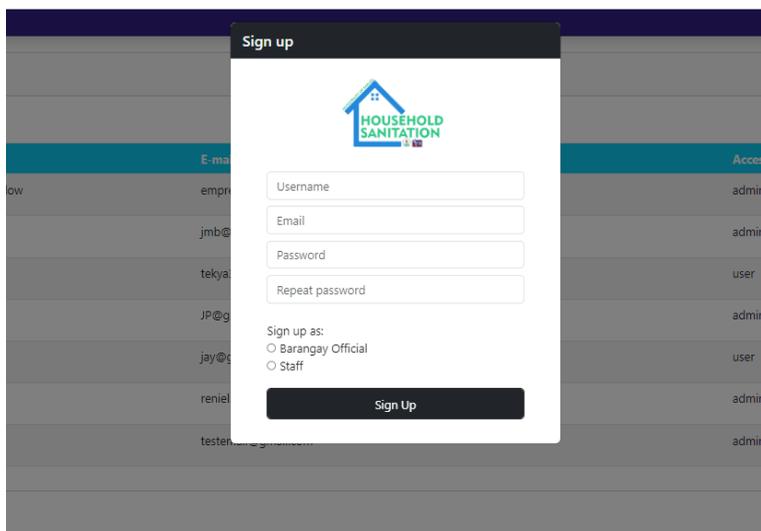
The screenshot shows a web application interface for managing accounts. On the left is a dark sidebar with navigation options: Dashboard, Records, Forum, Toilet Report, Water Report, Water Test, and Manage Acc. The main content area is titled 'Accounts' and features a table with columns for Username, E-mail, and Access. Each row also includes a red delete icon. A green 'Add User' button is located above the table.

Username	E-mail	Access
empreniadow	empreniadow@gmail.com	admin
jmb	jmb@gmail.com	admin
user	tekyaj37@yahoo.com	user
JP	JP@gmail.com	admin
Jay	Jay@gmail.com	user
Lia1	reniel.deloso.cdscib@gmail.com	admin
Test	testemail@gmail.com	admin

Figure 18 shows the manage accounts screen, showing records of all registered admin and user accounts. Meanwhile, Figure 19 shows the sign-up page. It allows the admin to add new admin and user accounts as needed.

**Figure 19**

*Sign-up page*



The screenshot shows a 'Sign up' modal window overlaid on the 'Manage Accounts' screen. The modal contains the 'HOUSEHOLD SANITATION' logo, input fields for Username, Email, Password, and Repeat password, radio buttons for 'Barangay Official' and 'Staff', and a 'Sign Up' button.

## Database Design

A database schema defines the logical structure of the database, outlining how data is organized, stored, and related within the system. It serves as the blueprint for the system's data management, supporting the proper storage of user information, survey data, reports, and other essential records in a structured and consistent manner.

**Figure 20**

*Database schema*

sanitation_system barangay_users	sanitation_system barangay_list
id : int(11)	id : int(11)
username : varchar(255)	houseHold_status : varchar(10)
email : varchar(100)	houseHold_head : varchar(50)
password : varchar(255)	purok : varchar(50)
verify_token : varchar(191)	barangay : varchar(100)
access : varchar(150)	numberOf_occupant : int(100)
	family_number : int(100)
	house&lot_ownership : varchar(50)
	waterSource_type : varchar(50)
	waterSource_accesability : varchar(50)
	waterHousehold_served : int(11)
	year_constructed : varchar(50)
	depth(ft) : varchar(50)
	microBiologyTest_date : date
	microBiologyTest_status : varchar(50)
	physicoChemicalTest_date : date
	physicoChemicalTest_status : varchar(50)
	practicingOpenDefecation_status : varchar(10)
	toilet : varchar(50)
	sanitaryToilet_type : varchar(100)
	sanitaryHouseHold_served : int(100)
	unsanitaryToilet_type : varchar(100)
	unsanitaryHouseHold_served : int(100)
	method : varchar(100)
	HH_practicingWasteSegregation : varchar(10)
	collectedByMun_collection&disposalSystem : varchar(10)
	disposalOf_biodegradable : varchar(50)
	disposalOf_nonBiodegradable : varchar(50)

**Table 4***User's table*

<b>Name</b>	Users	
<b>Description</b>	This table is for the Users of the system	
<b>Field</b>	<b>Type</b>	<b>Description</b>
id	Int(11)	Primary Key
username	varchar(255)	Stores username of the user
email	varchar(100)	Stores email of the user
password	varchar(255)	Stores password of the user
access	varchar(150)	Access of the user

Table 3 presents the User Table, which contains information about the login credentials of the system users. The table includes an ID as the primary key to prevent redundancy, along with fields for username, email, password, and access level, which indicates whether the user is an admin or staff member.

### ***System/Software Evaluation Testing***

This section provides the evaluation conducted through a survey in Sariaya, Quezon, involving IT experts, office staff, and barangay sanitation auxiliaries, with a total of thirty-six (36) respondents. The questionnaires were based on ISO 25010 and covered the following criteria: functionality, reliability, usability, efficiency, maintainability, portability, compatibility, and security.

Overall, the evaluation indicates that the developed system performs well across all ISO 25010 criteria, with most aspects rated between Good and Outstanding. Table 5 shows the overall weighted mean of each criterion based on the responses of 36 participants. The system evaluation survey yielded an average weighted mean of 4.30, showing that respondents agreed

on the system’s reliability, functionality, efficiency, usability, maintainability, portability, compatibility, and security. This result demonstrates that the system is capable of meeting the specified requirements effectively.

**Table 14**

*Weighted mean distribution of criteria for the developed system*

<b>Criteria</b>	<b>Weighted Mean</b>	<b>Remarks</b>
Functionality	4.36	Good
Reliability	3.68	Good
Usability	4.51	Outstanding
Efficiency	4.53	Outstanding
Maintainability	4.15	Good
Portability	4.34	Good
Compatibility	4.34	Good
Security	4.5	Outstanding
<b>Average</b>	<b>4.30</b>	<b>Good</b>

*Functionality:* The results show that the developed system effectively supports data encoding, meeting the needs of the sanitation office. Respondents were satisfied with this aspect, with a weighted mean of 4.36, interpreted as Good.

*Reliability:* The system was found to run consistently, with an overall weighted mean of 3.68, also interpreted as Good. This indicates that the system is reliable for regular use.

*Usability:* Respondents agreed that the system is easy to operate and understand. The usability criterion received an average weighted mean of 4.51, with a remark of Outstanding.

*Efficiency:* The system responds quickly and performs well in its operations. The efficiency criterion received an average weighted mean of

4.53, also interpreted as Outstanding.

*Maintainability:* The system allows for easy detection and correction of faults or errors. This criterion received a weighted mean of 4.06, interpreted as Good.

*Portability:* The respondents agreed that the system can be accessed easily across devices. Portability garnered a weighted mean of 4.34, interpreted as Good.

*Compatibility:* The system meets client requirements and functions correctly within the intended environment. Compatibility received a weighted mean of 4.34, with a remark of Good.

*Security:* The system provides protection against unauthorized modifications of data. The security criterion received a weighted mean of 4.50, interpreted as Good.

Economic feasibility assesses the cost-effectiveness of the system, primarily through a cost-benefit analysis. Its purpose is to determine the expected benefits of implementing the system. In this study, the institution found the system economically feasible, as it significantly reduces the time and effort required to collect data compared to traditional paper-based methods.

The system is technologically feasible and is expected to receive positive feedback from users. It contributes significantly to monitoring water quality, excreta disposal, and solid waste management in each community. Additionally, the system is easily accessible via the internet and can be efficiently managed and operated, making it a practical technological solution.

The developed system is operationally feasible due to its user-friendly interface and intuitive design. Clients expressed satisfaction with the system, noting that it is easy to operate and understand. The operational

process and demonstration showed that the system can be effectively used with minimal training and effort.

## **Conclusion**

The developed system is capable of collecting and managing sanitary information for every household. The system allows administrators to generate comprehensive reports, including the total number of households, water sources, households with and without sanitary toilets, and households practicing solid waste management. Its accessibility and security features ensure that survey activities in each community are more efficient, reducing the risk of data loss and redundancy while optimizing time and minimizing the workforce required. Furthermore, testing and evaluation demonstrated that the system meets ISO/IEC 25010 standards for functionality, reliability, usability, efficiency, maintainability, portability, compatibility, and security. Overall, the system provides a valuable tool for efficient data collection, storage, and monitoring, offering a significant contribution to sanitation management in the municipality.

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# Web-based School Appointment System

*Madel J. Sacristia, Ryan Kerth B. Quelazon, Jaypee H. Briñas & Johncarlo M. Deloso*

The web has recently emerged as a valuable tool for managing scheduling tasks, and web-based appointment systems have become a prominent area of study in educational institutions. Research on user satisfaction indicates that online scheduling provides a highly significant improvement, with most users expressing willingness to use such services again due to convenience and efficiency (Chen et al., 2020; Ostadmohammadi et al., 2025; Kitsios et al., 2023; Zheng et al., 2024).

According to Ala and Chen (2022), manual registration and scheduling procedures are often time-consuming, error-prone, and inconvenient. While this finding was highlighted in the healthcare sector, the same challenges are evident in schools where registrars and administrators handle a large volume of student requests daily. To address this issue, a web-based application can be implemented to manage and book appointments online, enabling students to access the registrar's services without long waiting lines. Such a system, developed with tools like MySQL, PHP, and JavaScript, can reduce unnecessary face-to-face interactions, eliminate redundant paperwork, and improve operational efficiency. Furthermore, it decreases staff workload while increasing

accuracy and user satisfaction among students and faculty. Traditional manual processes often result in duplication of records, scheduling conflicts, and general frustration for both staff and students.

Achieving a flawless manual appointment schedule within a school setting is virtually impossible, as it often leads to long queues at the registrar's office, extended waiting times, and frequent errors when changes or corrections are made. To address these challenges, an interactive web-based solution is essential. While medical appointment systems are more common in other countries, the adaptation of similar technology in the education sector remains underexplored in some regions. This study, therefore, seeks to identify the limitations of existing scheduling systems within schools and propose improvements to enhance efficiency and user experience.

According to Zhao et al. (2017), web-based appointment systems operate in two modes: asynchronous and real-time. In the asynchronous mode, appointment requests are sent via email or online forms and are later processed manually by staff. This process is similar to traditional paper- or telephone-based scheduling, where requests made outside office hours are only addressed when staff return. In contrast, the real-time mode allows students to directly interact with the school's scheduling system, receiving immediate confirmation of their appointment. The real-time approach is particularly beneficial for schools, as it reduces delays, prevents unprocessed requests, and ensures smoother communication between students and registrars.

This study focuses on developing a web-based appointment system accessible across multiple devices, designed with two access levels: administrator and student. By providing a readily available online platform, the system facilitates efficient scheduling of registrar services, eliminating

the need for traditional queuing and manual paging. Students gain the convenience of booking appointments anytime and anywhere, while administrators can better anticipate, organize, and manage daily schedules.

The study aims to design a web-based appointment system for the registrar and students of a private school. The system is expected to streamline scheduling processes, reduce manual errors, minimize waiting times, and enhance overall efficiency. By integrating modern web technology into school administration, institutions can significantly improve service delivery and student satisfaction.

## **Theoretical Framework**

### ***Implementation and Objectives of Web-Based Scheduling***

Schools, like hospitals, handle a high volume of scheduling needs on a daily basis. Registrar offices in particular must manage numerous student requests such as enrollment validation, transcript issuance, and consultation appointments. Traditional appointment systems in schools often lead to long queues, manual errors, and scheduling conflicts, which cause frustration for both students and staff. To address this issue, the proposed web-based scheduling system is designed to minimize waiting times and streamline registrar-related processes.

The system accommodates multiple stakeholders, including students, who can book appointments online; registrars and school staff, who manage and update appointment records; and school administrators, who monitor service efficiency. Drawing from best practices such as the DMADV framework (Define, Measure, Analyze, Design, and Verify), Six Sigma methodology, and Business Process Management (BPM), the system standardizes processes, reduces duplication of records, and enhances

service delivery. This integration ensures that both students and administrators can manage appointments seamlessly, improving institutional efficiency while addressing the student body's need for timely academic services.

### ***Benefits of Web-Based Scheduling***

The benefits of web-based scheduling extend beyond healthcare and are equally relevant in academic institutions. Such systems improve organizational workflows by reducing no-shows, lowering staff workload, shortening waiting times, and increasing user satisfaction (Morales et al., 2024; Cain & Haque, 2008; Zhao et al., 2017). Applied in schools, these outcomes translate into better student experiences, smoother registrar operations, and improved administrative efficiency. Furthermore, web-based scheduling systems allow schools to maintain accurate and organized records of student appointments, track historical data for audits, and generate reports that inform policy and resource allocation. This accessibility and transparency enable administrators to manage registrar services effectively while reducing reliance on manual scheduling. As a result, registrar offices can focus on student support and academic services rather than spending excessive time on routine administrative tasks.

### ***Adoption Challenges and Resistance***

Despite the benefits, the adoption of web-based scheduling systems in schools may face several challenges. Concerns often involve implementation costs, system flexibility, and integration with existing school databases. Issues of data security and privacy, particularly when handling sensitive student records, also require careful attention. Transitioning to digital scheduling necessitates staff training and workflow

adjustments, which may be challenging for institutions with limited technical expertise.

On the student side, resistance to web-based scheduling may arise from varying levels of digital literacy and access to devices. While many students are comfortable with technology, others may still prefer in-person requests or traditional methods of communication. However, as seen in the healthcare sector (Morales et al., 2024), organizations are increasingly adopting digital platforms because of their long-term benefits for efficiency and satisfaction. Schools, likewise, can overcome these barriers by ensuring the system is user-friendly, mobile-compatible, and accessible across different platforms.

Building on the insights of earlier studies on web-based appointment systems, this research adapts their lessons to the school context. While prior research highlights the benefits of reducing wait times, decreasing staff workload, and improving user satisfaction (Morales et al., 2024), it also notes barriers related to accessibility, familiarity, and integration. The proposed system for the registrar's office of a private school is therefore designed to leverage these advantages while mitigating adoption challenges. By incorporating dual access controls for administrators and students, ensuring multi-device compatibility, and prioritizing ease of use, the system seeks to streamline registrar appointments, enhance efficiency, and improve satisfaction for all stakeholders involved.

## **Research Framework**

### ***Data***

The data collected for this study were taken from the survey results of 27 respondents. The questionnaire was adapted from ISO 25010

standards, covering six quality aspects: system performance efficiency, maintainability, suitability, usability, compatibility, and security. These dimensions ensure a comprehensive evaluation of the system's functionality and reliability in meeting user needs. The researchers ensured that all information gathered would remain confidential, secure, and used solely for research purposes.

To analyze the responses, the researchers employed the weighted mean formula. A four-point Likert scale was used, with the following categories: strongly agree, agree, disagree, and strongly disagree. Each response option was assigned a corresponding mean range, which served as the basis for interpreting the evaluation results. This approach allowed the researchers to quantify user perceptions effectively and assess the system's overall performance.

### ***Experimental Design***

Figure 1 illustrates the experimental design of the study from the student's perspective. The process begins with the student accessing the system through the login page. After entering their username and password, the system validates the credentials and grants access to the student dashboard. From the dashboard, students can conveniently view the list of available appointments and proceed with their scheduling activities.

**Figure 1**  
*Student login design*



**Figure 2**

*Admin login design*



Figure 2 presents the experimental design of the study from the administrator's perspective. The process begins with the admin accessing the login page, where a valid username and password must be entered to successfully log in. Once authenticated, the system directs the admin to the administrator dashboard. From this interface, the admin can manage user accounts, oversee appointments, and monitor the overall functionality of the system.

### ***Ethical Considerations***

Ethical considerations are crucial in the development and implementation of the proposed web-based appointment system to ensure security, fairness, and equal access for all users. The system must provide services without discrimination based on background, work experience, or socioeconomic status. To enhance inclusivity, multiple access options, such as web-based and telephone scheduling, may be integrated, ensuring that users with varying levels of digital literacy or internet access can still benefit from the system.

To uphold ethical research practices, the following principles were observed:

Participants must not be subjected to harm in any form.

The dignity of all participants must always be respected.

Informed consent must be obtained from participants prior to their involvement.

The privacy and confidentiality of participants must be guaranteed.

A sufficient level of data protection must be maintained to safeguard information.

Anonymity of participants and institutions involved must be preserved.

Deception or misrepresentation of the study's objectives must be strictly avoided.

Any affiliations, sources of funding, or potential conflicts of interest must be fully disclosed.

Communication regarding the study must be conducted with honesty and transparency.

Misrepresentation of findings or biased interpretation of data must be avoided at all costs.

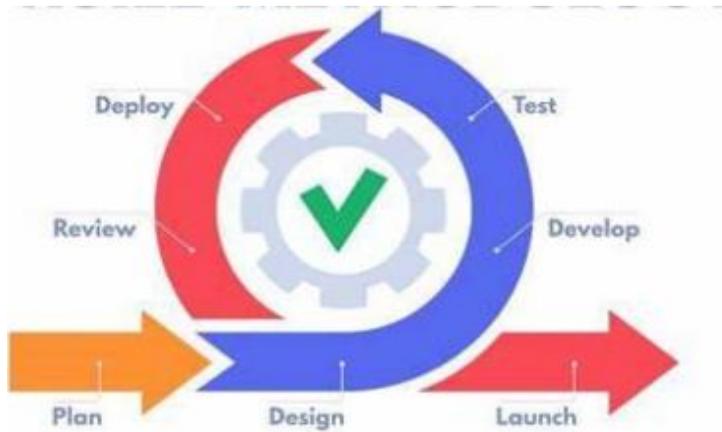
By adhering to these ethical standards, the study ensures that the integrity of the research process is maintained, participants' rights are protected, and the developed system upholds trust and accountability.

### ***System Development Approach***

This study adopted the Agile methodology in developing the proposed web-based appointment system. The Agile method was chosen because it promotes flexibility, continuous improvement, and close collaboration with users throughout the development process. The first step involved planning, during which the requirements of the system were identified based on the needs of the target users, students and school administrators.

**Figure 3**

*Agile methodology*



The next phase was design and development, where various programming languages and applications were utilized to build the system's functionalities and interface. Particular attention was given to creating a user-friendly visual design to ensure accessibility for students and administrators. Testing was then conducted to verify whether the system's functions were working correctly and whether the design was operating as intended. Only when no major errors were found did the researchers proceed to the deployment stage. In this phase, the system was reviewed and retested to ensure stability, reliability, and efficiency before being launched for use.

The system provides two distinct access points: one for students and another for administrators. Students are required to sign up using their student number to create an account. Once registered, they can log in with their credentials to request appointments with the registrar's office. Administrators, on the other hand, are given unique access codes to log in directly. From their dashboard, they can view student information, monitor requests, review requirements, and approve or deny appointments according

to the schedule.

### ***Procedures of Different Phases***

*Implementation.* The web-based appointment system was implemented in the registrar's office. Through this system, students can submit appointment requests online, while the registrar administrator can review, accept, or deny the requests. This feature eliminates the need for long queues and manual scheduling, streamlining the registrar's daily operations.

*Testing.* System testing played a critical role in development. Without rigorous testing, it would be impossible to verify whether the system performs as intended. Testing ensured that all functions were fully operational, user inputs were correctly processed, and errors were minimized. Continuous testing also provided opportunities to refine both functionality and design prior to full deployment.

*Deployment.* The system was deployed in the registrar's office, with the registrar administrator serving as the primary administrator and students as the main end-users. Deployment included installation, configuration, and another round of pilot testing to ensure that the platform operated smoothly within the school's environment.

*Maintenance.* To guarantee long-term efficiency and reliability, the system will undergo quarterly maintenance. This includes performance checks, database reviews, and backup creation to secure information and prevent data loss. Regular maintenance ensures that the system remains functional, secure, and responsive to the evolving needs of students and administrators.

## Technical Framework

### *Materials*

The primary materials used to access and operate the web-based appointment system include computers, laptops, mobile phones, and other internet-enabled devices. These devices serve as the main tools for both students and administrators in utilizing the system's features.

### *Software*

The development of the web-based appointment system required specific software tools. Visual Studio was used to compile and manage program codes, while XAMPP version 3.3.0 was employed to configure and manage the MySQL database as well as to run the local server environment.

### *Hardware*

Since the system is a web-based application, it does not demand high-end hardware specifications. It is designed to be accessible on commonly available devices, ensuring inclusivity and usability for all intended users. Minimum requirements include:

*Processor:* Intel Core Duo or higher

*Operating System:* Any version of Windows, macOS, or Linux

*Mobile Compatibility:* Any Android version and other mobile operating systems

*Device Type:* Desktop computers, laptops, tablets, and smartphones

This setup ensures that the system remains cost-effective and widely accessible, even without advanced or expensive technology. The system is designed to be accessible and flexible across multiple platforms. While a computer is typically used by administrators for database management and

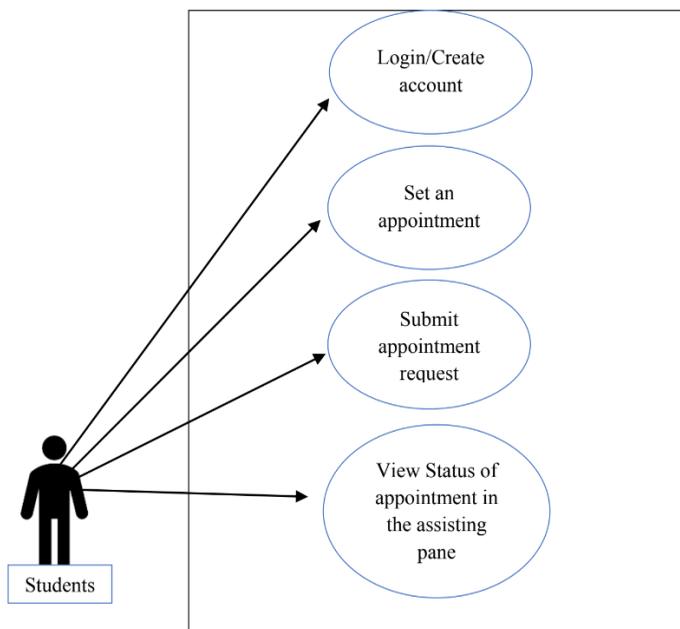
system operations, the appointment system is also accessible through Android phones and other mobile devices. This feature allows students to conveniently manage appointments outside of school premises and prepare before visiting the registrar’s office. By ensuring compatibility with both desktop and mobile devices, the system provides greater convenience, flexibility, and user readiness.

### ***Modeling***

Figure 4 outlines how a student can interact with the web-based appointment system. The process begins with the creation of a student account. If the student already has an account, they may proceed directly to the login page using their registered username and password. Once logged in, the student can schedule an appointment by filling out the necessary details and submitting an appointment request through the system.

**Figure 4**

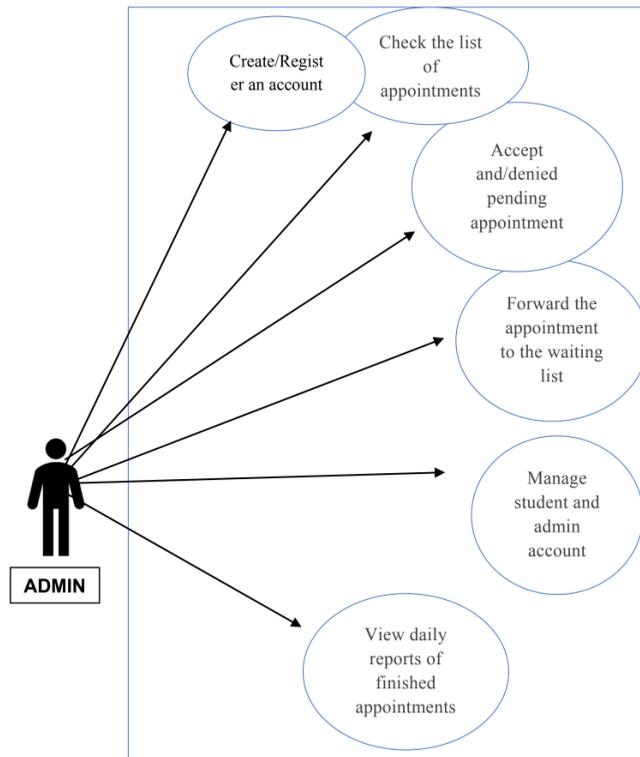
*Use a case diagram for the web-based appointment system*



After submission, the student may track the status of their appointment in the designated status pane, which provides real-time updates regarding approval or denial by the registrar’s office. In addition to appointment scheduling, students have access to account management features, such as updating their profile information, changing their password, and maintaining their personal records.

**Figure 5**

*Use case diagram for the web-based appointment system for an administrator*



The administrator’s role in the web-based appointment system begins with the creation of an account. If the administrator already has an existing account, they can proceed directly to the login page using their assigned credentials. Once logged in, the administrator gains access to the

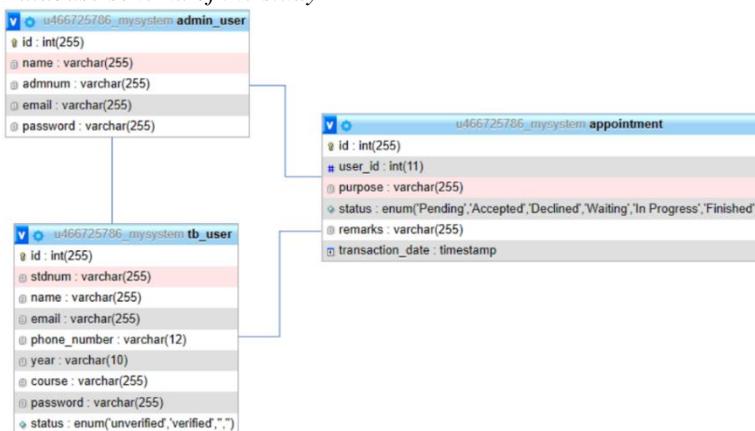
admin dashboard, where they can perform various management functions.

Administrators can view the list of appointments submitted by students and take necessary actions by either accepting or denying pending appointment requests. Approved appointments are automatically moved to the waiting list for processing, while denied requests are recorded for monitoring purposes.

In addition, administrators are responsible for managing student and administrator accounts, ensuring that user information remains updated and accurate. The system also provides the administrator with access to daily reports summarizing completed appointments, which supports record-keeping, monitoring, and decision-making for the registrar's office.

**Figure 6**

*Database schema of the study*



## *User GUI*

The following figures present the design of the developed system.

Figure 7 displays the login page for students, where they can either log in to an existing account or register for a new account. The interface is designed to be user-friendly, allowing students to quickly access the system

for appointment scheduling or account management.

**Figure 7**

*Login page*



**Figure 8**

*Student login page*



**Figure 9**

*Setting appointment page*

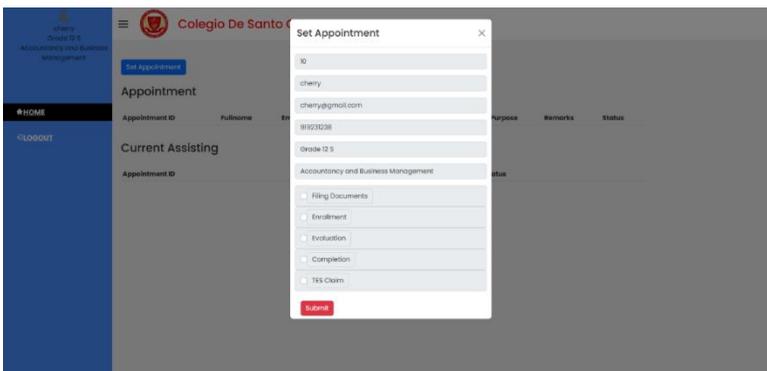


Figure 8 shows the login page for students, where they can either log in to their existing account or register for a new one. Meanwhile, Figure 9 presents the appointment system dashboard. Inside the appointment system, students can find the Home button, the Logout button, and an option to set an appointment.

**Figure 10**

*Setting an appointment*



Figure 10 shows the system designed for students to conveniently set or request appointments.

**Figure 11**

*Submitting an appointment*



Figure 11 shows the system design interface for submitting an

appointment.

**Figure 12**

*Appointment listing*

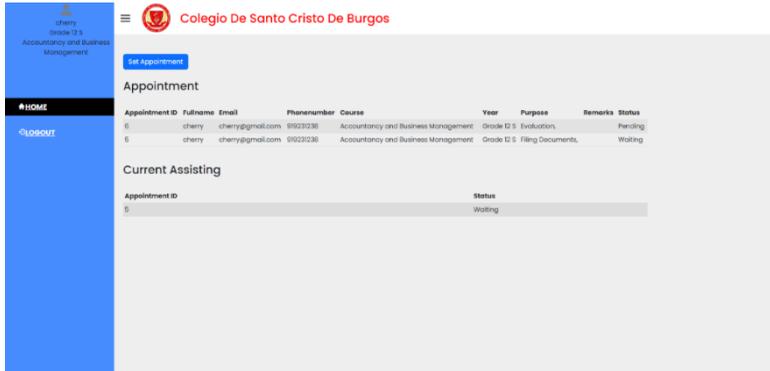


Figure 12 shows the system design interface for viewing the appointment assistance status on the assistance pane.

**Figure 13**

*Admin login page*



Figure 13 shows the system design interface for the administrator login and account registration.

**Figure 14**

*Admin list of appointments*



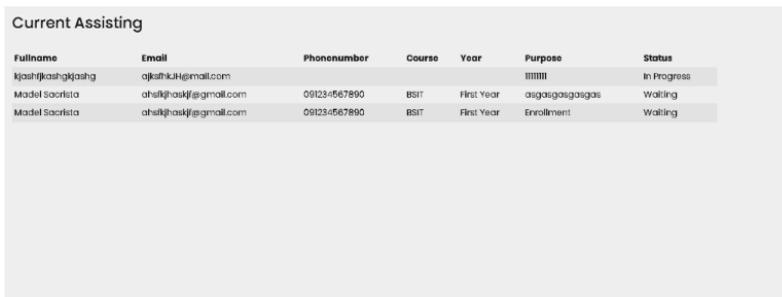
**Figure 15**

*Accepting appointments*



**Figure 16**

*Waiting list*



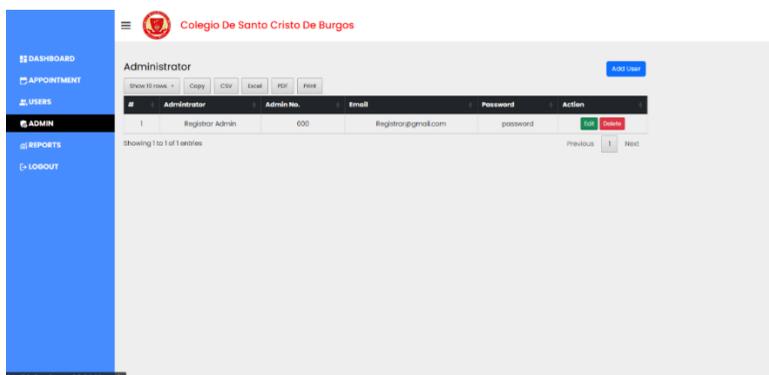
Figures 14 to 16 present the different system design interfaces for the administrator. Figure 14 shows the page design of the admin dashboard, where the administrator can access the appointment list, system users, system admins, reports, and the logout button. Figure 15 illustrates the

system design interface where the administrator can accept or deny pending appointment requests from students. Lastly, Figure 16 displays the system design interface that allows the administrator to forward an appointment to the waiting list.

**Figure 17**  
*Managing student account*



**Figure 18**  
*Administrator account*



Figures 17 and 18 illustrate the system design interfaces for account management. Figure 17 shows the interface where the administrator manages student accounts, while Figure 18 presents the interface for

managing administrator accounts.

### ***Development***

The web-based appointment system was developed using Visual Studio Code for programming, XAMPP to configure the local server and database, and phpMyAdmin for managing the MySQL database. The system incorporates JavaScript (JS), HTML, and CSS to build its functionality and user interface. The system includes:

Login and logout pages for both students and administrators.

An administrator dashboard that displays user statistics, appointment lists, and other management features.

Features for students to create accounts, schedule appointments, and track appointment status.

This combination of programming languages and tools ensures that the system is interactive, user-friendly, and fully functional across multiple devices.

### ***Testing***

Testing is a critical phase to ensure that the system performs as intended and meets the requirements of both students and administrators. In this phase, the researchers present a testing plan and operating procedure for each system function. Before implementation, two major testing stages are conducted:

*Test Case:* Specific scenarios are created to evaluate the correctness of each function, ensuring that inputs produce the expected outputs.

*Test Approach:* The overall strategy to assess system performance, reliability, usability, and security, including both functional and non-functional testing.

These testing procedures ensure that any errors or issues are identified and resolved prior to deployment, guaranteeing that the web-based system is reliable, efficient, and ready for use.

### ***Test Approach***

Both students and administrators can interact with the web-based appointment system according to their assigned roles and functions. The system is designed to provide the expected outputs and responses for each user type, ensuring that students can schedule and track appointments while administrators can manage requests, monitor schedules, and generate reports efficiently.

The web-based appointment system was deployed in the registrar's office, as it is specifically developed for the school's administrative processes. Deployment includes installation, configuration, and initial testing within the school environment to ensure full functionality.

For system maintenance, the research team will remain available to address issues, perform updates, and conduct routine maintenance after deployment. This ongoing support ensures that the system remains efficient, secure, and reliable for both students and administrators over time.

### ***System Testing and Observations***

The researchers present accurate and honest observations regarding the proposed web-based appointment system. Key observations and findings include:

The administrator account creation function operates successfully.

Administrators can view and manage the list of student appointments efficiently.

Administrators can accept or deny appointment requests submitted

by students.

The system allows administrators to manage both student and administrator accounts effectively.

Administrators can view daily reports summarizing completed appointments.

Students can create and log in to their accounts without issues.

Students can set or schedule appointments using the system.

Appointment requests are successfully submitted and recorded in the system.

Students can view the status of their appointments through the designated interface.

Students can manage and update their personal account information securely within the system.

These results confirm that the web-based appointment system is functional, reliable, and meets the intended objectives for both administrators and students.

### ***Evaluation of the System***

The system was evaluated using a survey administered to 27 respondents consisting of students and administrators. The questionnaire was designed based on ISO 25010 standards, covering the following aspects: functional system performance efficiency; system maintainability; system suitability; system usability; system compatibility and system security. To analyze the responses, the weighted mean formula was applied. The survey employed a four-point Likert scale with the following categories: strongly agree, agree, disagree, and strongly disagree. Each response option was assigned a mean range to facilitate the evaluation and interpretation of the system's effectiveness.

**Figure 19**

*System evaluation*

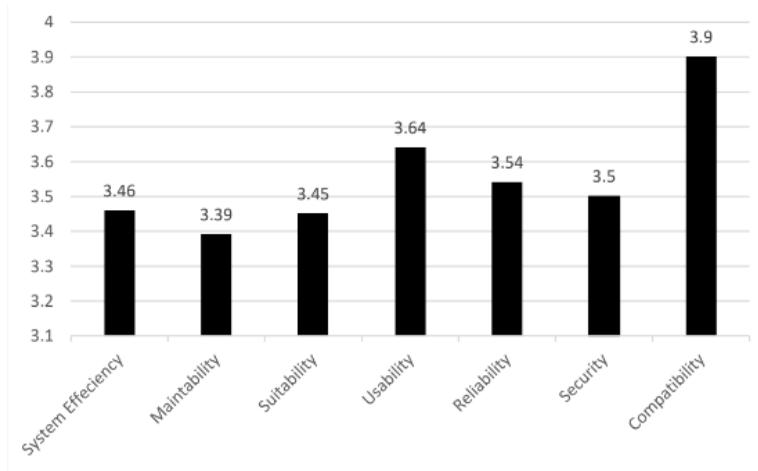


Figure 19 shows how well the system performs its functions. All three indicators, software functionality, responsiveness to user needs, and error-free operation, received weighted means above 3.3, with an overall average weighted mean (AWM) of 3.46, interpreted as “Strongly Agree.” This suggests that users found the system highly efficient and responsive, meeting its intended performance goals with minimal issues.

Maintainability assesses whether the system is easy and cost-effective to manage. Users strongly agreed that the system is easy to maintain (3.37), has low maintenance costs (3.36), and remains upgradable (3.35). With an AWM of 3.39, the system demonstrates good maintainability, ensuring sustainability over time with minimal technical challenges.

Sustainability focuses on the long-term usefulness and error-free functionality of the system. All three functions, suitability for the registrar, accuracy of transactions, and error-free operations, scored between 3.43 and 3.47, yielding an AWM of 3.45. This indicates strong user confidence in the system’s ability to remain effective and useful in the future.

Usability evaluates user interaction with the system. Respondents strongly agreed that the system has a user-friendly interface (3.49), is easy to operate (3.50), and easy to learn even for non-technical users (3.48). With an AWM of 3.64, the highest among the categories, usability emerges as one of the strongest features, reflecting the system’s accessibility to diverse users.

Reliability relates to the consistency of system performance. Users strongly agreed that the system is reliable for the registrar (3.88), for students (3.49), and in its functions (3.43). The AWM of 3.54 shows that reliability is a major strength, enhancing trust in the system for critical operations.

Security measures the protection of data and authentication processes. Respondents strongly agreed on the system’s confidentiality (3.20), secure data handling (3.30), and identity authentication (3.10). Despite slightly lower scores compared to other dimensions, the AWM of 3.50 indicates that users perceive the system as sufficiently secure, though improvements could still be made in authentication.

Compatibility checks whether the system works across devices and locations. The system was found to be compatible with different devices (3.50), accessible anywhere (3.47), and usable by multiple users at once (3.56). The AWM of 3.90 is the highest across all categories, highlighting compatibility as the system’s strongest feature.

The graph visually presents the evaluation results across the seven dimensions (performance efficiency, maintainability, sustainability, usability, reliability, security, and compatibility). It likely shows that all dimensions scored in the “Strongly Agree” range (above 3.20), with Compatibility and Usability ranking the highest, while Security scored slightly lower but still within “Strongly Agree.” The figure supports the

conclusion that the system is well-developed, user-friendly, reliable, and future-ready. The system evaluation demonstrates consistently strong performance across all dimensions, with the highest strengths in compatibility, usability, and reliability. While all areas achieved positive feedback, Security is slightly lower, suggesting it could be prioritized for future improvement.

## **Conclusion**

The developed web-based appointment system effectively addresses the challenges associated with traditional appointment scheduling. The system allows both administrators and students to create and manage accounts efficiently. For administrators, the system provides the ability to view the list of scheduled appointments, accept or deny student appointment requests, and transfer approved appointments to a waiting list. Administrators can also manage student and administrator accounts and access detailed reports, including both recent and historical records of completed appointments. For students, the system enables the creation of accounts, submission of appointment requests, and tracking of appointment status, providing a convenient and accessible platform for scheduling registrar transactions.

Further testing and evaluation demonstrated that the system meets the standards outlined in ISO/IEC 25010, confirming its efficiency, maintainability, sustainability, security, usability, and reliability. These results indicate that the system is a practical and effective solution, significantly improving the appointment scheduling process compared to traditional manual methods.

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## Chapter 3

### *Prototyping Cross-Platform IT Solutions*

Welcome to the opening chapter of *Information Technology Cross-Platform Application Development*. You are about to dive into one of the most exciting and practical stages of IT development—prototyping. This is where ideas begin to take shape, where your concepts move from theory to something you can actually test, interact with, and improve.

In this chapter, you will explore how to create prototypes that work across different platforms—whether it’s Android, iOS, Windows, or hardware-based systems like microcontrollers and sensors. You will learn how to bring together your technical skills and creativity to build early versions of real-world IT solutions.

This book takes a project-based learning approach. Each project introduces you to the principles of cross-platform development, system integration, and data management. From IoT and Machine Learning to Virtual Reality and automation systems, every project begins with a prototype—a simple, functional version that helps you validate design, performance, and user experience before full-scale development.

A prototype is your first working model—a tangible draft of your idea. It lets you test how your system behaves, uncover flaws early, and refine your design. For cross-platform projects, prototyping is especially important because it helps ensure your app or system runs smoothly on different devices and operating systems.

In this chapter, you will learn how to conceptualize, design, and build early-stage prototypes using various tools and technologies. The focus is on the iterative nature of prototyping—testing, improving, and testing again—until you create a strong, reliable solution.

Throughout this chapter, you will encounter diverse examples of cross-platform projects that solve real-world problems. These projects integrate hardware, software, and data analytics to deliver innovative, functional systems.

# A Sensor-Based Gas Leakage Detection System for Kitchen Safety Using Arduino Uno R3

*Kristian Paul A. Alcala, Justine C. Alcance, Marvin T. Eclavea & Amiel S. Landicho*

Safety is a crucial concern in the modern world since accidents can occur anywhere. Areas that use flammable gases are especially prone to accidental fires. The advancement of futuristic technologies, such as the Internet of Things (IoT), enables the integration of devices and automation of daily tasks (Sokienah, 2023; Alahi et al., 2023; Choudhary, 2024; Zreikat et al., 2025; Rathi et al., 2025). In this study, IoT is applied as part of a gas detection system to identify leaks, alert users, and prevent further gas-related hazards. One hazardous gas widely employed in industry and detrimental to human health must be closely monitored; if its levels exceed the average range, the system ensures that immediate safety measures are taken (Márquez-Sánchez et al., 2023).

Gas leak detection systems are designed to prevent explosions by identifying leaks at an early stage. As science and technology advance, these systems continue to evolve and become more sophisticated. A commonly monitored gas is Liquefied Petroleum Gas (LPG), also known as butane, which is extensively used in both residential and commercial settings but

poses serious risks if mishandled. The use of detection systems is therefore essential for guaranteeing safety.

Several innovations have been developed to improve the effectiveness of such systems. For instance, unlike conventional gas detection devices, the LPG Gas Leakage Detection Control System by Bairagi et al. (2024) not only triggers an audible warning but also automatically turns off the gas valve when a leak is detected. This additional feature enhances safety by preventing further leakage and reducing the risk of accidents. Similarly, Faye et al. (2025) designed a system that employs an audible alarm to promptly notify users of a gas leak, enabling them to take immediate corrective measures and prevent potential disasters. Mishra et al. (2025) further emphasized the role of IoT by integrating detection systems with the Blynk Application, which provides real-time information about the type and concentration of gas detected. This ensures that users can easily interpret the data and respond effectively. The integration of Arduino technology provides additional advantages by simplifying the connection of sensors and components into a compact and user-friendly system (Ga et al., 2021; Gao et al., 2021; Sharipov et al., 2025). This design improves both efficiency and reliability, making the system more effective in everyday use. Researching gas leakage detectors also highlights the importance of adhering to safety regulations and understanding the dangers posed by gas leaks.

Gas leaks remain a global concern due to their potentially lethal consequences. They may occur when gas appliances such as stoves or heaters are not properly maintained, or when gas pipelines are damaged (Márquez-Sánchez et al., 2023). To address this issue, researchers have developed gas leakage detectors that utilize chemical, electrochemical, or physical sensors to detect the presence of specific gases or groups of gases.

Once a leak is detected, the system typically triggers alarms to warn nearby residents and may even notify designated personnel.

Preventive action is critical once a leak is identified. Turning off the gas supply before or alongside triggering an alert system minimizes further leakage and significantly reduces the risk of fire or explosion. Detection systems may then activate alarms through multiple channels, including audio alerts, visual indicators, or mobile notifications, ensuring that people are informed promptly. The use of Arduino Uno R3 further enhances system reliability, as it processes sensor data autonomously and activates appropriate responses without requiring manual input. This enables the system to sound alarms, enforce safety protocols, or shut off the gas supply, providing a dependable solution for enhancing safety, particularly in kitchens.

The main objective of this study is to design and demonstrate a sensor-based gas leakage detection system capable of locating LPG leaks under varying environmental conditions. The proposed system aims to detect, signal, and control gas leaks efficiently while providing users with timely alerts. At the core of this design is a sensor that can quickly and accurately identify gas leaks, thereby helping prevent accidents and safeguarding lives and property.

## **Theoretical Framework**

### *Gas*

Gas, an invisible state of matter, permeates the environment and plays a fundamental role in both natural and human-made phenomena. From the air people breathe to the stars in the night sky, gas is an ethereal entity that impacts daily lives. Safety is paramount in modern society, as

accidents involving gases can occur anywhere. Environments handling volatile and flammable gases pose a higher risk of accidental fires. Particular attention must be given to hazardous gases commonly used in industry due to their harmful effects on human health. Continuous monitoring of gas levels allows abnormal increases to be promptly detected, enabling timely safety interventions (Márquez-Sánchez et al., 2023).

LPG, commonly used as cooking gas, is a crucial resource in households and commercial settings. However, LPG use presents potential hazards. Accidental depletion during cooking or unnoticed gas leaks can lead to critical situations, including house fires.

### ***LPG Gas Leak***

Gas leaks are a leading cause of residential fires, resulting in property damage and potential loss of life (Brotsky et al., 2024). LPG leaks are often difficult to detect with the naked eye, and without detection systems, the risk of fire increases. According to the Bureau of Fire Protection (BFP) incident statistics, 492 fires in 2019 were caused by gas or oil stoves (BFP, 2019).

While LPG offers convenience, mishandling it can pose serious risks. Dedicated gas leak detection systems for LPG are therefore essential. Friday et al. (2025) and Subramanian et al. (2020) emphasize the importance of integrating sensors to detect LPG leaks and issue early warnings, such as SMS notifications, allowing affected parties to take preventive measures. Asafe et al. (2022) demonstrated a system using an embedded microcontroller and MQ-2 gas sensor to detect gas leaks and notify owners or service stations of potential hazards. Such systems have proven effective in alerting users promptly and preventing explosions.

## *Gas Leakage Prototype*

Hasibuan et al. (2019) developed a gas leak detection system that identifies gas leaks and prevents accidents, ensuring the safety of individuals and property. The system employs sensors to detect gases in residential and industrial settings. Upon detecting a leak, the system alerts users through audible alarms and may send SMS notifications. Preventive measures include activating alarms, turning on exhaust fans to mitigate gas accumulation, and automatically shutting off the main power source to reduce hazards.

Similar systems, such as the Design and Development of Kitchen Gas Leakage Detection and Automatic Gas Shut-Off System, detect leaks, notify users, and automatically shut off gas supplies to prevent accidents (Apeh et al., 2014). Kuruvilla et al. (2025) proposed an integrated sensor system capable of detecting LPG under varying environmental conditions, maintaining accuracy across different temperatures and humidity levels. Mishra et al. (2025) highlighted the effectiveness of using Arduino with gas sensors to monitor toxic gases such as butane and methane, providing users with precise readings through the Blynk application.

The LPG Gas Leakage Detection Control System developed by Bairagi et al. (2024) goes a step further by automatically shutting off the gas valve in addition to issuing audible alarms, significantly reducing risks. Shah et al. (2024) developed a system that primarily relies on audible alarms to alert users when leaks are detected. Overall, these advancements demonstrate the critical role of sensor-based systems in ensuring safety by detecting, notifying, and preventing gas-related hazards.

## **Research Framework**

This study employed a survey-based approach to evaluate the effectiveness of a sensor-based gas leakage detection system. A total of 205 respondents participated in the study. The sample size was determined using Slovin's formula, and questionnaires were distributed through a random sampling technique to ensure representative participation. The questionnaire was developed based on the ISO 25010 software quality standard, covering key aspects such as functional suitability, reliability, usability, performance efficiency, and maintainability. To analyze the collected data, the researchers applied the weighted mean formula, which allowed each component's relative importance to be quantified and an overall score to be calculated. This approach provided a comprehensive evaluation of the system's quality, offering quantitative insights into its performance according to ISO 25010 criteria.

Respondents answered each question using a four-point Likert scale with the categories: strongly agree, agree, disagree, and strongly disagree. Each response was assigned a corresponding value, and the resulting mean scores were interpreted according to predefined ranges to determine the evaluation outcomes. This methodology enabled a systematic assessment of the software's quality attributes, ensuring reliable and valid results for the study.

### ***Experimental Design***

The experimental design for evaluating gas leakage detectors involved creating controlled environments, such as a chamber or room, where gas leaks could be safely simulated and the performance of the detectors assessed. This process required selecting appropriate gas detection

technologies and defining the experiment's parameters and procedures.

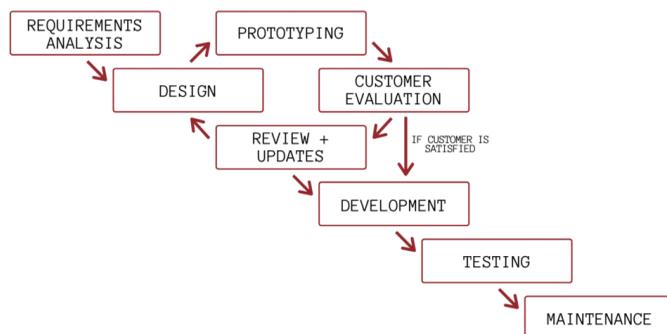
Researchers first determined which gases, such as methane or propane, would be used to test the sensitivity and accuracy of the detectors. The test chamber was then prepared, ensuring it was properly sealed and equipped with the necessary monitoring and measurement tools. Once the chamber was set up and the experimental guidelines were established, the tests commenced. Data collected during the experiments were analyzed to evaluate the detectors' sensitivity, accuracy, and overall performance.

The experimental design encompassed setting up controlled environments, selecting suitable gas detection technologies, establishing testing procedures, conducting experiments, and analyzing the results to determine the effectiveness of the gas leakage detectors.

### ***Modeling***

The models chosen had a significant influence on the testing process. They specified what, where, and when the anticipated testing would occur, guided regression testing, and helped determine the appropriate testing methodologies. For the proposed system, the researchers employed the prototype model during its development, as it was the most suitable strategy for iterative testing and refinement.

**Figure 1**  
*Prototyping model*



The prototyping model used for developing the sensor-based gas leakage detection system involved an iterative process of creating and refining the system through multiple prototype iterations. The initial prototype served as a proof of concept, demonstrating the system's core features and functionalities. Feedback and insights from testing the initial prototype informed subsequent iterations, leading to improvements and enhancements that addressed identified issues. This approach aligns with existing literature on software prototyping techniques, highlighting the benefits, challenges, and best practices associated with using prototypes (Khan, 2021).

### ***Procedures of the Different Phases***

The development of the gas leakage detection system followed several distinct phases under the prototyping model.

*Planning and design.* The planning and design phases began with identifying the research questions and specific objectives of the study. A literature review was conducted to understand the current state of knowledge, identify gaps, and determine areas requiring further research.

*Requirements analysis.* During the initial phase of the prototyping model, an extensive analysis of system requirements was conducted. This involved thoroughly examining the specifications and understanding the users' needs and expectations through effective communication. Researchers also assessed the availability and suitability of the required tools and materials for the project.

*Design.* In the design phase, an initial, rudimentary design of the gas leakage detector was created. This preliminary design was not fully detailed but served as a framework to provide users with a basic understanding of the system's functionality and structure.

*Prototyping.* The prototyping phase involved constructing a tangible, operational model of the system. Researchers acquired essential components such as the Arduino Uno R3 microcontroller, sensors, jumper wires, and a GSM module to build a working prototype. This allowed the team to evaluate and refine the system's design and functionality iteratively.

*Customer evaluation.* The prototype was presented to the client for initial evaluation. Feedback regarding strengths and weaknesses was collected and provided to the developers for improvements. If the client was satisfied with the prototype, the researchers proceeded directly to the development phase; otherwise, the review and update process was implemented.

*Review and updates.* When feedback indicated that the prototype required refinement, the researchers modified the system according to the client's suggestions. This iterative review ensured that user requirements were incorporated effectively before final development.

*Development.* In the development phase, the final working system was constructed to meet all identified requirements. The system was built, tested, and verified to ensure it performed as intended, incorporating all modifications suggested during the prototyping and evaluation phases.

*Testing.* The gas leakage detector underwent thorough testing to evaluate performance and identify potential errors. Minor flaws were corrected, and necessary adjustments were made to ensure the system operated reliably and met established standards.

*Maintenance.* After completing the final prototype, the fully developed system was deployed for operational use. Comprehensive evaluation ensured the system could accurately detect target gases, maintain sensor sensitivity and precision, and perform reliably under various conditions.

## Technical Framework

This section explains the various components of the prototype.

### *Software*

The software requirements for the proposed system are detailed in Table 1. These include the various programs necessary to develop a gas leakage detection system.

**Table 1**

*Software specification*

Software		Description
IDE Platform		contains a text editor for writing code, a message area, a text console, a toolbar with buttons for common functions and a series of menus.
Blynk Application		Blynk is an IoT platform for iOS or Android smartphones that is used to control Arduino, Internet.
Operating System		A Microsoft Windows operating system that runs on a 32-bit or 64-bit architecture used in the development of the system
Web browser		Chrome (recommended) or any web browser installed

The researchers used the IoT Blynk Application to interface with sensors and collect data, while an operating system managed hardware resources and provided a platform for other software components. Together, these software elements processed sensor data, facilitated decision-making, and allowed users to monitor and control the system. Additional software, such as a web browser or an Integrated Development Environment (IDE) for coding, was also required depending on the specific needs of the system.

**Table 2***Hardware specification*

Hardware	Specification
Arduino UNO 	microcontroller board based on the ATmega328P (datasheet) USB 2.0 Cable Type A/B
MQ-2 Sensor 	The MQ-135 gas sensor detects gases like smoke, alcohols, aromatic chemicals, ammonia, nitrogen, and oxygen.
GSM- Module 	The SIM800 offers all hardware interfaces between the module and customers' boards and contains 68 SMT pads.
Buzzer 	The Arduino buzzer is a device that produces sound when an electric current is passed through it.
NodeMCU ESP8266 	Amica NodeMCU measures 49mm x 26mm with a standard pin space of 0.1" between pins and 0.9" between rows.
Wood slices 	Wood slices used for prototype frame and main box.
Plastic cap 	Used for the closing mechanism for the lid of Gas tank
Handle Bar 	Used as a frame and handle for the plastic cap. Attachable to gas tank handle.

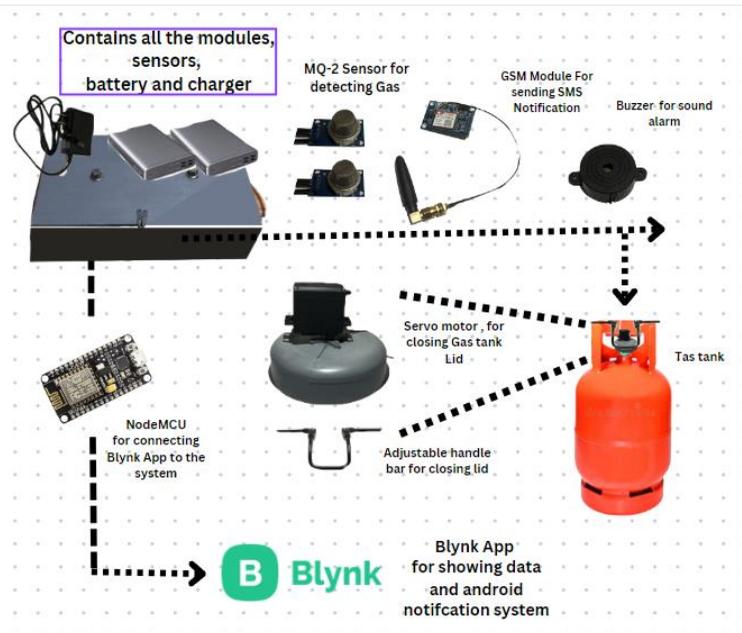
The hardware requirements for the gas leak detection system included several essential components. The researchers used sensors to detect the presence of gas, an Arduino microcontroller to process sensor data and make decisions, and the Blynk application to display the system's status. These components worked together to detect gas leaks and promptly alert users to any potential hazards.

## System Design

Figure 2 illustrates the process flow of the system. After completing the coding process, all sensors and modules were initialized while the system was in a connected state.

**Figure 2**

*System architecture*

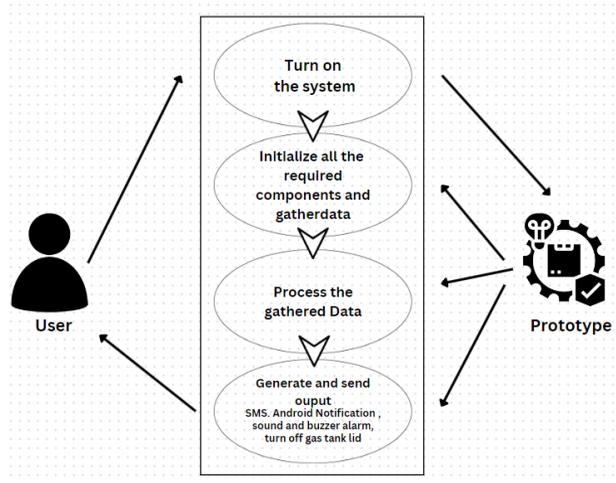


Following initialization, the sensors evaluated the environment based on predefined parameters. The microcontroller compared each sensor output against these parameters to determine whether the conditions were met. If a parameter exceeded the specified limits, the microcontroller activated the GSM module and triggered the buzzer to send an SMS alert indicating which parameter was breached. If the parameters were within acceptable ranges, the system continued to monitor the environment. Simultaneously, the IoT Blynk application displayed the current status of

the system.

**Figure 3**

*Use case diagram*



The Use Case diagram provided a comprehensive overview of the system's operation. During the implementation of the Sensor-Based Gas Leakage Detection System for Kitchen Safety using Arduino Uno R3, the user first installed and started the system. Once installed, the system automatically initialized all required sensors and components. It continuously monitored gas levels in the kitchen environment, collecting critical data. When a gas leak or abnormal gas level was detected, the system communicated the information to the user through multiple channels, including SMS notifications to mobile phones and Android notifications via the Blynk application.

Figure 4 shows that the prototype incorporated various functions to detect gas leaks and notify users. It used gas sensors to identify leaks in the kitchen environment, triggering multiple notification methods, including SMS messages, Android notifications, a sound buzzer, and automatic

closure of the gas tank lid. When a gas leak was detected, the system sent SMS alerts to designated phone numbers, delivered notifications to Android devices via the Blynk application, emitted a loud sound through the buzzer, and automatically closed the gas tank lid to reduce potential hazards. The prototype, however, did not include provisions for cleaning the system or the LPG gas tank. While the design focused on leak detection, user notification, and safety measures, it did not address the maintenance or cleaning requirements of these components.

**Figure 4**

*System boundary*

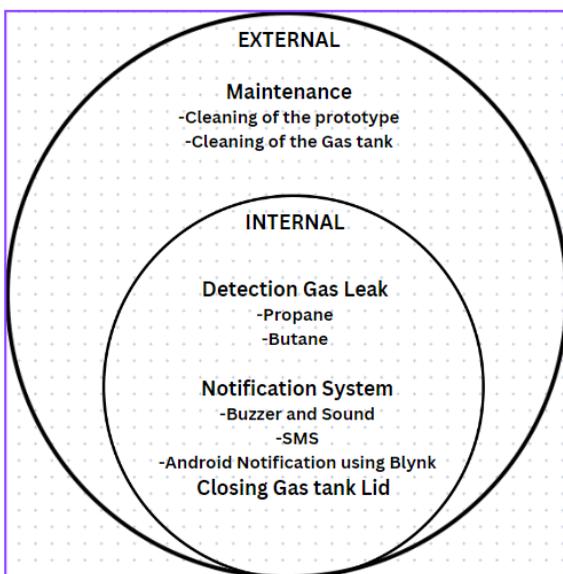
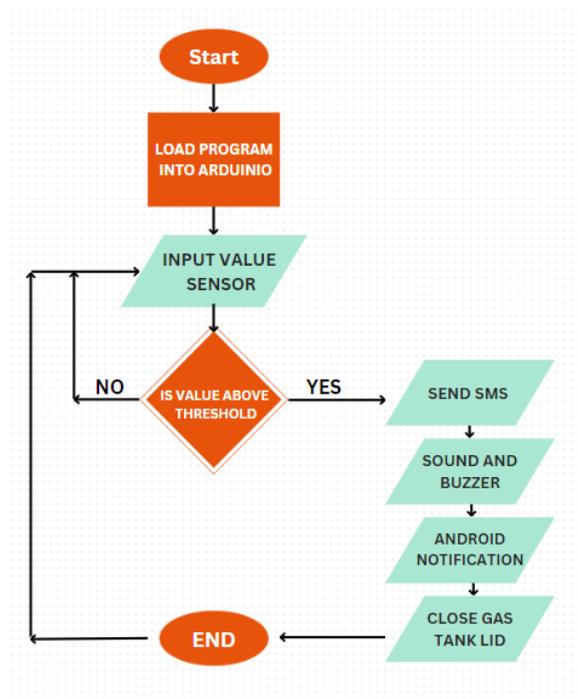


Figure 5 represents the data flow diagram of the proposed system. The system's operation began with initializing all sensors and modules to ensure proper connectivity. The program was loaded onto the Arduino board, which then continuously monitored gas levels in the kitchen. When a gas leak exceeded the predetermined threshold, the system activated several response mechanisms. These included closing the gas tank lid as a

preventive measure, activating a sound alarm and buzzer to alert nearby individuals, sending SMS notifications to designated contacts, and delivering Android notifications to connected devices. After executing these safety measures, the system returned to continuous monitoring of the kitchen environment to maintain safety.

**Figure 5**  
*Data flow diagram*



**Figure 6**  
*Circuit diagram*

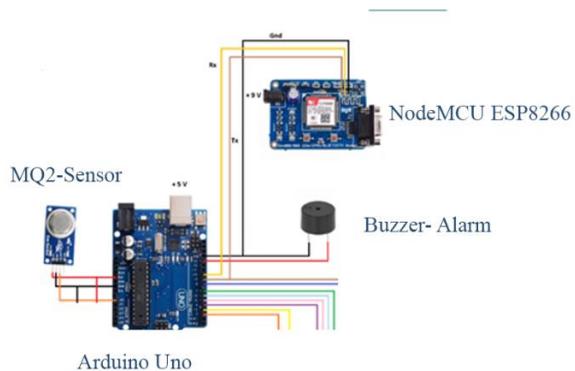


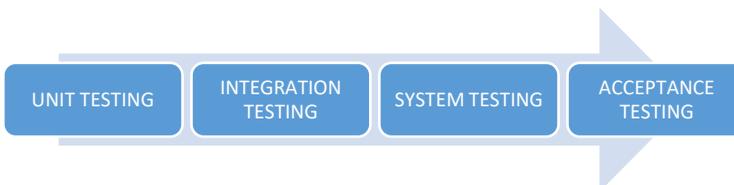
Figure 6 illustrates the overall architecture and circuit layout of the system, designed for ease of installation and use. The system incorporated various components to ensure efficient operation. The Arduino board served as the central control unit, while the NodeMCU ESP8266 module enabled connection to the Blynk application for remote monitoring and control. Gas monitoring was achieved using the MQ2 sensor, recognized for its high sensitivity to gases, ensuring accurate leak detection. A buzzer alarm provided immediate audible alerts when gas levels exceeded a predetermined threshold, allowing prompt response. By effectively integrating these components, the system provided reliable monitoring, remote accessibility, and enhanced safety management.

### ***Testing***

The researchers conducted unit testing, leveraging their familiarity with the system’s code and component design. This approach allowed them to create test cases tailored to the specific functionality and requirements of each component. Unit testing also facilitated the early detection and diagnosis of potential issues, ensuring that individual components functioned correctly before full system integration.

**Figure 7**

*Test case of the propose prototype*



*Test approach.* Unit testing was conducted using specialized software tools that automated the execution of test cases and reporting of

results. These tools enabled the researchers to generate and run multiple test cases while tracking progress and outcomes. Unit testing was essential in accelerating the evaluation process and ensuring comprehensive assessment of each component. Its primary objective was to enhance the system's quality and reliability by identifying and rectifying defects in individual elements before they affected overall functionality.

*Integration testing.* Integration testing was performed to validate the interaction and compatibility between various system components, including the Arduino Uno R3, NodeMCU ESP8266 module, MQ2 gas sensor, Blynk Application, and buzzer alarm. The researchers simulated different scenarios to evaluate system behavior, including the accuracy of gas detection, activation of the alarm, and communication with the Blynk application.

*System testing.* System testing involved simulating various kitchen scenarios and examining the integrated operation of all system components. This phase ensured that the system functioned correctly, responded appropriately to detected gas leaks, and maintained compatibility across all modules.

*Acceptance testing.* Acceptance testing assessed the system's compliance with user requirements and its ability to perform its intended functions. End users or their representatives evaluated the system in real-world kitchen scenarios to confirm its accuracy in detecting gas leaks, timely generation of alerts, and effectiveness in enabling users to take appropriate actions. The usability of the interface, integration with notification systems, and clarity of training materials were also evaluated to ensure a seamless user experience.

### ***Field Trials and Pilot Testing***

Field trials were conducted in real-world environments to obtain actual performance data. This approach allowed the researchers to identify issues that were not evident in controlled laboratory conditions. User feedback gathered during pilot testing was used to refine system design and improve functionality. For example, if the system failed to detect leaks consistently, the researchers adjusted sensor placement or modified detection algorithms to enhance performance.

### ***Deployment and Maintenance***

The deployment strategy involved installing the gas leakage detection system in selected buildings or facilities where active monitoring was required. Sensors were strategically positioned to detect gas leaks promptly and notify users immediately. Regular maintenance and inspections were conducted, including monitoring battery levels, cleaning sensors, and replacing worn or damaged components. Additionally, users received training on system operation and appropriate response protocols in the event of a gas leak.

### ***Observations and Results***

The researchers' observations are presented in this chapter, including results from testing and validation, alongside interpretations based on the study objectives. Safety is paramount in environments using flammable gases, as accidents can occur unexpectedly. The integration of IoT technology facilitated a system capable of detecting gas leaks, alerting users, and preventing further leakage.

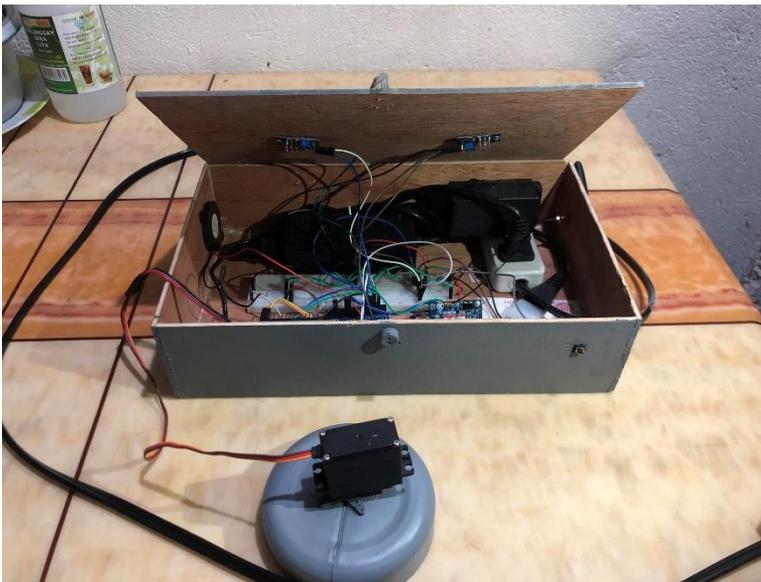
The gas leak detection system developed using Arduino UNO proved effective. Gas sensors accurately detected leaks, triggering alarms

and notifications. Upon detection, the system autonomously shut off the gas supply, ensuring immediate mitigation of potential hazards. Users received instant notifications on their devices, providing timely alerts to take necessary action.

The prototype successfully prevented fires, explosions, and health risks through sensor detection and automatic valve closure. It complied with safety guidelines established by the Bureau of Fire Protection (BFP) and demonstrated reliability in real-world applications. Furthermore, evaluation based on ISO 25010 criteria confirmed the system's high standards of usability, functionality, reliability, and performance efficiency.

**Figure 8**

*The developed prototype*



The effective utilization of Arduino UNO in designing the gas leakage detection system provided a reliable solution to enhance safety in various environments. By integrating gas sensors, the system accurately detected leaks and enabled prompt responses. Additional safety measures,

including an alarm system and automatic lid closure, further reinforced protection. The developed prototype effectively mitigated the risks of fires, explosions, and health hazards associated with gas leaks, addressing the urgent need for enhanced safety precautions. By employing advanced gas sensors, the system was capable of detecting even minimal leaks, ensuring rapid and effective response measures.

### *System Evaluation / Testing*

This section presented the survey results from 205 respondents calculated using Slovin's formula, and questionnaires were distributed using a random sampling technique. The questionnaire was based on the ISO 25010 standard and covered key aspects of software quality, including functional suitability, reliability, usability, performance efficiency, and maintainability.

**Table 3**

*Weighted mean distribution of the criteria for the developed system*

<b>ISO 25010</b>	<b>Weighted Mean</b>	<b>Remarks</b>
Functional suitability	3.35	Strongly Agree (SA)
Reliability	3.21	Agree (A)
Usability	3.40	Strongly Agree (SA)
Performance efficiency	3.36	Strongly Agree (SA)
Maintainability	3.35	Strongly Agree (SA)
<b>Average</b>	<b>3.33</b>	<b>Strongly Agree (SA)</b>

The functional suitability of the system received a weighted mean of 3.35, indicating a high level of agreement among respondents. Similar results were observed for reliability and maintainability, with weighted means of 3.36 and 3.40, respectively, all corresponding to “strongly agree”

remarks. The system's usability also scored 3.35, indicating strong agreement, while performance efficiency was slightly lower at 3.21, still receiving "agree" remarks. Overall, the average weighted mean across these criteria was 3.33, demonstrating that respondents strongly agreed that the system effectively met the specified requirements, performed efficiently, and was reliable, maintainable, and user-friendly.

The evaluation further indicated that the system successfully fulfilled all specified tasks and user objectives, evidenced by an average weighted mean of 3.44, corresponding to a "strongly agree" remark. This confirmed the system's effectiveness in meeting user expectations and achieving high user satisfaction. User satisfaction is critical for gas leakage detection systems, where an intuitive interface and seamless operation are essential. This finding aligns with Choche et al. (2021), whose study of similar systems showed high satisfaction in usability, reliability, and ease of understanding.

The system's reliability was also affirmed, with a weighted mean of 3.34, reflecting consistent and accurate gas leakage detection. Gas sensors employed advanced algorithms to minimize false alarms and maintain stability, ensuring continuous and dependable operation. This reliability instilled confidence in users regarding the system's ability to detect gas leaks and enhance overall kitchen safety.

The system's usability received an average weighted mean of 3.61, corresponding to a "strongly agree" remark. Users found the interface clear and straightforward, with simple installation procedures, informative feedback, and easily understandable alerts. This allowed homeowners to quickly respond to potential gas leakage incidents, reinforcing trust in the system's effectiveness.

Regarding performance efficiency, the system effectively utilized

the Arduino Uno R3's processing speed, memory, and energy consumption, achieving a weighted mean of 3.34. This ensured that the system operated consistently and efficiently, promptly detecting gas leaks and enabling timely risk mitigation.

Finally, the system's maintainability was highly rated, with a weighted mean of 3.45, indicating that maintenance, troubleshooting, and future enhancements could be performed easily. Clear and well-documented code, a modular design, and standardized components facilitated long-term reliability and effectiveness of the gas leakage detection system.

*Economic feasibility.* The economic feasibility of the system was evaluated to determine whether the expected benefits outweighed or met the anticipated costs. The analysis considered both advantages and disadvantages to assess overall viability. Using the ISO 25010 questionnaire-based assessment, the study gathered insights on the system's efficiency, cost-effectiveness, and potential return on investment.

*Technological feasibility.* The technological feasibility was assessed by evaluating the suitability of Arduino Uno R3 for the sensor-based gas leakage detection system. This evaluation involved examining hardware and software compatibility, gas leak detection accuracy, system reliability, and scalability for future enhancements. Accessibility to development tools and maintenance support was also considered to ensure that the system could be practically implemented and maintained.

*Operational feasibility.* Operational feasibility focused on whether the system could be effectively integrated into real-world kitchen environments. Factors such as user acceptance, technical capability, integration with existing infrastructure, and availability of training and support were analyzed. This assessment confirmed that the Arduino Uno

R3-based system could be practically deployed, meet user requirements, and operate effectively with the necessary tools and expertise.

## **Conclusion**

The study successfully demonstrated the development and implementation of a sensor-based gas leakage detection system, providing a reliable and effective solution to enhance safety in various environments. The integration of gas sensors allowed for accurate detection of even minor leaks, while safety features such as an alarm system, automatic lid closure, and real-time notifications ensured timely alerts to users. The developed prototype effectively mitigated the risks of fires, explosions, and health hazards associated with gas leaks, addressing the urgent need for improved safety measures in homes. Its user-friendly interface enabled intuitive monitoring and response, empowering LPG users to proactively prevent accidents. Furthermore, the system complied with the Bureau of Fire Protection (BFP) safety regulations, incorporating audible and visual alarms to alert nearby individuals, demonstrating its reliability and adherence to established standards. Evaluation based on ISO 25010 criteria confirmed the system's high performance in functionality, reliability, usability, performance efficiency, and maintainability. Overall, the system provided a practical, efficient, and dependable solution for enhancing kitchen safety, ensuring that users could confidently detect and respond to gas leak incidents while minimizing potential hazards.

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# **I Clean: A Prototype Solar Vacuum and Floor Cleaner Robot**

*Angelie D. De Villa, Jhins C. Aller, Grald V. Anyayahan & Aiza Comahig*

The world is currently experiencing a period of remarkable technological advancement, profoundly impacting the daily lives of the current generation. Modern technologies provide enhanced productivity, improved time management, and simplified lifestyles (Diawati et al., 2023; Chuang et al., 2025; Ra et al., 2019; Rasool et al., 2022). Among these technologies, artificial intelligence (AI) has emerged as a key area of study, focusing on giving computers the ability to perform intellectual tasks traditionally reserved for humans. Recent advancements in AI have significantly influenced societal behavior and productivity, enabling improved labor efficiency, reduced labor costs, optimized human resource allocation, and the creation of new employment opportunities (Kassa et al., 2025; Wang et al., 2024; Georgieff & Hye, 2022; Venugopal et al., 2024; Babashahi et al., 2024; Liu & Li, 2025; Chuang et al., 2024).

Nowadays, robots have become increasingly common in manufacturing, packaging, shipping, research laboratories, quality control, and many other industrial and consumer sectors. They are particularly valuable for performing tasks that are dull, dirty, or dangerous, such as floor

cleaning, which is often considered tedious and labor-intensive (Takayama et al., 2008; You et al., 2025). For instance, improper waste management and ineffective cleaning practices can have detrimental effects on health and the environment. Cleaning involves the removal of dust, pathogens, and other contaminants from a space or object. While some cleaning tasks are simple, others are challenging, particularly in large areas that require multiple personnel. Hence, advances in robotics offer potential solutions to these challenges. Robots, as autonomous machines, can perform tasks without direct human intervention, even if they do not mimic human appearance or behavior.

In response to these challenges, this study aimed to develop a solar-powered floor-cleaning robot capable of cleaning large outdoor areas, patios, public restaurants, and extensive campuses with minimal human labor and reduced need for frequent recharging. The system was designed to assist in emergencies while promoting efficiency and sustainability. With today's busy lifestyles, maintaining cleanliness in homes and surrounding areas is increasingly difficult. Conventional vacuum cleaners still require human operation, and social distancing measures further limit the ability to perform manual cleaning, exposing people to allergens, dust, and potential health risks such as colds, coughs, rashes, and other respiratory issues.

The study's goal is to innovate an autonomous, efficient, and environmentally friendly floor-cleaning robot capable of automatically removing dust and dirt, reducing manual effort in scrubbing and sweeping, and enhancing traditional cleaning methods. This prototype integrates innovation, defined as the application of new technologies or processes to improve products or services and create new value (Nurjaya et al., 2021). In the context of household cleaning, automation and robotics have become essential for adapting to modern life, allowing routine chores to be

completed efficiently with minimal human intervention.

To achieve practicality and affordability, the prototype employs Arduino technology, enabling simple and effective automation of cleaning tasks. By leveraging AI and automation, the system addresses limitations in conventional floor cleaning techniques and enhances living conditions (John et al., 2022). Additionally, the robot is powered by solar energy, a sustainable, environmentally friendly, and cost-efficient energy source, supporting long-term operation without reliance on conventional electricity.

Modern robot vacuums have evolved significantly and are capable of improving household life by effectively removing dust, allergens, and debris, surpassing the performance of traditional hand-operated vacuums. They provide users with more free time while promoting cleaner, healthier living environments. The primary objective of this prototype is to develop a solar-powered vacuum and floor-cleaning robot that can autonomously collect dry dust particles and mop floors without human intervention, thereby improving household cleaning efficiency and overall quality of life.

## **Theoretical Framework**

### ***Vacuum Cleaner Market Overview***

The Philippines vacuum cleaner market, according to research, is projected to expand between 2020 and 2026 (Expert Market Research, n.d.). Technologies such as robotic vacuum cleaners are becoming increasingly common as part of the “digital revolution” in domestic life (Nicholls & Strengers, 2019). In the pursuit of the “smart home,” numerous automated appliances are being introduced to the market, offering more ecologically friendly, convenient, safer, and enjoyable living environments. Recent research has focused not only on improving the cleaning capabilities of

these robots but also on enhancing their interactivity with users (Liu et al., 2024; Malobický et al., 2025; Liu et al., 2024; Muthugala et al., 2020). Interactive elements that allow robots to communicate their status and needs are increasingly valued, as the lack of such communication can reduce the quality of human-robot interaction.

### *Development of Smart Vacuum Cleaners*

The study by Sukumaran et al. (2022) explored the development of a solar-powered, Bluetooth-enabled intelligent vacuum cleaner using an Arduino microcontroller. The system integrates input from a Light Dependent Resistor (LDR) sensor and an ultrasonic sensor to determine the vacuum's navigation path. The device can automatically recharge via a solar panel when the battery is low or after cleaning, and it sends Bluetooth alerts to notify the user when a cleaning cycle is complete. Compared to traditional corded vacuum cleaners, this design offers faster cleaning, energy efficiency, and broader applicability, including use in the food industry, parks, and other public spaces.

In another study, Yatmono et al. (2020) developed an “Intelligent Floor-Cleaning Robot” capable of navigating, vacuuming, dusting, and polishing floors. The robot is equipped with Omni wheels, a vacuum, and floor-polishing motors, controlled via an Arduino microcontroller and software environment, enabling automated operation and efficient floor maintenance. Similarly, Sarmast et al. (2020) integrated both remote operation (via an Android smartphone) and autonomous cleaning modes. The system monitors battery voltage and prevents overcharging, alerting users via text messages when cleaning is completed. Advantages include prolonged motor life, energy efficiency, and reduced operational risks.

### ***Automatic Floor Cleaners***

Automatic floor cleaners are designed to perform cleaning tasks with minimal human intervention. Jain et al. (2017) describe a system that navigates autonomously while vacuuming designated areas. Ultrasonic sensors detect obstacles and prevent the robot from falling off elevated surfaces, while side brushes sweep debris toward the suction mechanism. The robot's movement is powered by DC motors controlled via an H-Bridge Configuration Driver (L293D), enabling forward and reverse navigation. These devices provide efficient, safe, and user-friendly cleaning solutions, saving both time and effort.

### ***Solar Energy Integration***

The use of solar energy enhances the sustainability and efficiency of robotic cleaners. Kabir et al. (2018) discuss the potential and prospects of solar energy, emphasizing its capacity to meet future global energy demands and its environmental benefits. Adeyoyin et al. (2019) explored solar-powered systems for ICT infrastructure in Nigerian universities, highlighting widespread knowledge and acceptance of solar energy as a reliable power source. By integrating solar panels, floor-cleaning robots can achieve longer operation times, reduced energy costs, and environmentally friendly performance.

### ***Prototyping in Robot Development***

Prototyping plays a critical role in designing effective robotic cleaners. Dam and Siang (2018) highlight a user-driven prototyping approach, where users create prototypes to better convey their needs and assumptions. Prototyping allows designers to test and communicate ideas about a system's form and functionality, providing essential feedback for

iterative development and refinement.

### ***Sensor Technologies***

Ultrasonic and infrared sensors are widely employed in intelligent cleaning robots to enhance navigation and obstacle detection. In the study of Irawan et al. (2021), the ultrasonic sensor measures distances to detect obstacles, prompting the robot to change direction when necessary. The DC motor, controlled by a Motor Shield L298 and Arduino Uno microcontroller, powers the robot's movement. It was also demonstrated that integrating ultrasonic and infrared sensor arrays with real-time environmental awareness significantly improves a cleaning robot's navigation and route-planning capabilities. Electric-map-based grid-scanning algorithms further optimize coverage and efficiency, ensuring that the robot completes the cleaning task effectively.

### ***Comparative Analysis***

Table 1 presents a comparative analysis of the proposed solar-powered floor-cleaning robot against existing vacuum cleaner systems. Comparative analysis involves evaluating different systems to identify their similarities, differences, strengths, and limitations. In this study, the researchers compared their prototype with currently available vacuum cleaners to determine areas for improvement and to ensure that the proposed system offers additional value to users. This analysis also helps users understand the unique features and advantages of the proposed prototype.

The 3-in-1 Intelligent Sweeping Robot available in the market features one-button start, sweeping, mopping, vacuum cleaning, USB charging, universal driving, obstacle avoidance, anti-drop technology, low noise, low repetition, and high coverage. Once activated, it navigates across

the floor, using intelligent sensors to avoid walls and obstacles, leaving dust and pet hair-free surfaces. However, it lacks an automatic charging station, so it turns off automatically when the battery is depleted.

**Table 1**

*Comparative analysis*

<b>Description</b>	<b>Proposed Capstone Project</b>	<b>System 1 3-in-1 Intelligent Sweeping Robot</b>	<b>System 2 Upgrade High-Performance Robot Vacuum</b>
Obstacle Detection	/	/	/
Automatic	/	/	/
Waste bin detection	/	x	x
Metal detection	/	x	x
Sanitize	/	x	/
Dry and wet	/	x	x
Sounds generated	/	x	x
Humidifier	x	x	/
USB Charging port	x	/	/
Ultra-thin	x	/	/
Power indicator	/	/	/
Anti-drop	x	/	/
Electric Charging	/	/	/
Solar Panel	/	x	x
Mobile Application	/	x	x
SMS Notification	/	x	x

The Upgrade High-Performance Robot Vacuum includes a comprehensive set of smart sensors, anti-collision and anti-drop mechanisms, strong suction power, and effective side brushes. It supports multiple cleaning modes, all-terrain detection, and a floating rolling brush, allowing it to adapt to various floor types. Additional features include a humidifier and UV disinfection, enhancing hygiene and cleaning efficiency.

Regarding solar-powered vacuum cleaners, Sukumaran (2022)

proposed a practical method for developing a solar-powered, Bluetooth-enabled intelligent vacuum cleaner using an Arduino microcontroller. The system receives input from a Light Dependent Resistor (LDR) sensor and an ultrasonic sensor, which guides the vacuum's navigation. The battery can be recharged mechanically, and the device automatically recharges via a solar panel either after cleaning or when the battery level drops below a certain threshold. In addition, Irawan et al. (2021) used ultrasonic sensor, Motor Shield L298, Arduino Uno microcontroller, servo, and DC motor. The DC motor is powered by the Motor Shield L298, and the Arduino interprets data from the ultrasonic sensor to detect obstacles. The robot automatically changes direction when an obstacle is detected, ensuring uninterrupted cleaning. Finally, Sarmast et al. (2020), developed a vacuum cleaner that can be operated remotely via an Android smartphone or in autonomous mode. The system monitors battery voltage to prevent overcharging and notifies the user via text message when cleaning is complete. This dual-mode operation improves battery longevity, energy efficiency, and user convenience.

Through this comparative analysis, the proposed solar-powered floor-cleaning robot combines the best features of existing systems while integrating solar energy, autonomous navigation, and user-friendly operation, offering enhanced functionality and sustainability compared to current market alternatives.

## **Research Framework**

### *Data*

This study gathered data from the results of a survey conducted with seventy (70) respondents. The study used the ROA Soft formula to

determine the total number of respondents and employed a random sampling method to distribute the questionnaires. The survey questions were based on the ISO 25010 standard, covering the following characteristics: usability, performance efficiency, functional suitability, reliability, portability, compatibility, and maintainability.

To gather responses, the study used a four-point Likert scale, allowing respondents to indicate their level of agreement with each statement. The scale included the categories: strongly agree, agree, disagree, and strongly disagree. Each category was assigned a corresponding mean range to facilitate clear and consistent interpretation of the survey results.

Table 2 presents the set of data used for creating the prototype. This data provides detailed descriptions of the various measurements considered during the prototype's development, including the width, range, and size of the materials. These specifications ensure that the prototype is accurately constructed, functions effectively, and meets the design requirements for optimal performance.

**Table 2**

*Data set considered in creating a prototype*

<b>Data Set</b>	<b>Description</b>	<b>Unit of Measurement</b>
<b>Ultrasonic Sensors (Obstacle)</b>	Weight	Gram
	Range	Centimeter
	Length	Centimeter
<b>IR Sensor (Waste Bin)</b>	Width	Centimeter
	Distance	Inches
	Length	Inches
<b>Metal Sensor</b>	Width	Inches
	Weight	Gram

**Table 3***Dataset for creating the prototype*

<b>Data Set</b>	<b>Description</b>	<b>Unit of Measurement</b>
<b>Battery</b>	Weight	Kilogram
	Length	Inches
	Width	Inches
	Operating Current	Voltage
<b>Water Pump</b>	Length	Inches
	Width	Inches
	Operating Current	Voltage
<b>Vacuum</b>	Weight	Kilogram
	Length	Inches
	Operating Current	Voltage
<b>Servo Motor</b>	Weight	Gram
	Operating Current	Voltage
<b>PVC Pipe</b>	Length	Inches
	Width	Inches
	Diameter	Area

Table 3 presents the set of data used for creating the prototype. The table includes details on the weight, size, and operating current of the materials considered. The researchers specifically examined the operating current of the materials to estimate the prototype’s lifespan and ensure its durability and efficient performance.

### ***Ethical Considerations***

The study adhered to Republic Act No. 10173, also known as the Data Privacy Act, which aims to protect personally identifiable and sensitive information. This law applies to individuals and organizations that handle sensitive data.

To avoid ethical violations, the researchers ensured that

participation in the study was entirely voluntary. Every participant provided informed consent, making voluntary participation a fundamental principle of research ethics.

Collecting personal information was an essential part of the study, and the researchers ensured the confidentiality of all participants and their responses. No data was shared with unauthorized individuals, except in cases where disclosure was legally required. As Pye (2009, p. 136) emphasizes, ethical decisions in research involve balancing the preservation of data for future use with the protection of participants' rights in the present.

Participants were informed of the study's objectives and were free to withdraw at any time during interviews or surveys. They also consented to the recording of their information and responses, with the assurance that participation would not result in any adverse consequences. Furthermore, all participants were informed that their data would remain confidential.

### ***Experimental Design***

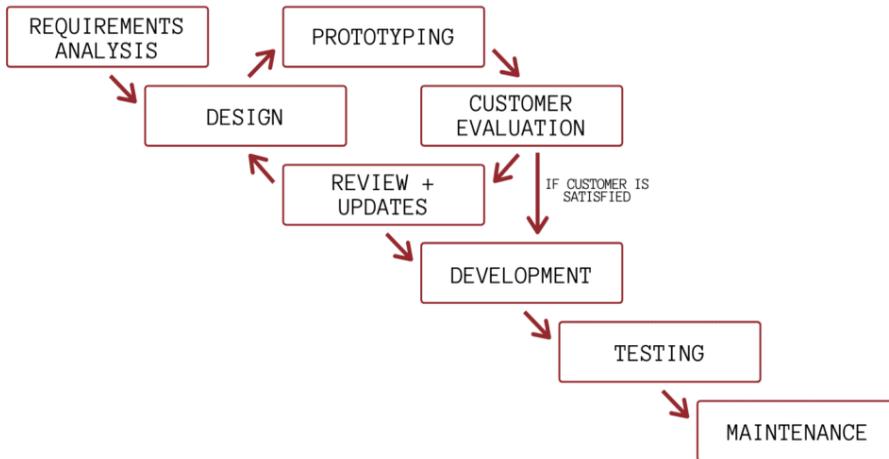
Various system development methodologies were designed and applied to achieve the system's objectives. In this study, the researchers employed a prototyping model. This approach involved building and testing a prototype before developing the final, fully functional version of the system. The prototyping model was particularly suitable in scenarios where not all project requirements were fully defined at the outset.

### ***Procedures of the Different Phases***

Figure 1 presents the prototyping model used for developing the prototype.

**Figure 1**

*Prototyping model*



The model followed an iterative process of creating and refining the system through multiple prototype iterations. The initial prototype served as a proof of concept, demonstrating the core features and functionalities of the system. Feedback and insights obtained from testing the initial prototype informed subsequent iterations, leading to improvements and enhancements that addressed identified issues. User requirements and feedback were continuously gathered and integrated throughout the design process. This iterative approach ensured flexibility and adaptability, resulting in a final prototype that effectively detected obstacles and incorporated other essential features. The model also enabled the integration and testing of various sensors and components to ensure accurate detection and reliable performance.

*Requirements analysis.* During this phase, the researchers collected and analyzed user expectations. The researchers conducted interviews with clients to better understand the system flow and document request process. They defined the problem, gathered relevant data from clients, and analyzed and determined the system’s objectives and software requirements.

*Design.* Following requirements analysis, the researchers moved to the design phase. The design incorporated user suggestions, feedback, and identified system components to finalize the system. Team members collaborated continuously to study, develop, and innovate the project, ensuring optimal output.

*Prototyping.* The prototype served as a compact and operational model of the system, enabling evaluation and enhancement of design and functionality. During this stage, the researchers acquired essential components, including a microcontroller, sensors, jumper wires, and a GSM module, to construct a tangible prototype. Development was based on insights gathered from the preliminary design phase, allowing for practical testing and further improvements.

*Customer evaluation.* At this stage, the system was presented to the client for an initial evaluation. This process identified the strengths and weaknesses of the working model. Comments and suggestions were collected from the client and provided to the researchers for refinement. If the client was satisfied with the first prototype, the review and update phases were bypassed, proceeding directly to the development phase.

*Review updates.* If the client was not satisfied with the prototype, the researchers refined the system based on the feedback and suggestions provided. Adjustments were made to enhance functionality while ensuring all client recommendations were addressed.

*Development.* In the development phase, the researchers created the final working system or product, implementing the tasks it was designed to perform. After incorporating client requirements and requests, the system was constructed and tested to ensure it functioned correctly.

*Testing.* The system underwent comprehensive testing to verify correct functioning and identify potential issues. Researchers performed

continuous troubleshooting and supported software development throughout this phase. Intensive checks were conducted to ensure error-free operation and compliance with necessary standards.

*Maintenance.* After testing, the prototype was implemented in the client environment or deployed for market use. Regular maintenance was planned to ensure that the robots operated effectively and efficiently, keeping the system functional and reliable over time.

## **Technical Framework**

### ***Materials***

This section presents the software and hardware requirements in developing the system.

### ***Software***

The researchers utilized various software and tools to design and implement the system effectively. The Arduino Integrated Development Environment (IDE), a cross-platform application written in Java, was used to write and upload programs to the microcontroller. The Arduino IDE supports C and C++ programming languages with specific code structuring rules and provides a software library from the Wiring project, offering numerous standard input and output procedures. The C programming language was employed as a general-purpose, object-oriented, and imperative language, allowing for low-level memory manipulation and flexible system control. Additionally, the researchers used MIT App Inventor, an intuitive visual programming environment that enables the creation of fully functional smartphone and tablet applications, facilitating user interface design and remote system control.

## Hardware

Table 4 outlines the planned hardware requirements for the system, detailing the materials and specifications needed to construct the prototype.

**Table 4**

*Hardware Requirements*

	<b>Specifications</b>
Arduino Mega 2560 	Microcontroller: ATmega2560 Operating Voltage: 5V Input Voltage(recommended):7-9V Input Voltage(limit):6-9V Digital I/O Pins: 54 (of which 15 provide PWM output) Input Pins:16
Arduino Uno 	Microcontroller Microchip ATmega328P Operating Voltage 5V USB Standard Type B Digital I/O Pins 14 PWM Digital I/O Pins 6 Analog Input Pins 6
MG996R 	Weight: 55g Dimension: 40.7×19.7×42.9mm Stall torque: 9.4kg/cm (4.8v); 11kg/cm (6.0v) Operating speed: 0.19sec/60degree (4.8v); 0.15sec/60degree (6.0v) Operating voltage: 4.8~ 6.6v
MG995 	Weight: 55g Dimension: 40.7×19.7×42.9mm Stall torque: 9.4kg/cm (4.8v); 11kg/cm (6v) Operating speed: 0.20sec/60degree (4.8v); 0.16sec/60degree (6.0v) Operating voltage: 4.8~ 6.6v

### Vacuum Cleaner



Item Length: 30cm  
Material Type: ABS  
Weight: 0.52kg  
Item Width: 10.5cm  
Size: 304x74x74mm  
Suction:4800PA

### Bluetooth Module



Bluetooth protocol: Bluetooth Specification v2.0+  
EDR  
Frequency: 2.4GHz ISM band  
Modulation: GFSK (Gaussian Frequency Shift Keying)  
Speed: Asynchronous: 2.1Mbps (Max) / 160 kbps, Synchronous: 1Mbps/1Mbps

### SIM800C GSM module



Supports Quad-band 850/900/1800/1900 MHz, which can transmit voice calls, SMS messages, and low-power data.  
GPRS multi-slot class 12/10  
Compatible with GSM 2/2 + Class 1 (1 W 1800 / 1900MHz)  
Bluetooth 3.0 + EDR compatibility  
FM: International band 76 ~ 109MHz, 50KHz correction level.  
Control over AT instruction set  
Voltage: 4.1 ~ 5VDC  
Operating Temperature: -40 ~ 85

### IR Infrared Obstacle Avoidance



Item size:32x14mm/1.26x0.55in  
Package size: 45x45x20mm/1.77x1.77x0.79in  
Package weight:8g

### Metal detector



LJC18A3-B-Z/BX/AY/BY/AX proximity sensor  
cylindrical capacitive proximity switch 10mm  
detection distance NPN/PNP NO/NC DC6-36V

### Ultrasonic Sensor

Working Voltage: 5V DC



Detection Range: 2cm-450cm.

Weight: 10g

Size: 45mm x 21mm (L x W)

Connector Pin: VCC, Trig (T), Echo(R), OUT, GND

Mini Water Pump



Operating Current: 130 ~ 220mA

Flow Rate: 80 ~ 120 L/H

Maximum Lift: 40 ~ 110 mm

Outlet Outside Diameter: 7.5 mm

Outlet Inside Diameter: 5 mm

Brand Name: Jungla

Weight: 0.98kg

Size: 70x56x37 MM

Model: 3S2P

Nominal capacity: 12800mAh

Weight: 0.98kg

Size: 70X56X37 MM

Normal Capacity: 12800MAH

Battery standard: 18650 lithium battery

Internal resistance: 3c

Battery



DC Gear Motor and Wheels



Length: Approx. 67mm / 2.64inch

Wheel diameter: 65mm / 2.56inch

Shaft diameter: 4mm / 0.16inch

Voltage: DC 12V

Color: Silver

Solar Panel



Maximum Power: 25W

Weight: 2.05 kg

Dimension: 550x364x25

Max. Voltage: 600

Cell Technology; Monos

H-Bridge Driver

Chip: L298N (ST NEW)

Logical voltage: 5V

CM<sup>+</sup>  
DIY MORE



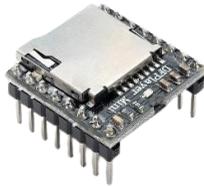
Arduino MP3 Module

Drive voltage: 5V-35V

Logical current: 0mA-36mA

Drive current: 2A (MAX single bridge)

Max power: 25W



Limit Switch



Supports sampling rates (KHz): 8 / 11.025 /  
12/16 / 22.05 / 24/32 / 44.1 / 48

24-bit DAC output, dynamic range support:  
90dB, SNR support: 85dB

Fully supports FAT16, FAT32 file system,  
maximum support 32G TF card, support U disk  
to 32G, 64M bytes of NORFLASH

Micro Switch Hinge Roller Lever 15A V-156-  
1C25

Model: V-156-1C25

Rating:15A, 1/2HP, 125/250VAC

0.6A,125VDC; 0.3A, 250VDC

Relay Module



Control Voltage: 5V DC

Max Control Capacity:10A 250VAC or 10A  
30VDC

PVC Pipe



50.8mm

18x14 inch

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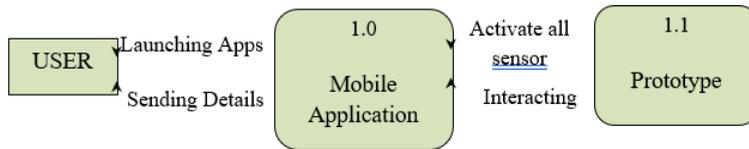
The researchers utilized a variety of hardware components, including sensors to detect obstacles and an Arduino microcontroller to process sensor data and make decisions. These components work together to ensure accurate detection, proper functioning, and reliable performance of the prototype. All specified materials were essential for the successful development and operation of the solar vacuum and floor-cleaning robot.

## Modeling

Figure 2 presents the context diagram, illustrating the fundamental operation of the user-controlled prototype.

**Figure 2**

*Context diagram of the developed system*



The diagram shows that the user must first launch the mobile application to activate all sensors and power on the prototype. Once activated, the prototype communicates with the user by sending relevant information and updates through the application, ensuring real-time monitoring and control of the cleaning process.

**Figure 3**

*Context diagram of the developed system*

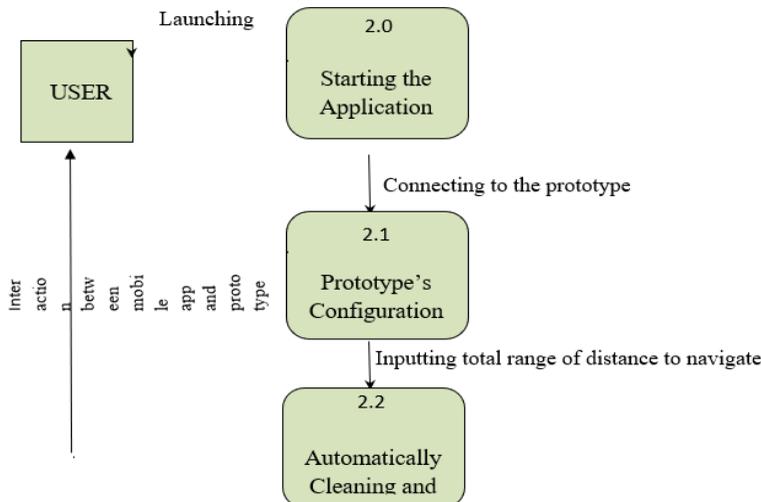


Figure 3 presents the context diagram of the developed system, illustrating the interaction between the user and the prototype. To operate the system, the user must first start the application and establish a direct connection with the prototype. The user then inputs the total range of distance for the cleaning operation. Once configured, the prototype autonomously vacuums dust and mops the floor. If the prototype detects any obstacles such as metal objects, a low battery, or a full dustbin, it communicates with the user by sending a notification via text message to the mobile phone, ensuring timely intervention and continuous operation.

**Figure 4**

*Flowchart of the developed system*

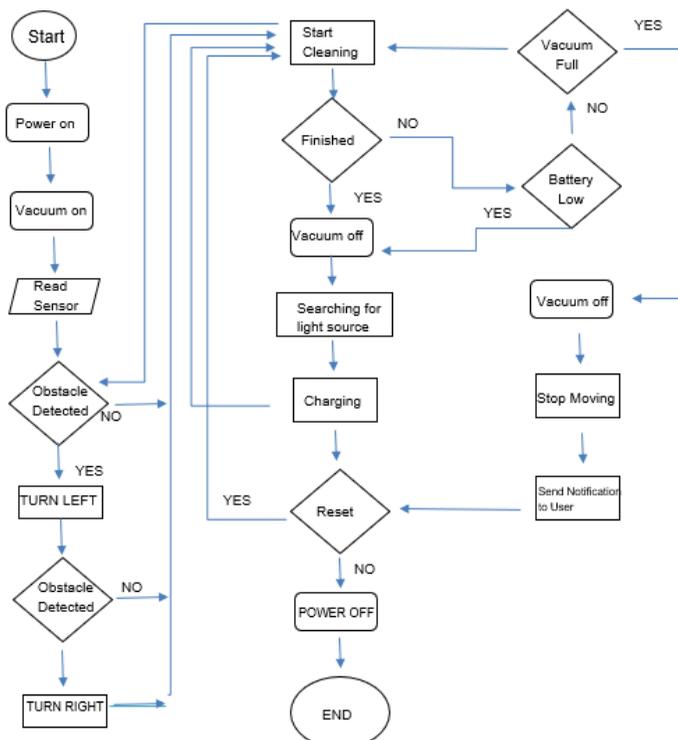


Figure 4 presents the flowchart of the developed prototype,

illustrating the system's operational process. The procedure begins with the initialization of all sensors and modules to ensure proper connectivity. The program is activated through commands from the mobile application, which functions as the prototype's on/off control. The DC motor then initiates forward motion, and the ultrasonic sensor continuously monitors for obstacles. Upon detecting an obstacle, the device automatically reverses its route to avoid collisions. The system also incorporates SMS notifications to inform the user of critical conditions, such as a full dustbin or low battery. When the battery reaches a low level, the vacuum ceases cleaning and searches for a power outlet. The user can then recharge the device and power it off, ensuring safe and continuous operation.

**Figure 5**

*Story board of the developed system*

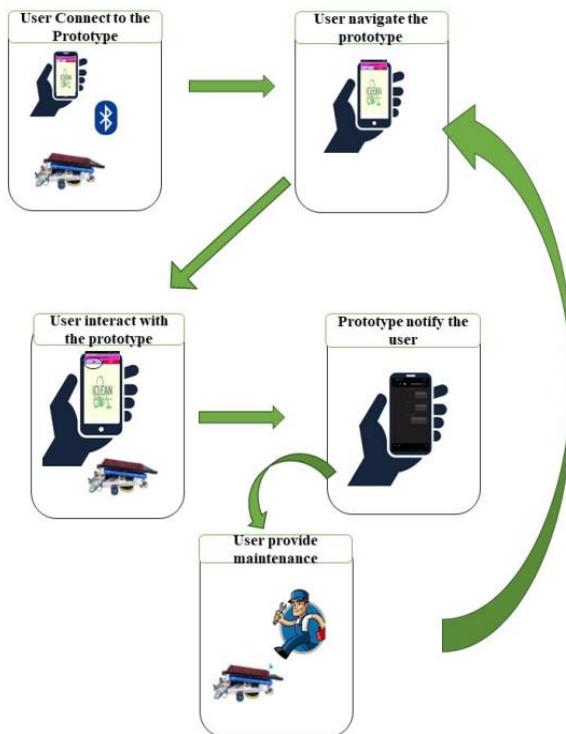


Figure 5 presents a visual guide illustrating the interaction between the user and the prototype throughout the operational process. The user first connects to the prototype via Bluetooth and ensures the device is ready for operation. Once activated, the prototype begins moving automatically, performing its cleaning tasks.

During operation, the prototype continuously monitors conditions such as the presence of metal, a full dustbin, or a low battery. When any of these conditions are detected, the system promptly notifies the user via text message. Finally, the user provides necessary maintenance to the prototype, ensuring its continued efficiency and proper functioning.

**Figure 6**

*Prototype*



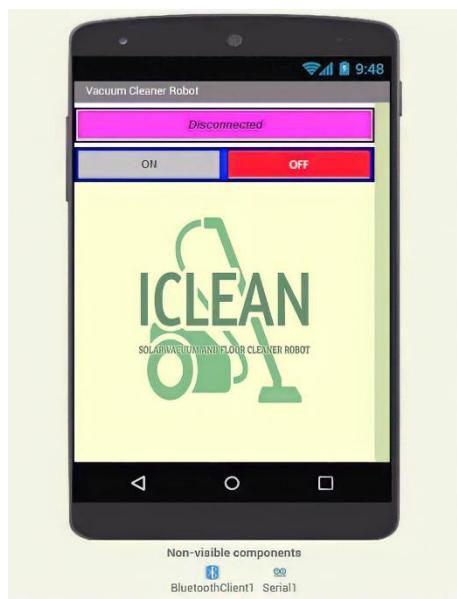
Figure 6 shows the prototype. Using an Arduino microcontroller and various sensors, the system interprets ultrasonic signals as distance measurements. The cleaning robot automatically changes direction if an ultrasonic sensor detects an obstacle. When the sensor reads a distance of less than 5 cm, the robot adjusts its path to avoid collisions. According to Huang (2022), with the rapid advancement of AI theory, particularly deep learning neural networks, robot vacuums powered by AI can autonomously

clean indoor floors using intelligent programming and automated vacuuming services.

The prototype is equipped with two batteries, each rated at 12,800 mAh, providing a combined capacity of 25,600 mAh. The total power consumption of the prototype is 10,400 mAh. Using a battery life calculator, which estimates operational time based on nominal battery capacity and device consumption, the estimated battery life was 2 hours and 27 minutes. Manual testing confirmed that a fully charged prototype could clean continuously for up to 2 hours. If the batteries were not fully charged, the prototype's operational time was reduced to approximately 30 minutes to 1 hour, demonstrating the practical endurance of the system under varying conditions.

Figure 7 shows the mobile app controlling the device. The study utilized MIT App Inventor to create a simple mobile application for controlling the vacuum cleaner. This web-based tool enabled seamless integration of the mobile application with the prototype via Bluetooth.

**Figure 7**  
*The mobile app*

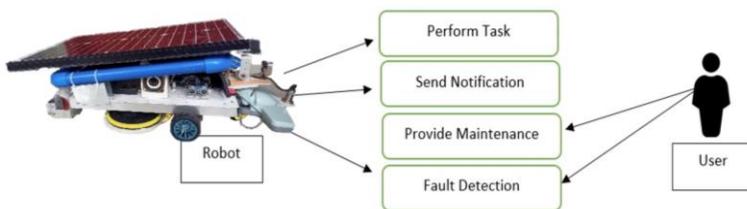


A Bluetooth-based Android interface was developed to control the robot effectively. Using MIT App Inventor, the researchers successfully built the application, which features a main screen with an On/Off button and a Bluetooth connection button that displays the connection status as either “Connected” or “Disconnected.” During the initial stage, the Android application was developed using the Design and Block editors of MIT App Inventor, compiled, and then installed on an Android device. Communication between the Arduino microcontroller, responsible for controlling the robot, and the Android application was established via Bluetooth, allowing the user to operate the robot remotely.

Figure 8 presents the use-case diagram illustrating the interactions between the user and the prototype.

**Figure 8**

*UML use case model between the user and the prototype*



This diagram highlights the high-level functions and scope of the system, showing how the prototype performs its cleaning tasks while monitoring its environment. The prototype detects faults such as obstacles, a full dustbin, or low battery, and sends notifications to the user for appropriate action. Meanwhile, the user provides maintenance, monitors the prototype’s performance, and addresses any detected defects, ensuring the system operates efficiently and reliably.



**Figure 10**

*Presents the system architecture of the prototype*

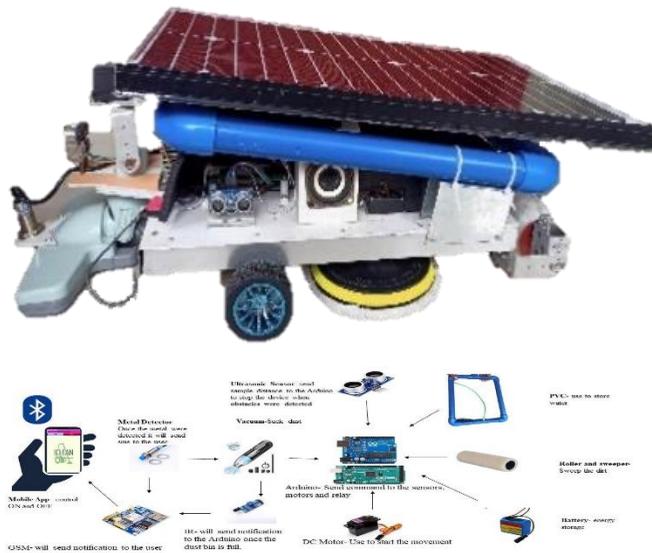


Figure 10 illustrates the process flow of the developed system. After completing the coding phase, the system begins by initializing all sensors and modules to establish a connected and ready state. Once initialized, the sensors start monitoring the environment based on the parameters set in the system. The Arduino microcontroller sends these specific parameters to the sensors to verify whether the conditions are met. The GSM module serves as a communication interface, notifying the user when the system detects metal obstacles, a full dustbin, or a low battery condition.

Table 5 presents the detailed breakdown of the materials, tools, and equipment used in developing the prototype, including their respective prices and the total project cost. This cost documentation is crucial as it provides transparency regarding the resources utilized and the financial requirements necessary to complete the system. It also allows future researchers, developers, or potential investors to clearly understand the financial considerations involved in replicating or improving the project.

**Table 5***Cost and Benefits Analysis*

<b>Name</b>	<b>Unit Price</b>	<b>Quantity</b>	<b>Total</b>
Arduino mega2560	₱ 900	1	₱ 900
Arduino Uno	₱ 590	1	₱ 590
MG996R	₱ 300	3	₱ 900
MG995	₱ 300	1	₱ 300
vacuum cleaner	₱ 1300	1	₱ 1300
Bluetooth module	₱ 275	1	₱ 275
SIM800C GSM module	₱ 700	1	₱ 700
IR through beam sensor	₱ 100	1	₱ 100
metal detector	₱ 800	1	₱ 800
ultrasonic sensor	₱ 100	3	₱ 300
mini water pump	₱ 300	1	₱ 300
18650 Battery 2S Charging Module Board	₱ 235	1	₱ 235
18650 Battery 3S Charging Module Board	₱ 235	1	₱ 235
DC geared motor	₱ 350	2	₱ 700
3S-2P 12V 12800mAh battery	₱ 750	2	₱ 1500
65mm Rubber Tire	₱ 150	2	₱ 300
25W solar panel	₱ 1025	1	₱ 2500
L298 H bridge driver	₱ 100	1	₱ 100
Arduino mp3 module	₱ 200	1	₱ 200
Limit switch	₱ 60	2	₱ 120
Relay module	₱ 150	1	₱ 150
Misc	₱ 3000	1	₱ 3000
<b>TOTAL</b>			<b>₱ 15,505</b>

To determine the project's economic feasibility, the researchers performed a cost-benefit analysis by summing up all incurred expenses and comparing them with the anticipated advantages of the system. This evaluation is an essential part of project development as it establishes whether the benefits gained will outweigh the costs invested. By doing so,

the researchers ensured that resources were allocated effectively, minimizing unnecessary expenditures while maximizing potential returns.

The analysis further highlighted the practicality of implementing the “I Clean: A Prototype Solar Vacuum and Floor Cleaner Robot” as a viable solution for household cleaning. Since the system is powered by solar energy, it offers long-term savings by reducing electricity consumption compared to traditional vacuum cleaners. Additionally, its multifunctional cleaning features present added value to users by combining vacuuming and floor cleaning in one device, which reduces the need to purchase multiple cleaning tools. These advantages demonstrate not only convenience and efficiency but also sustainability and cost-effectiveness.

### ***Evaluation of the System***

This section presents the results of a survey conducted with seventy (70) respondents. The survey questions were based on ISO 25010 standards, covering key system characteristics such as usability, performance efficiency, functional suitability, reliability, portability, compatibility, and maintainability.

**Table 6**

*Weighted mean distribution of the criteria of the proposed system*

<b>Criteria</b>	<b>Weighted Mean</b>	<b>Remarks</b>
Functional Suitability	3.49	Strongly Agree
Performance Efficiency	3.58	Strongly Agree
Compatibility	3.53	Strongly Agree
Usability	3.53	Strongly Agree
Reliability	3.55	Strongly Agree
Maintainability	3.53	Strongly Agree
Portability	3.64	Strongly Agree
<b>Average</b>	<b>3.55</b>	<b>Strongly Agree</b>

Table 6 presents the weighted mean results of each quality characteristic based on ISO 25010, gathered from 70 respondents. The overall system evaluation obtained an average weighted mean of 3.55, which corresponds to Strongly Agree. According to ISO 25010, the software quality model evaluates systems across several dimensions: usability, performance efficiency, functional suitability, portability, compatibility, reliability, and maintainability. The results suggest that the proposed system is ready for operation and capable of performing the specified requirements.

*Functional suitability.* The system achieved an average weighted mean of 3.49, interpreted as Strongly Agree. This indicates that the prototype effectively fulfills its intended purpose, automating traditional cleaning tasks such as dusting and sweeping floors. It performs the designated actions accurately, achieving the desired results by automatically cleaning with the required precision. This demonstrates the system's capability to provide the intended functionality.

*Performance efficiency.* The prototype scored an average weighted mean of 3.58, also interpreted as Strongly Agree. This was the highest rating among the categories, highlighting the system's ability to produce the intended results with minimal waste of time, effort, and resources. In terms of time behavior and resource utilization, the system performed efficiently and met the expected requirements.

*Compatibility.* With an average weighted mean of 3.53, the system was rated Strongly Agree in terms of compatibility. This reflects the prototype's ability to exchange information and perform required functions while operating within a shared hardware or software environment. It demonstrates that the system can operate effectively alongside other

products without negative impact.

*Usability.* The system also achieved an average weighted mean of 3.53, interpreted as Strongly Agree. This indicates that the prototype is user-friendly, allowing users to easily determine whether the product meets their needs, particularly useful for busy individuals. Moreover, the inclusion of solar charging enhances usability during emergencies. Overall, the system is both effective and enjoyable for users.

*Reliability.* The prototype obtained an average weighted mean of 3.55, with a remark of Strongly Agree. This suggests that the system operates reliably under normal conditions. It remains functional and accessible when needed and is capable of restoring its original condition after interruptions or failures. This demonstrates the robustness of the system against operational challenges.

*Maintainability.* The maintainability rating, with an average weighted mean of 3.53, was also interpreted as Strongly Agree. This indicates that the system components can be adjusted independently without negatively affecting performance. The prototype can be modified or updated efficiently, ensuring sustainability over time.

*Portability.* The highest weighted mean was recorded under portability, with a score of 3.64, also corresponding to Strongly Agree. This demonstrates that the prototype is portable, easy to install and uninstall, and adaptable for replacement with other specified software serving similar functions. Its design enables operational flexibility and efficient adaptation to evolving requirements.

*Economic feasibility.* Economic feasibility assesses whether the anticipated benefits of the system are equal to or greater than its projected costs. To determine this, a cost-benefit analysis was performed. This analysis provided insights into both the advantages and limitations of the

system, offering a clearer comparison between costs and benefits. The ISO 25010 questionnaire-based system assessment further validated that the prototype functions correctly and delivers value, thereby supporting its economic feasibility.

*Technological feasibility.* Feedback gathered after the successful completion of the project highlighted the innovative nature of the prototype. Respondents emphasized that the construction of the system represents a unique technological advancement that benefits its users. As technology continues to progress, the development of an automatic cleaning robot contributes to everyday convenience, particularly for busy individuals. Overall, comments from respondents consistently recognized the prototype as an excellent technological achievement.

*Operational feasibility.* The prototype is operationally feasible, as users can operate it with ease and minimal instruction. Survey results showed that it took only a few minutes of demonstration before users were able to control the robot independently. The system requires a simple on-and-off mechanism to activate movement and cleaning, and users can conveniently connect it via Bluetooth to initiate operations. These findings demonstrate the practicality and usability of the prototype in real-world settings.

## **Conclusion**

The study demonstrated that the design and construction of the prototype significantly enhanced traditional cleaning methods such as dusting and sweeping. The system was able to automatically detect obstacles and collect dust through the integration of components such as the Arduino microcontroller and ultrasonic sensors, which enabled it to

interpret distance and adjust movement accordingly. Furthermore, the researchers successfully integrated the prototype with a mobile application installed on an Android device, allowing users to control the robot through Bluetooth communication with the Arduino microcontroller. This seamless integration between hardware and software proved the system's capability for efficient and convenient remote operation. Testing also revealed that the prototype could operate for one to two hours on a single charge, requiring approximately two hours of charging using electricity and four to five hours using solar panels. This dual charging feature, along with extended battery life, provides a clear advantage over many conventional vacuum cleaners available in the market. In addition, the evaluation of the system using ISO 25010 standards confirmed that the prototype met and, in several areas, exceeded the quality requirements in terms of functional suitability, performance efficiency, compatibility, usability, reliability, maintainability, and portability. These high ratings affirm that the system functions as expected, offering an efficient and effective cleaning solution.

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# **RFID-based Attendance Monitoring System with SMS Notification and Data Analytics**

*Maynard M. Reynoso, Leila Mae B. Derada, Aubrey Tracey G. Arconado & Angelica Ligzon*

Student attendance plays a vital role in monitoring learners' engagement with their course of study. It serves as proof of a student's presence in class and participation in school activities. Traditionally, attendance has been recorded using a paper-based system before students enter the campus. However, this method presents several limitations, such as the difficulty of processing and analyzing attendance data since records are not uploaded into a centralized system (Aldabagh, 2025; Ali et al., 2018; Acasamoso et al., 2021). Currently, most of the schools, colleges and universities in the Philippines still rely on this manual paper-based approach (Grefaldo et al., 2025; Santos et al., 2021; Acasamoso et al., 2021), which highlights the need for a more efficient and accurate solution.

To address this, this study proposed the development of a Radio Frequency Identification (RFID) based attendance monitoring system with SMS notification and data analytics. This system will automatically record students' time-in and time-out upon entering and leaving the campus. Additionally, SMS notifications will be sent to parents once their child taps

the RFID card at the school gate, ensuring transparency and real-time communication. The use of RFID cards allows for quick, accurate, and efficient identification of multiple students, thereby streamlining the attendance process.

According to Aldabagh (2025), the student attendance management system with SMS notification eliminates the traditional pen-and-paper process and promotes online attendance recording with just a click. Teachers can easily track and manage attendance information using both mobile and desktop devices. By scanning a digital RFID card, a student's attendance is automatically recorded in the system, reducing teachers' workload and saving valuable instructional time. Similarly, Khan et al. (2020) emphasized that conventional attendance systems requiring students to manually sign attendance sheets are inefficient. RFID-based systems address this limitation by automating the process. Furthermore, Puckdeevongs et al. (2020) developed a web-based application for daily student attendance within universities, demonstrating that such systems can generate reports, evaluate attendance eligibility, and significantly reduce the use of human and material resources. By integrating RFID technology with SMS notifications and data analytics, the project aims to modernize attendance monitoring, reduce manual workload, and enhance communication between the school and parents.

The main objective of this study is to develop the RFID-based Attendance Monitoring System with SMS Notification and Data Analytics for the Senior High School and College students of a private college in the Philippines, to efficiently monitor their time-in and time-out on campus.

## **Theoretical Framework**

### ***Web-Based and Electronic Solutions on Student Attendance***

Monitoring student attendance is essential in academic institutions as it verifies student presence and engagement. However, traditional methods such as manual signing or paper-based systems are often inefficient, time-consuming, and prone to errors. These systems also hinder data processing and analysis, delaying administrative tasks and reducing monitoring effectiveness. Hence, adopting automated attendance systems is crucial to improve accuracy, efficiency, and reliability.

Several studies emphasize the benefits of modern, web-based, and electronic attendance systems (Ali et al., 2022; Rahaman et al., 2025; Nguyen-Tat et al., 2024). Jacksi et al. (2018) proposed a web-based application for daily student attendance at the university level, which could generate reports and evaluate student eligibility based on attendance records. This system not only improved monitoring but also conserved human and material resources. In a similar context, Gillespie (2020) explained that electronic gadgets provide students with greater access to information, more opportunities for collaboration, and enhanced communication, all of which contribute to independent learning and improved educational outcomes. By extension, these technological innovations can also be applied to attendance monitoring, making the process faster and more reliable. These systems allow teachers to monitor attendance through mobile and desktop devices, thereby minimizing workload and saving valuable classroom time. With just a scan of a digital or RFID card, attendance data is captured instantly, ensuring that teachers can focus on instruction rather than administrative tasks.

### ***Integration of RFID Technology in Attendance Systems***

RFID has become one of the most effective tools in modern attendance systems. Su et al. (2023) describe RFID as a technology that uses radio waves to automatically recognize people or objects. By embedding a serial number and related details in a microchip attached to an antenna, RFID readers can efficiently identify individuals and log their entry or exit. This integration simplifies data recording and enhances system reliability.

According to Farag (2023), implementing RFID-based systems can significantly improve the monitoring of students' attendance, benefiting both administrators and lecturers. By replacing manual signing with RFID scanning, schools reduce errors and increase efficiency. Likewise, Ukoima et al. (2019) developed a student monitoring system that used low-frequency RFID in combination with SMS to track students. The study confirmed the accuracy of the system in monitoring entry and exit times and suggested that future research explore the use of high-frequency RFID readers for even greater convenience, allowing students to simply wear or carry RFID-enabled cards.

### ***RFID with SMS Notification for Enhanced Monitoring***

The combination of RFID technology with Short Messaging Service (SMS) notification adds a valuable communication layer between schools and parents. Anitha et al. (2023) emphasized that when students use their RFID card to enter the school premises, the system verifies the card against the school database. At the same time, SMS alerts are sent to parents informing them of their child's arrival and departure. This ensures real-time parental awareness, even if they are not physically present at school.

A similar approach was explored in the study of Rahman et al. (2019) where RFID cards were utilized to track entry and exit. Text

messages were automatically sent to both administrators and parents, specifying the time students entered and exited the school campus. This enhanced transparency reassures parents of their children's safety while providing school administrators with accurate attendance data.

In addition, Farag (2023) highlighted that RFID and SMS-based systems could also extend functionality beyond simple attendance monitoring. Their system was able to track not only time-in and time-out but also account balances and class schedules, offering a multi-functional tool for school administration. This demonstrates the adaptability of RFID-SMS systems to serve broader institutional needs.

## **Research Framework**

### ***Data***

The data in this study were gathered from 150 respondents selected using Slovin's formula and a random sampling method for questionnaire distribution. The respondents were Senior High School students in Sariaya, Quezon. The number of respondents and their percentage distribution by age are as follows: one hundred thirty-eight (138) respondents belonged to the age bracket of 17–25 years and above, representing 75% of the total respondents; eleven (11) respondents belonged to the age bracket of 26–30 years and above, accounting for 20% of the total respondents; and one (1) respondent was in the age bracket of 34 years old, representing 5% of the total respondents.

The questionnaire is based on ISO 2510, which contains functional suitability, performance efficiency, compatibility, usability, reliability, security, maintainability, and portability. The study used the four-point Likert scale that contains these categories: strongly agree, agree, disagree,

and strongly disagree. Each scale has a mean range assigned to determine the evaluation result.

### *Experimental Design*

The developed system intended to transform the existing paper-based attendance method into an RFID-based attendance monitoring system. This involved coding the system components, integrating RFID functionality, and preparing the platform for subsequent testing and evaluation.

**Figure 1**

*Experimental design of the study*



Figure 1 presents the experimental design of the study. The design begins when a student arrives at the school gate. Each student uses an RFID

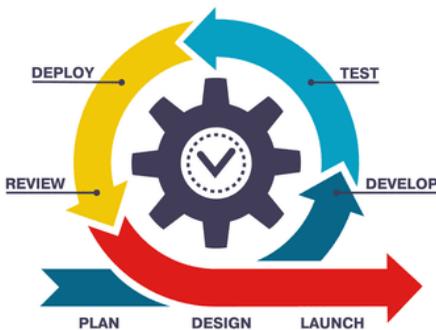
card, which is tapped against the RFID reader installed at the entrance. Once tapped, the student's information is validated by the system and automatically displayed on the monitor. At the same time, an SMS notification is sent to the parent or guardian, informing them that their child has arrived safely at the school premises.

At the end of classes, the same process is repeated. Students tap their RFID card before leaving the campus. The system validates the card, records the time-out information, and sends a second SMS notification to the parent or guardian indicating that the student has left the school grounds. This design ensures accurate monitoring of student attendance while providing parents with real-time updates of their child's whereabouts.

### ***System Development Approach***

Figure 2 illustrates the System Development Life Cycle (SDLC) Agile Model, which follows a sequential yet iterative process. In this model, development is not viewed as a one-time sequence but as a circular process that includes planning, system design, system development, system testing, system deployment, review, and launch. This cycle ensures that the system is continuously improved based on feedback and testing results.

**Figure 2**  
*Agile model*



The development of the system followed the Agile-inspired SDLC methodology, which consists of the following phases:

*Planning.* Developing a project plan was the initial and essential phase. The researchers collected information on how to create an attendance system suitable for the school, conducted requirement analysis, and defined system specifications.

*Designing.* In the design phase, the researchers used the data and insights gathered during planning to create system designs, interfaces, and functions tailored to the target users—the students and administrators.

*Developing.* During this phase, the system was coded using the selected programming languages and applications. Both the back-end functionality and the visual interface of the system were created to ensure usability and efficiency.

*Testing.* Once the system was fully developed, it underwent testing to verify that all code worked correctly. This included testing individual modules as well as the integrated system.

*Deployment.* The system was then deployed in the school environment. This phase allowed students to enter and leave the campus efficiently without the need for manual paper-based attendance, streamlining the process.

*Review.* The review phase involved evaluating the system's performance to ensure that all modules operated as intended and that the system met the defined objectives.

*Launch.* After successful review and verification, the system was officially launched and made operational for everyday use in the school.

*Testing.* In the testing phase, the researchers conducted systematic evaluations of each module. Two primary types of testing were applied:

*Test Cases* – Specific scenarios were prepared to evaluate whether each function of the system performed as expected.

*Test Approach* – Methods and procedures were defined to systematically verify the system’s operations, including time-in/time-out recording, RFID validation, SMS notifications, and data storage.

### ***Procedures of Different Phases***

The following procedures describe how the system operates during different phases of student entry and exit:

*Tapping the RFID card upon entering the school campus.* Before entering the school gate at Tierra Monde, students must tap their RFID cards on the reader. This action serves as their official time-in record.

*Displaying student information.* Once validated by the system, the student’s basic information, along with their picture, is displayed on the monitor. After this confirmation, the student can proceed to their classroom.

*Sending SMS notification to parents.* After validation, the system sends an SMS notification to the parent or guardian, confirming that the student has entered the school premises.

*Tapping the RFID card upon leaving the campus.* At dismissal, the student taps the RFID card again at the school gate. This records the student’s time-out and ensures that the system logs the exact time the student leaves.

*Sending second SMS notification to parents.* Once the time-out is validated, the system generates a second SMS notification to inform parents that their child has left the campus safely.

This cycle ensures that both school administrators and parents have accurate, real-time attendance records of the students.

## Technical Framework

### Materials

The development of the system required the use of specific software and hardware to ensure functionality, efficiency, and ease of integration.

### Software

The following tools and languages were utilized in coding and developing the system:

**Table 1**

*Software specifications and software platform*

System Type	Web-Based
Operating System	Windows
System Model	Asus X454L
Language	JAVASCRIPT, PHP
Text Editor	Visual Studio Code
Designing	HTML, CSS
Web server and Database	XAMPP

*JavaScript.* JavaScript is a dynamic programming language commonly used in web development. It allows the creation of interactive features, controls multimedia, updates web content dynamically, and supports the development of web-based applications and games.

*Visual Studio Code.* Visual Studio Code (VS Code) is a free, open-source code editor developed by Microsoft. It is lightweight yet powerful, supporting multiple platforms including Windows, Linux, and macOS. With its rich features, extensions, and debugging capabilities, VS Code has become one of the most widely used development environments.

*HTML (HyperText Markup Language).* HTML is the standard markup language used to structure content on the web. It defines the layout of web pages, including text, images, tables, and multimedia elements. In

this system, HTML was used to design and structure the user interface.

*CSS (Cascading Style Sheets)*. CSS is a styling language used to control the visual presentation of web pages written in HTML or XML. It is responsible for the design, layout, fonts, colors, and responsiveness of the web interface, enhancing the user experience.

*XAMPP*. XAMPP is an open-source cross-platform web server solution that includes Apache, MySQL, PHP, and Perl. It is primarily used for local web application testing. Developers use XAMPP to simulate a server environment on their personal computers, enabling them to run and test their code before deployment.

*PHP (Hypertext Preprocessor)*. PHP is a widely used server-side scripting language designed for web development. It is primarily employed for creating dynamic web pages and applications. In this study, PHP handled system logic, database interaction, and back-end processes.

## ***Hardware***

The system required the following hardware specifications for the development of this project as itemized in Table 2.

**Table 2**

*Hardware specifications*

<b>Laptop</b>	<b>Specs</b>
Processor	Intel Core i3-5010U (3M Cache, 210GHz)
RAM	4GB DRAM DDR3
Hard Disk Space	1TB 5400RPM
Edition	Windows 10
RFID	Specs
RFID Card	125 khz
RFID Reader	125 khz

The system required the following hardware components.

**Figure 3**

*RFID card*



The RFID card uses radio frequency to identify, track, and store information such as serial numbers. It serves as a primary component of the system, with RFID tags functioning as intelligent labels that store details about students when entering and leaving the school premises.

**Figure 4**

*RFID reader*



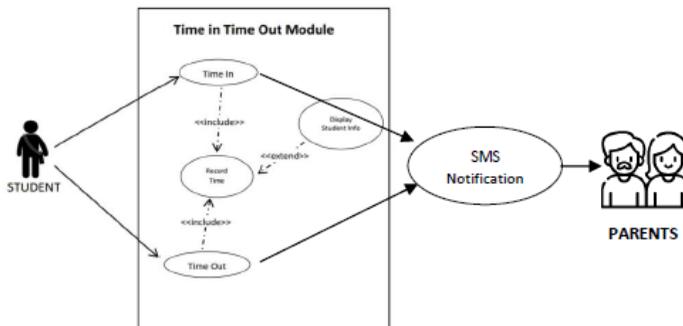
The RFID reader is a device that validates the RFID card when it is tapped. This device must be connected to a monitor, laptop, or PC via a USB port to function properly.

## Modeling

Figure 5 shows the use case diagram of the system. The system records the time-in and time-out of each student and displays the student's picture on the monitor.

**Figure 5**

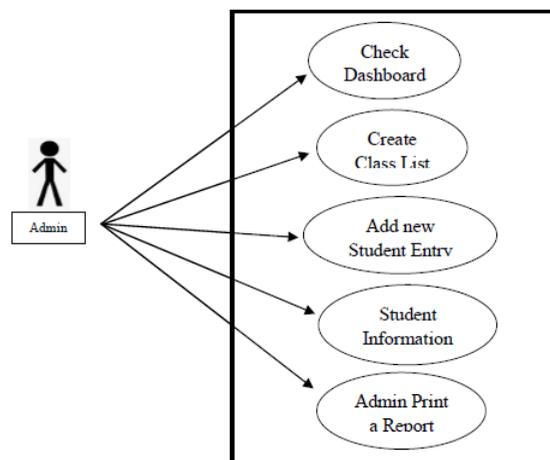
*Use case diagram time-in, time-out module*



When a student taps their RFID card, the time-in is automatically recorded in the database, and an SMS notification is sent to the parents. Similarly, upon tapping the card when leaving, the time-out is recorded, and a second SMS notification is sent. The student's time-in and time-out records can be accessed through the system's attendance form.

**Figure 6**

*Use case diagram for admin*

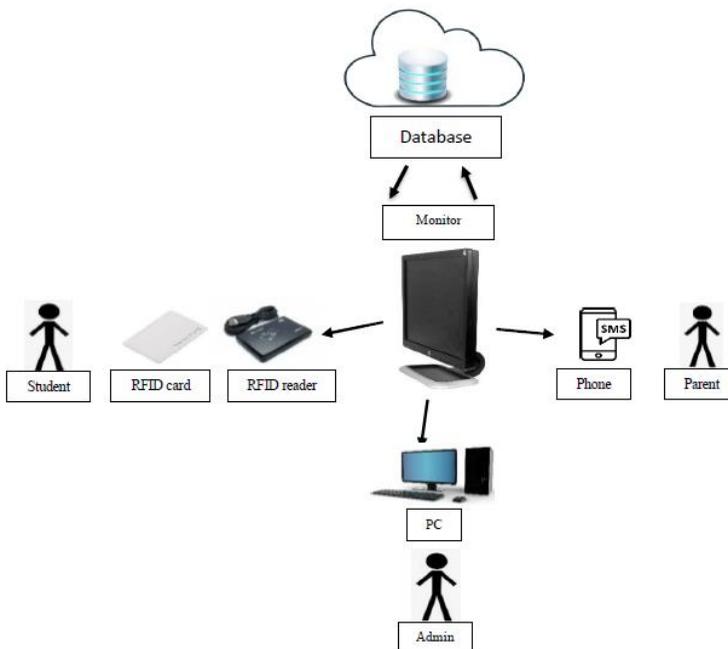


The system administrator can use the dashboard to monitor student attendance and manage class lists for each course. The administrator is also responsible for adding new students by registering their RFID cards, collecting their personal information, and generating printable reports containing attendance records and other relevant student data.

### System Architecture

Figure 7 shows the system architecture, which illustrates the overall framework of the proposed system, including its major components and how they interact with one another. It provides a visual representation of the flow of processes, data, and communication between hardware, software, and users, ensuring a clear understanding of how the system operates as a whole.

**Figure 7**  
*System architecture*

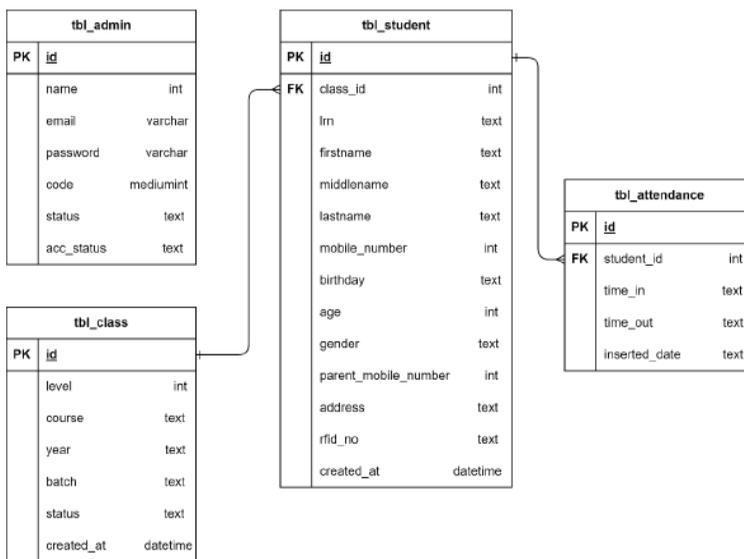


## Database Schema

Figure 8 presents the database schema, which outlines the structure of the database, including the tables, fields, and relationships among them. It provides a clear visualization of how data is organized, stored, and connected within the system to support efficient data management and retrieval.

**Figure 8**

*Database schema*



## System Design

The system was developed using the following programming languages and applications: Visual Studio Code, XAMPP, phpMyAdmin, HTML, CSS, and PHP. The system is web-based and consists of several key modules, including:

*Login Page* – Allows the administrator to securely access the system.

*Dashboard* – Displays real-time information on the number of students entering the school campus.

*RFID Scanner Form* – Automatically shows the student information when the student taps their RFID card.

*Student List Module* – Displays all registered students, allows management of student information, and provides the option to generate printable reports.

**Figure 9**

*Login form*

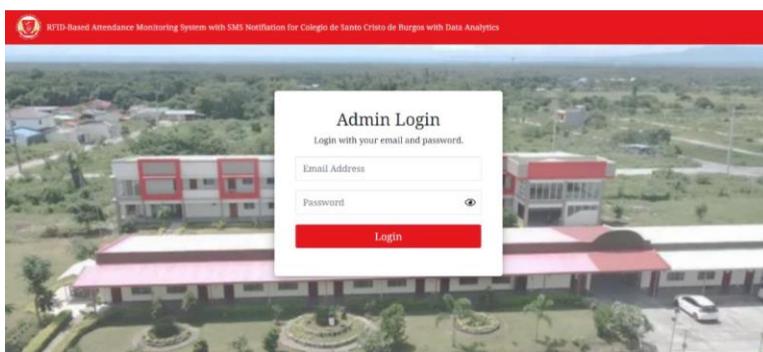


Figure 9 shows the login form, where users can access the site by entering their Gmail account and password. The login process is initiated after plugging in the RFID reader, ensuring secure and authenticated access to the system.

**Figure 10**

*Creating class in class list*

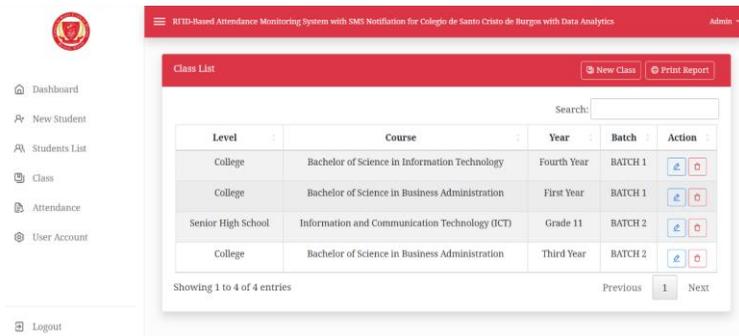


Figure 10 shows the process of creating a class in the Class List. In this part of the system, the admin can add and manage Class Lists for both Senior High School and college students, ensuring proper organization of student records within the database.

**Figure 11**

*Adding new student*

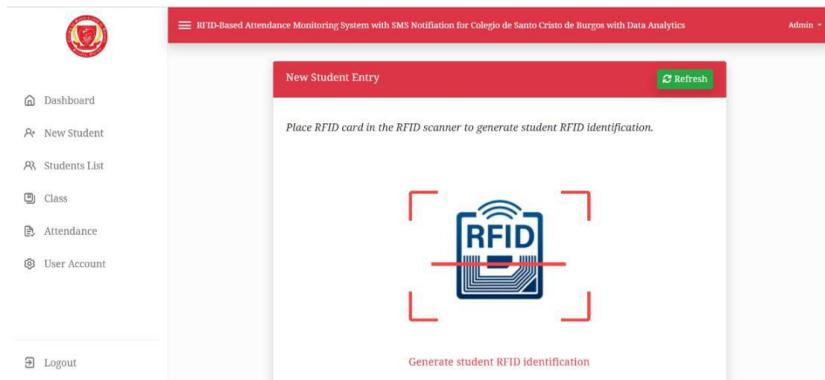


Figure 11 shows the 'Add New Student' feature in the New Student Entry module. This is a vital part of the system, as it uses the student's RFID card and the RFID reader to register new students and automatically generate their unique RFID number.

**Figure 12**

*Managing student list*

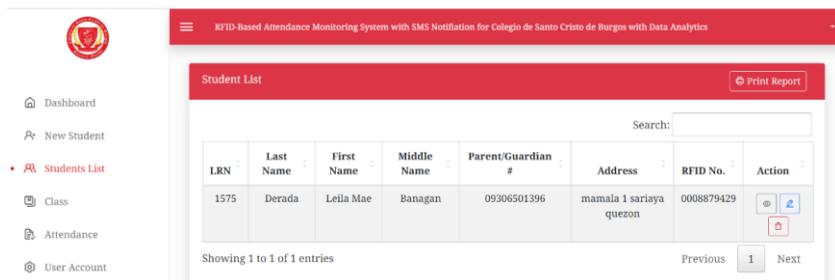


Figure 12 shows the 'Manage or Update Student List' feature. After completing the student information, the newly added student is automatically included in the system's Student List, where records can be managed and updated as needed.

**Figure 13**

*Attendance time-in and time-out*

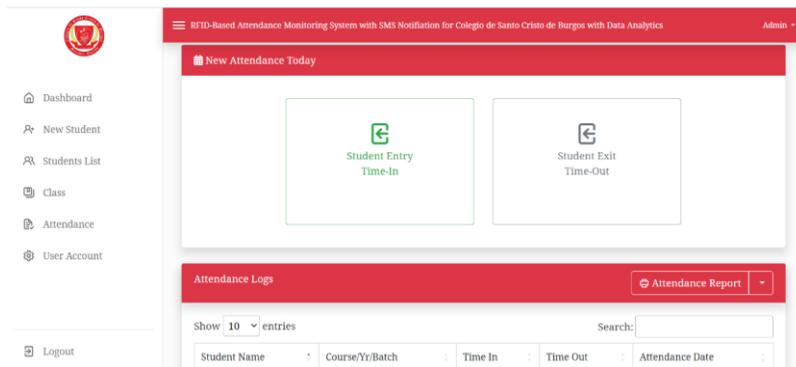


Figure 13 shows the 'Start Attendance Time-in and Time-out' feature. In this process, students tap their RFID cards when entering and leaving the school gate, allowing the system to automatically record their attendance.

**Figure 14**

*Tap card*

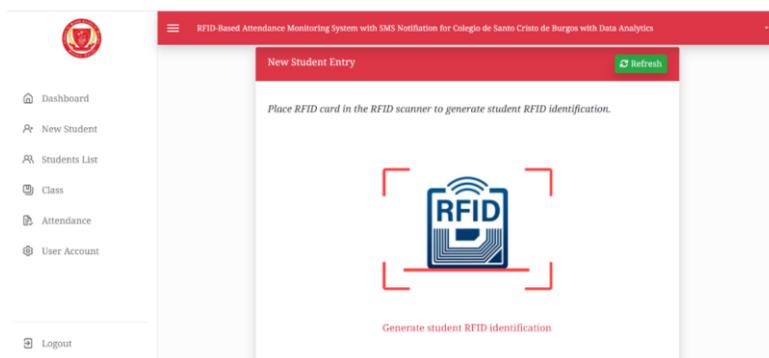


Figure 14 shows the 'Tap RFID Card' process, where students tap their RFID card or ID on the reader to authenticate their identity and record their attendance.

**Figure 15**

*Attendance monitoring dashboard*



Figure 15 shows the 'Check and Monitor Student Attendance' feature in the dashboard. After logging into the site, users are directed to the student dashboard, where attendance records can be viewed and monitored in real time.

**Figure 16**

*Print report*

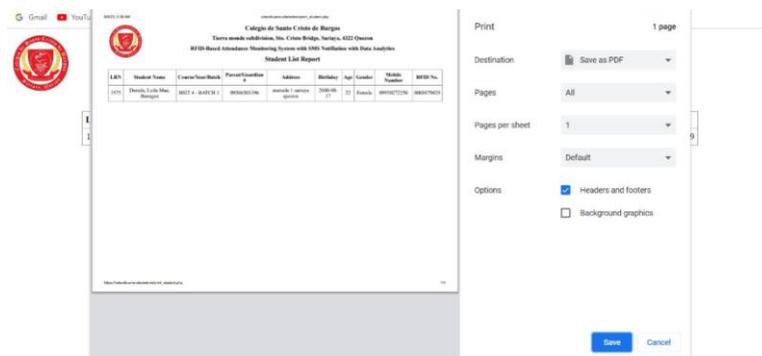


Figure 16 shows the 'Print Report' feature, which allows the generation and printing of attendance reports for students who have attended on the school campus.

**Figure 17**

*Scanning RFID Card*

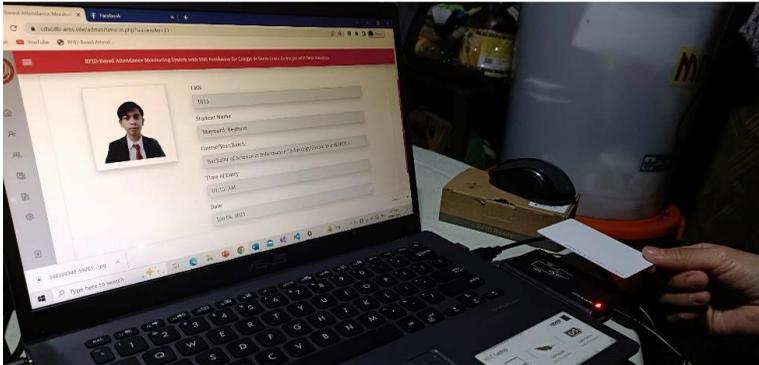


Figure 17 shows the system user scanning their RFID card upon entering the campus, which records their time-in. The same process applies when leaving, recording the time-out automatically.

**Figure 18**

*SMS Notification*

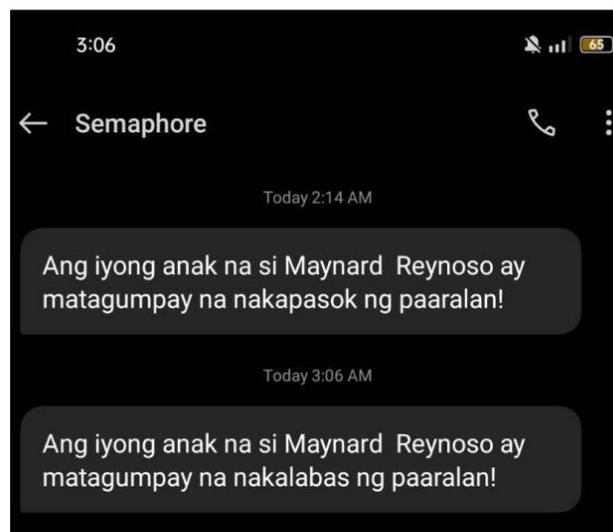


Figure 18 shows the SMS notification feature, where parents receive alerts indicating that their child has entered or left the campus, providing real-time updates on student attendance.

### ***Test Approach***

Both students and the system administrator can use the RFID-based Attendance Monitoring System according to their respective roles and expected outputs.

For deployment, the researchers employed a parallel approach to ensure the system functions correctly. This involved monitoring the devices, validating the data in the database, and verifying system performance in a real-world environment. The system was installed on the school premises, and user training was provided to ensure students and administrators could effectively operate the system.

Maintenance of the system includes remedial care such as revisions, updates, and fixing issues identified either by users or through reports generated by the system. Additionally, quarterly maintenance is performed to evaluate system efficiency during operation. Regular database backups are conducted to prevent data loss and ensure system reliability.

### ***System Evaluation***

This section presents the survey results based on responses from 150 respondents. The questionnaire was designed according to ISO/IEC 25010 standards, covering the following software quality aspects: functional suitability, performance efficiency, compatibility, usability, reliability, security, maintainability, and portability. A four-point Likert scale was used, with the following response categories: Strongly Agree, Agree, Disagree, and Strongly Disagree. The results indicate that the system was

generally well-received by respondents.

**Table 3**

*Weighted mean distribution of the criteria for the developed system*

<b>Criteria</b>	<b>Weighted Mean</b>	<b>Remarks</b>
Functional Suitability	3.7	Agree (A)
Performance Efficiency	3.7	Agree (A)
Compatibility	6.7	Strongly Agree (SA)
Usability	3.66	Strongly Agree (SA)
Reliability	3.65	Agree (A)
Security	3.7	Agree (A)
Maintainability	3.71	Strongly Agree (SA)
Portability	3.69	Strongly Agree (SA)
<b>Average</b>	<b>3.69</b>	<b>Strongly Agree (SA)</b>

Overall, the average weighted mean of 3.69 (Strongly Agree) indicates that respondents perceive the system as highly effective, reliable, user-friendly, and secure. The evaluation demonstrates that the system successfully meets its intended objectives of improving student attendance monitoring and facilitating communication with parents.

**Functional Suitability:** The system is highly functional and meets the intended objectives of monitoring student attendance. Respondents agreed that it performs effectively and is easy to use. The weighted mean is 3.7 (Agree).

**Performance Efficiency:** Respondents found the system efficient and responsive, facilitating smooth operation. The weighted mean is 3.7 (Agree), indicating satisfaction with the system’s performance.

**Compatibility:** The system integrates well with existing devices and software, allowing seamless operation. Respondents strongly agreed that it functions correctly across platforms, with a weighted mean of 3.66

(Strongly Agree).

**Usability:** The system is user-friendly and easy to manage. Respondents were satisfied with its ease of use, with a weighted mean of 3.65 (Strongly Agree).

**Reliability:** The system consistently performs as expected without errors or failures. Respondents agreed that it is reliable, with a weighted mean of 3.7 (Agree).

**Security:** The system effectively safeguards student information and prevents unauthorized access. Respondents agreed that the system is secure, with a weighted mean of 3.7 (Agree).

**Maintainability:** The system is easy to maintain, update, and analyze, ensuring continued effective use. Respondents strongly agreed, with a weighted mean of 3.71 (Strongly Agree).

**Portability:** The system can be adapted to different environments and is easy to deploy. Respondents strongly agreed with its portability, with a weighted mean of 3.69 (Strongly Agree).

## **Conclusion**

The RFID-based Attendance Monitoring System with SMS Notification and Data Analytics is effective, reliable, and user-friendly. The system successfully records students' time-in and time-out attendance while allowing administrators to create new classes, update class lists, and register new students using RFID cards. It efficiently stores students' information along with their parents' or guardians' contact details, enabling real-time SMS notifications for monitoring purposes. The system also generates accurate and comprehensive reports per class and attendance summaries through data analytics. Students can easily scan their RFID cards upon

entering and leaving the campus, streamlining the attendance process, while parents receive timely notifications of their child's attendance. Overall, the system meets its intended objectives by improving student attendance monitoring, enhancing communication with parents, and providing a reliable and technologically feasible solution for the school.

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# **METACREATION: A PC Assembling and Disassembling Using VR for ICT Computer System Servicing NC II**

*Gilbert Parungao, Jackeilyn M. Ramos, Andrea A. Sebuc &  
Eugene J. Valencia*

Virtual reality (VR) is rapidly advancing mobile technology into a more sophisticated and immersive environment that parallels our natural world. VR is an immersive technology that creates a virtual environment where users can interact with objects and processes as they would in the real world. This capability allows for enhanced learning, simulation, and experimentation without the limitations of physical space or resources. Recently, the concept of the Metaverse has gained attention as a major trend in technological development (Tukur et al., 2024). The Metaverse, popularized by Facebook CEO Mark Zuckerberg, is described as the next evolution of social connection and the successor to the mobile internet (Kraus et al., 2022). Although the term gained mainstream attention only recently, it was first conceptualized in Neal Stephenson's 1992 novel *Snow Crash*, in which the protagonist navigates a virtual world called the Metaverse. Over time, this idea inspired the creation of online communities

and virtual platforms, such as Second Life, which allowed users to interact socially and functionally in virtual spaces (Dwivedi et al., 2022).

The Metaverse represents a collection of interconnected 3D virtual environments where users interact through avatars or digital representations. Platforms such as Rec Room, a virtual reality massively multiplayer online game, allow users to explore and create interactive experiences that blend real and virtual worlds. Rec Room is available on multiple platforms, including Microsoft Windows, Xbox, PlayStation, Meta Quest 2, and mobile devices. In these spaces, users can engage in activities ranging from parkour courses and virtual boxing to laser tag and dodgeball, offering both entertainment and educational potential.

This study focuses on the development of a VR-based system for PC assembly and disassembly aimed at ICT students. The system is designed to provide a safe, interactive, and cost-effective learning environment. By using VR, students can practice assembling and disassembling computer components without risking damage to school equipment or personal safety. The virtual environment allows learners to gain practical experience while reducing material costs and resource usage, making training more sustainable and accessible. Users interact with virtual objects that can be upgraded, reused, and manipulated repeatedly, enabling a hands-on learning process that closely mirrors real-world operations. To use the system, learners install Rec Room on PCs, laptops, or mobile devices if a VR headset is unavailable. Within the simulation, students can explore a virtual environment containing computer components and follow guided instructions for assembling and disassembling a PC. This approach not only reinforces theoretical knowledge but also develops practical skills through experiential learning.

The study acknowledges that developing VR-based learning

technologies requires significant time and effort. However, its benefits extend across multiple sectors, including education, business, transportation, and communication, providing innovative solutions for training, collaboration, and skill development. By integrating VR and Metaverse platforms into learning processes, the research aims to enhance student engagement, promote interactive learning, and prepare learners for real-world applications in ICT and other technology-driven fields.

Ultimately, this research demonstrates the potential of VR and Metaverse technologies to transform education by offering immersive, practical, and cost-effective learning experiences, particularly in contexts where physical resources are limited. The integration of PC assembly and disassembly simulations into a virtual environment represents an innovative step toward bridging theoretical knowledge with practical skills in a safe, interactive, and scalable manner.

## **Theoretical Framework**

### ***Virtual Reality in Education***

VR has emerged as a transformative tool in education, particularly during periods of restricted physical access, such as the social distancing measures implemented during the COVID-19 pandemic. According to Try et al. (2021), VR has been successfully integrated into civil engineering laboratory courses, allowing students to engage in complex experiments that would have been otherwise impossible due to limitations in equipment, accessibility, safety, and cost. By creating a virtual replica of a laboratory environment, students can experiment, make mistakes, and learn from them without risking physical damage to materials or harm to themselves.

Beyond simply providing a visual representation of concepts, VR

enables students to actively interact with virtual elements, promoting a deeper understanding of the subject matter. There are two main methods of utilizing VR in education: through conventional computer interfaces using keyboards and mice, or via immersive devices like helmet-mounted displays (HMDs) or VR controllers. While the former allows basic interaction, HMDs and similar devices provide a fully immersive experience, enabling learners to feel present in the virtual environment. This immersion is crucial in reinforcing experiential learning, as students are not merely observing a process; they are actively participating in it.

### ***Benefits of Virtual Reality for Learning***

The primary strength of VR in education lies in its ability to facilitate experiential learning. Unlike traditional learning methods, where students passively receive information, VR encourages active engagement by allowing learners to manipulate objects, perform tasks, and navigate complex systems (Strzałkowski et al., 2024). This type of learning is particularly beneficial in technical fields such as engineering, ICT, and health sciences, where practical skills are as important as theoretical knowledge.

Studies have shown that students using VR exhibit improved memory retention, stronger knowledge connections, and higher learning outcomes compared to conventional learning methods (Analyti et al., 2024; Parong & Mayer, 2018; Crogman et al., 2025; Kubr et al., 2024; Lin et al., 2024; Liu et al., 2025; Cinar et al., 2024). For instance, by simulating real-world tasks in a safe virtual space, students can explore consequences, test hypotheses, and troubleshoot errors without real-world repercussions. This not only enhances cognitive understanding but also builds students' confidence in applying knowledge to practical scenarios. Additionally,

VR's interactive nature encourages engagement, motivation, and curiosity, factors that are closely linked to effective learning.

### ***Related Systems and Applications***

Several VR applications illustrate its educational and training potential. For example, PC Creator: Building Simulator is a mobile application that allows users to assemble computers, install operating systems, upgrade components, and troubleshoot software. By simulating a real-world PC-building environment, the application provides an interactive learning experience that develops both technical and problem-solving skills. Users can experiment with different hardware configurations, encounter simulated errors, and learn strategies for resolving issues, all within a risk-free environment.

Similarly, Rec Room is a VR platform that combines social interaction with immersive gameplay. Available across multiple platforms, including PC, consoles, VR headsets, and mobile devices, Rec Room allows users to participate in collaborative activities such as parkour courses, virtual boxing, laser tag, and dodgeball. The platform also offers tools for users to design and customize virtual spaces, encouraging creativity, collaboration, and spatial problem-solving. These applications demonstrate how VR can move learning beyond theoretical instruction, integrating practical experience, creativity, and social interaction into educational contexts.

### ***VR and the Metaverse in Modern Learning***

The concept of the Metaverse represents the next frontier of immersive education. Often described as a fully interconnected, 3D virtual Internet, the Metaverse leverages VR and augmented reality (AR) to create

spaces where users can socialize, collaborate, and engage in interactive experiences. Within the Metaverse, learners are not constrained by physical classrooms; instead, they can explore multiple environments, participate in simulations, and interact with both peers and virtual objects in real time.

The Metaverse also enables new forms of experiential learning. For instance, students can enter a virtual laboratory or workshop, manipulate digital objects, and observe outcomes that mirror real-world physics and engineering principles. Through avatar-based interactions, learners can collaborate with peers, exchange ideas, and solve problems collectively, fostering social and cognitive development simultaneously. As VR platforms like Rec Room continue to expand into educational applications, the integration of the Metaverse allows for scalable, immersive, and collaborative learning experiences that extend beyond traditional classroom boundaries.

### ***Implications for Education and Skill Development***

The adoption of VR and Metaverse-based learning tools carries significant implications for education and professional training. For ICT students, a VR-based PC assembly and disassembly simulation provides hands-on experience with hardware components, troubleshooting, and system configuration in a safe, controlled environment. This reduces reliance on physical resources, minimizes the risk of property damage, and lowers training costs while maintaining the quality of skill development.

Beyond technical skills, VR encourages critical thinking, problem-solving, and adaptive learning. Students are required to make decisions, anticipate consequences, and develop strategies in virtual scenarios that closely mimic real-life challenges. The ability to repeat simulations, practice complex tasks, and receive immediate feedback enhances learning

outcomes and prepares students for real-world applications. Furthermore, as VR and Metaverse technologies continue to evolve, their integration into educational curricula offers opportunities for lifelong learning, cross-disciplinary collaboration, and global knowledge exchange.

## Research Framework

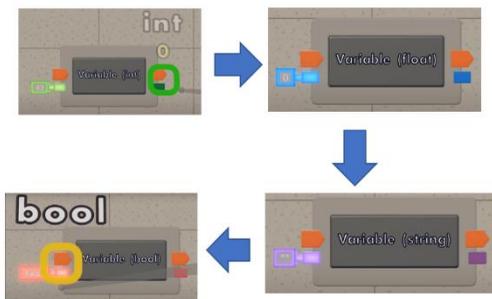
### *Data*

The data for this study were gathered from survey responses of 35 participants. Slovin's formula was used to determine the total number of respondents, and a random sampling method was employed to distribute the questionnaires. The questionnaire was based on ISO 2510 and included the following aspects: performance efficiency, maintainability, suitability, and usability.

A four-point Likert scale was applied, consisting of the following categories: strongly agree, agree, disagree, and strongly disagree. Each respondent was required to answer every item. The mean range for each scale was used to calculate the evaluation outcomes.

**Figure 1**

*Circuits System Mechanics*



As shown in Figure 1, the system does not need to collect any personal data, as it is primarily focused on the mechanics of building a PC.

In RECROOM, circuits serve as the type of data, with different input pin colors indicating their data types: blue input pins represent floats, green input pins represent integers, red input pins represent booleans, and purple input pins represent strings. However, a Gmail account is required to access the virtual environment or application, similar to other apps typically installed on devices.

### *Ethical Considerations*

Participants are expected to treat one another respectfully. Language, conduct, or content that is sexist, racist, discriminatory, or harassing is strictly prohibited. Participants must not encourage, support, or engage in criminal activities. Players under the age of 12 must use a junior account, and only one participant is allowed per account. The player's birthdate must match the account information.

Content that is disruptive or inappropriate in public spaces, such as pornographic material or contentious topics, is not allowed. Private or unlisted rooms are exempt from these rules, but all participants must consent to activities within these spaces. Spaces that could be potentially sensitive should clearly indicate their purpose to other users before entry. Participants should not impersonate developers, moderators, or authority figures, and should avoid interfering with other players' games. The proponents aim to minimize regulations governing conduct in every game. Prohibited behaviors include cheating, misusing in-game controls, poor sportsmanship, or general disruptive behavior. Code of Conduct violations should be reported using the in-game reporting features.

*Player-created rooms.* The behavior of a room reflects the actions of its owners and builders. Public custom rooms that violate the Code of Conduct will be treated as if all owners committed the infractions. Room

creators are responsible for ensuring their spaces do not become hazardous or disruptive. If room creators are unable to monitor their rooms regularly, such as when traveling, they should consider making them private or appointing reliable co-owners. All co-owners are accountable if they are able to maintain the room; otherwise, they are not. Room owners should remove themselves if they will be absent for an extended period or no longer wish to manage the room. The ultimate responsibility lies with the room creator.

*Clubs.* Owners and co-owners must actively manage their clubs to ensure adequate moderation and maintain a positive reputation. If additional time or support is required, owners should consider making the club private or appointing co-owners or moderators. Sexually themed clubs must remain private. Clubs cannot promote illegal activities. Clubs with repeated moderation issues may be closed or made private, and temporary or permanent bans may be imposed on the founder and other owners.

### ***Experimental Design***

In this study, the independent variable is the use of VR, while the dependent variable is its impact on the learning process.

Using a stand-alone VR application, Rec Room provides a compact and basic portable solution for creating virtual worlds within the platform itself. It allows users to design objects and implement desired functions without requiring complex coding. Instead, it utilizes a logical drag-and-drop system that is already prepared and modifiable. The application emphasizes logic-based functionality, with minimal coding needed, and does not require any additional software beyond the platform. It is similar to Horizon Worlds by Facebook Meta; however, it has not yet been released in the Philippines.

**Table 1**

*Dependent and independent variables*

<b>Experimental Group (With VR)</b>	<b>Control Group (No VR)</b>
Sample/Group A	Sample / Group B
	
Studying Using VR	Studying in a traditional way
Assessment The Proponents prepare a short lesson regarding solar system with a fix time duration, then let them take a short test with 10 items (identification).	Assessment The Proponents prepare a short lesson regarding solar system with a fix time duration, then let them take a short test with 10 items (identification).
<b>Test Score: 8</b>	<b>Test Score: 6</b>

Participants using VR achieved higher scores compared to those not using VR. Follow-up interviews were conducted to understand how VR influenced their learning process. Participants who used VR reported that learning was much more enjoyable because the immersive environment enhanced engagement, provided excellent visualizations of subjects, and allowed them to focus more closely on the material. In contrast, participants who did not use VR stated that conventional study methods were routine and offered little variation, often requiring them to contend with distractions from their surroundings. Therefore, the proponents conclude that VR can effectively support learning due to its immersive environment. It allows learners to experience actual demonstrations of objects and concepts, which are more likely to be retained in memory.

### *Procedures of the Different Phases*

The SDLC is often referred to as a framework for planning, developing, testing, managing, and delivering reliable technical services. It simplifies the process of identifying the current phase in which developers are working, determining the resources required, and outlining the subsequent steps needed to complete the project.

**Figure 2**

*Agile model development phases*



Before starting development, the team studies the business, including its functions, requirements, and challenges related to assembling and disassembling components of interest to researchers. Developers then assist in defining the requirements, organizing development sprints, and determining the type of solution that will best meet those needs. Understanding business requirements prior to development is essential, but the Agile methodology allows for adaptability, enabling changes to be made as they arise. This approach ensures the effectiveness of the carefully designed software solution. Planning conducted before development

enhances project success and prepares the team for upcoming development sprints.

*Analysis.* The first stage of the project involves gathering requirements and performing an analysis. During this phase, all subsequent activities related to product development are outlined. This stage is dedicated to resolving uncertainties regarding planning, design flow, and software specifications.

*Design.* The design phase follows analysis and includes the conceptualization of the product's panels, buttons, and other user interface components. Additionally, it affects how smoothly the software's business logic operates.

*Development.* The third stage of the SDLC is development, also referred to as functionality implementation or scripting. During this phase, the designed software elements are implemented, and the source code is written.

*Testing.* This phase involves verifying the product to identify and fix bugs or errors in the code. The solution undergoes thorough testing, often in multiple cycles, to eliminate all issues and ensure proper functionality.

*Deployment.* Deployment is the process of launching the software and distributing the product to end users.

*Maintenance.* The maintenance phase ensures that the solution remains relevant and continues to meet evolving market demands. Additionally, if a user encounters an issue, it can be addressed through hot-fixes or scheduled updates to maintain optimal performance.

## **Technical Framework**

### ***Materials***

The primary technology material required for this system is a VR headset, specifically the Meta Quest 2 (formerly Oculus Quest 2). VR is an immersive technology that creates a virtual environment in which users can interact similarly to the real world. With the recent emergence of the metaverse as a major technological trend, VR platforms have become increasingly significant for research and development.

The platform used is Rec Room, a VR gaming platform that allows users to navigate different worlds, participate in games, hangouts, or relevant applications, and even develop their own applications as “Creators.” The proponents selected this platform based on prior experience and confidence that it can effectively support the system, although further research is required.

### ***Software***

Rec Room is the primary software platform used in this study. It is a standalone VR platform that is freely accessible to users. Rec Room allows users to create virtual worlds, build gaming simulations, and engage in games, hangouts, or other applications. Users who create content within the platform are referred to as “World Creators.” Rec Room is a VR massively multiplayer online game with an integrated game creation system, developed and released by Rec Room Inc.

Rec Room is compatible with Microsoft Windows, Xbox One, Xbox Series X and Series S, PlayStation 4, PlayStation 5, Meta Quest 2, as well as iOS/iPadOS and Android devices via the App Store.

## Hardware

The hardware required for this system includes a VR headset, laptop/PC, or mobile device.

*Virtual Reality Headset (VR Headset).* The VR headset used is the Meta Quest 2 (formerly Oculus Quest 2). VR headsets are head-worn devices that provide an immersive 3D experience by covering the eyes and displaying a virtual environment in which users can interact as they would in the real world. VR headsets may be self-contained, such as the Meta Quest, or connected to a powerful computer, such as the HTC Vive, to handle complex animations. These devices are critical for providing users with a fully immersive experience and are central to exploring current trends in the metaverse.

**Table 2**

*Hardware specification*

<b>1. VR Headset</b>	<b>VR Meta Quest 2</b> (specs: RAM: 6GB; ROM: 256GB Chipset: Qualcomm Snapdragon XR2)
<b>2. PC Laptop</b>	<b>Operating System:</b> Window 10 or Higher <b>Processor:</b> Intel i7 or Ryzen 5 3600 <b>Memory:</b> 16GB RAM <b>GPU:</b> GTX 980 or RTX series
<b>3. Mobile Phone</b>	<b>Operating System:</b> IOS / Android 11 <b>Processor:</b> Snapdragon series / Helio Series <b>Memory:</b> 6GB RAM

Table 2 shows the system requirements to ensure compatibility across different devices. This is due to the Rec Room VR platform, which is used for developing the PC Building Simulator. Rec Room is a cross-platform VR environment that hosts the project within it. Because it

provides an immersive virtual environment, the system demands substantial graphics rendering, high refresh rate performance, and a strong, stable internet connection. Therefore, the system requires at least mid-range devices to operate at its full potential.

The authors first determined the required functions based on actual PC building operations. They then analyzed and identified a suitable VR platform capable of representing the entire system, including both design and functionality, which was found to be REC ROOM. The analysis also considered the necessary hardware, identifying the VR headset as the primary device for developing and operating the system.

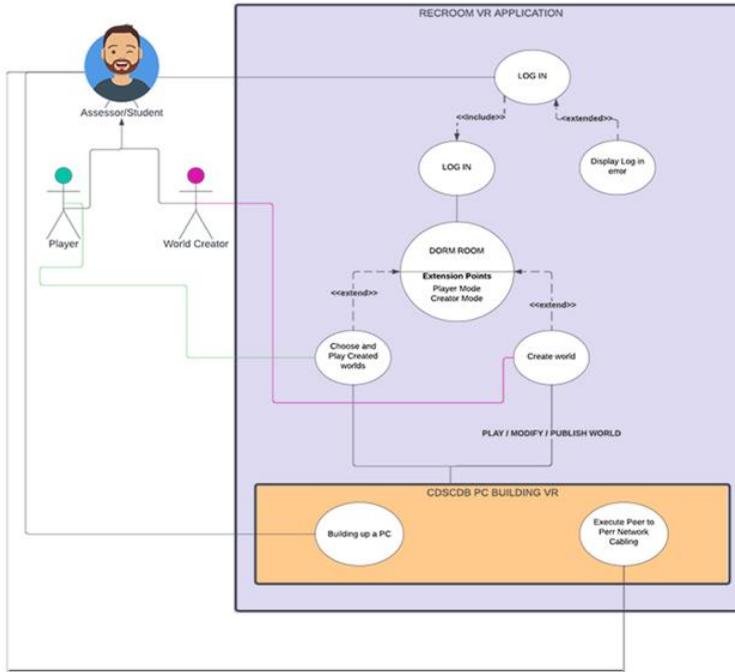
### ***System Design***

System Design is the process of defining the architecture, components, modules, interfaces, and data that satisfy specific requirements of a system. It serves as the blueprint for building and integrating the hardware, software, and processes that work together to achieve the system's objectives. By providing a structured framework, system design minimizes errors, guides implementation, and supports long-term adaptability of the system.

The UML Use Case diagram (Figure 3) provides a visual representation of the overall interaction between users and the system through the Rec Room VR application. It outlines the sequence of actions that a user can perform, beginning with system access via devices such as a PC or VR headset. Through the Rec Room VR platform, users are able to navigate and explore a variety of virtual environments that have been created and shared by other users, highlighting the collaborative and user-generated nature of the platform.

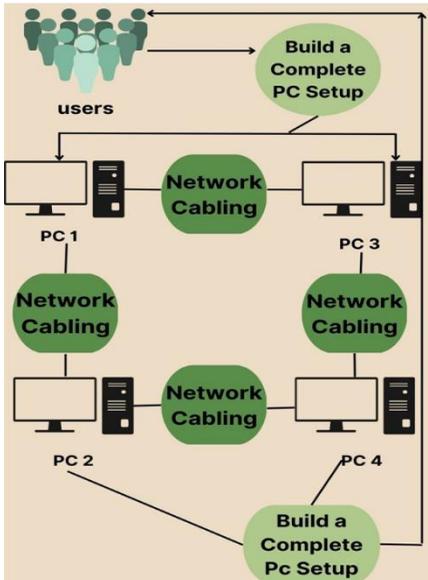
**Figure 3**

*Use case diagram*



**Figure 4**

*System Design*

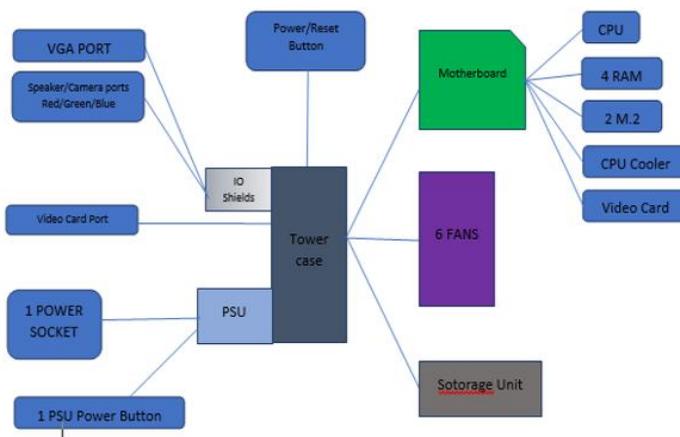


As shown in Figure 4, users can understand complex systems by using system diagrams. These diagrams serve as tools to aid in comprehending how various components of a system interact. Changes in one component can affect other factors, making these diagrams particularly useful. They are also an effective tool for analyzing the potential long-term impact of virtual reality on society.

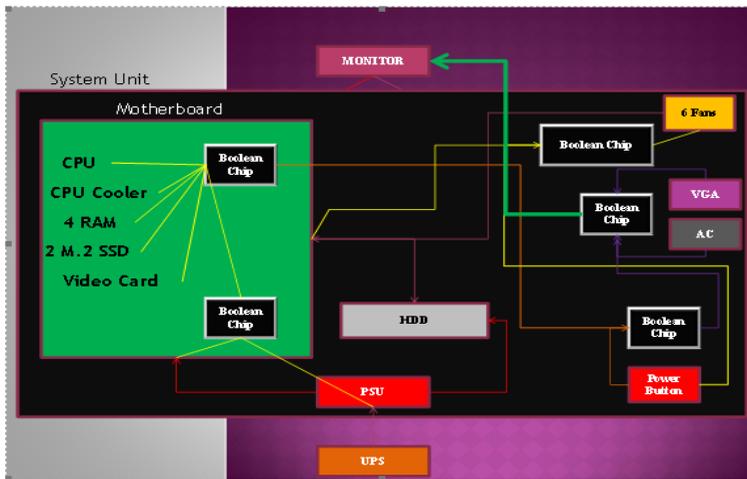
Figure 5 shows the electrical, direction and connection of the system. The building sequence of a computer begins with setting up the Power Supply Unit (PSU), which provides the necessary power for all components. Next, the motherboard is prepared by installing essential parts such as the CPU, CPU cooler, RAM, M.2 SSD, and video card. Once these components are securely in place, the motherboard itself is installed into the case, followed by the installation of additional storage devices such as the HDD. After all hardware is mounted, the necessary cables are connected to ensure proper power delivery and data transfer between components. Finally, the system is powered on by turning on the switch, completing the assembly process.

**Figure 5**

*Electrical, direction and connection*



**Figure 6**  
*System logic*



As shown in Figure 6, the chips or circuits containing the program module are responsible for detecting the objects required to trigger the next event in a sequence, depending on the wiring connections. For example, the monitor requires a VGA cable, a power cable (AC), and an electrical supply provided through the power cable connection to the PSU. These components must first meet the required conditions before the monitor can become active and the computer can be powered on.

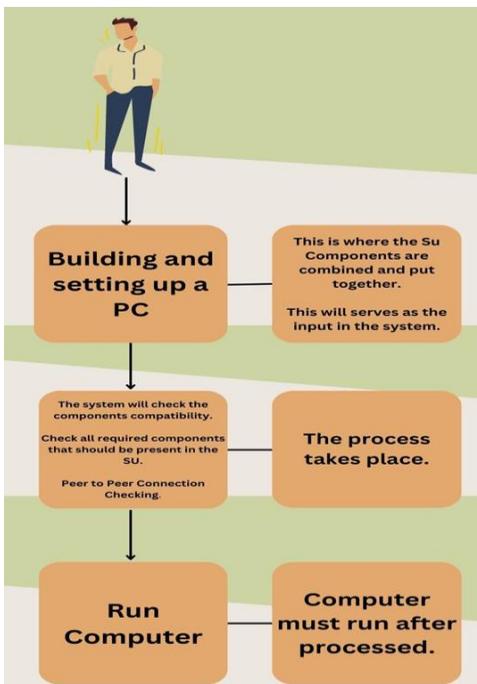
### ***Data Flow Diagram***

This system is specifically designed to simulate the process of building and setting up a PC, with a key focus on ensuring that all components are compatible with one another. It serves as the primary input mechanism for the system, allowing users to interact directly with the interface and engage with the simulation's mechanics. The system emphasizes user interface design, providing intuitive controls and feedback to guide users through each step of the PC assembly process. Internally, the

system uses circuit-based logic to manage the interactions between components, ensuring that actions occur in a sequential and realistic pattern. By combining interactive mechanics with component validation, the system not only enhances user engagement but also provides an educational experience in understanding hardware assembly and compatibility.

**Figure 7**

*Data flow diagram*

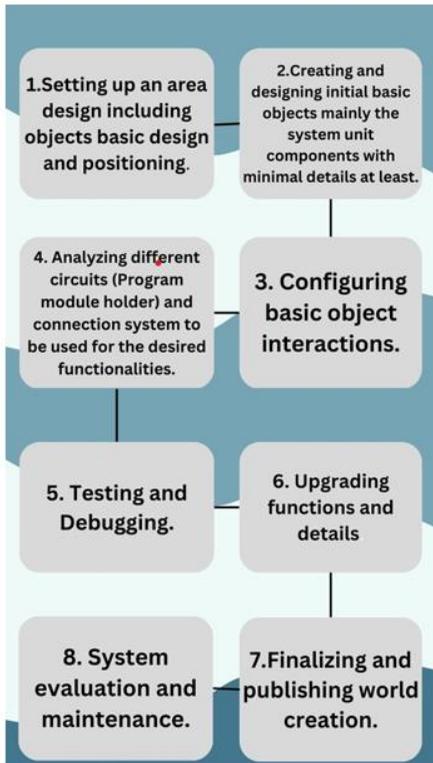


As shown in Figure 8, in the development stage of the system, the first step is designing the area, followed by creating and designing the initial basic objects. Next, fundamental object interactions are configured, and different circuits and connection systems are analyzed. This is followed by testing, debugging, and upgrading functions and details. Finally, the world creation is finalized and published, after which system evaluation and

maintenance are conducted.

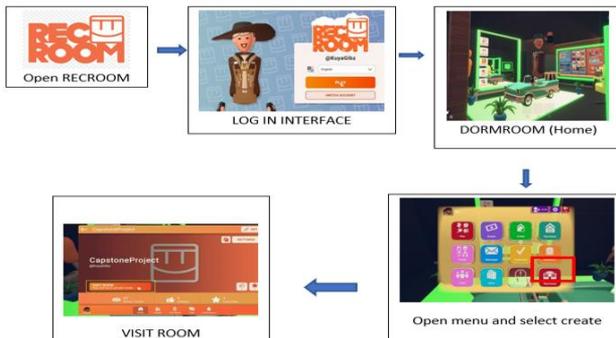
**Figure 8**

*Steps of the system development*



**Figure 9**

*Opening the world*



After completing the stages, the player will reach the virtual world,

where other players can be invited to explore it. Once the world has been published in the game, anyone can freely enter and experience it.

**Figure 10**

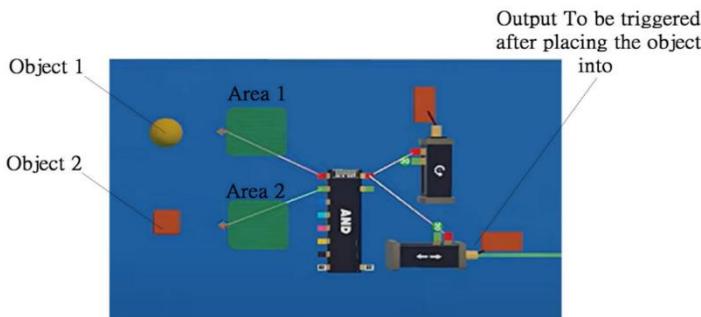
*VR interface*



Players can enter the world created by the proponents within Rec Room VR. This is what the world looks like once inside; it was initially created by the proponents and may be modified in the future. It also provides a summary of the testing facility, where several experiments were conducted for various purposes that can be applied to the project and future updates.

**Figure 11**

*System testing demo*

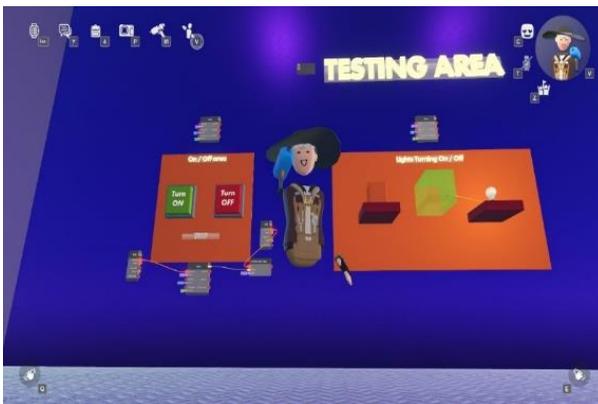


The objects represent the system unit components that are inserted into their designated sockets. The area serves as the system's socket, where each component is placed. This trigger zone determines whether a component has been inserted correctly and verifies that all required components are present before the system can operate as intended. The image demonstrates only a portion and specific function, but there is much more to explore within the system.

### *Testing Case*

**Figure 12**

*Testing area of the system*



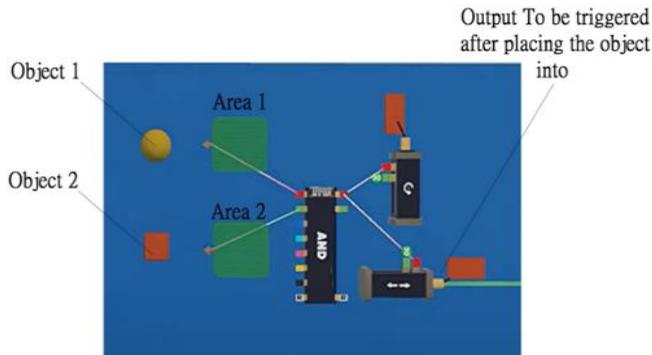
The scope and objective of the testing process are to ensure that the system operates in a manner closely aligned with real-world procedures for building a PC, including all basic networking processes. Various testing setups are employed to verify that the desired functionalities are achieved. The specific functions to be tested are outlined below.

As shown in Figure 13, the system interface for the Object Trigger Zone Detection System is designed to detect and verify whether an object is correctly attached to its designated area or part within the PC tower case.

The system also identifies and ensures that all required components to operate the computer are properly attached and placed. Additionally, it manages interactions between objects and the virtual environment.

**Figure 13**

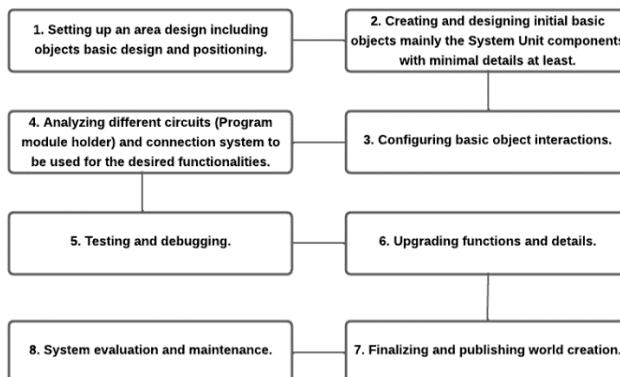
*Testing setup*



The researchers employed a proactive testing approach, commonly used in system development. This technique was chosen because it allows errors and bugs to be identified at early stages of development. Programmers begin the test design process as soon as possible to detect and fix faults before the system build is completed.

**Figure 14**

*Development of maintenance*



Setting up the area design is the first step in system development. The subsequent steps include creating and designing the initial basic objects, configuring fundamental object interactions, analyzing various circuits and connection systems, testing, debugging, upgrading functions and details, and finally finalizing and publishing the world creation, followed by system evaluation and maintenance.

### ***System Evaluation***

One of the fundamental challenges faced by ICT students in PC assembling and disassembling is encountering non-functional or damaged system units at the beginning of their learning process. To address this, studies have been conducted to develop a system that assists students in assembling and disassembling a system unit more effectively, efficiently, and in an organized manner. This system leverages VR technology, focusing on performance efficiency, maintainability, suitability, and usability.

**Table 3**

*Operational cost analysis*

<b>Operational Cost</b>	<b>Quantity Unit</b>	<b>No. of Months</b>	<b>Cost</b>	<b>Total</b>
Electricity (Computer and Printer)	2	7	Php 500.00	Php 3,500.00
Internet Fee	1	7	Php 400.00	Php 2,800.00
Maintenance Fee	1	3	Php 1300.00	Php 3,900.00
VR Headset (MetaQuest2)	1	7	Php 27,000.00	Php 27,000.00
<b>Subtotal</b>				<b>Php 37,200.00</b>

Operational cost-benefit analysis estimates and sums the monetary value of the system's benefits and costs to determine whether it is

productive and worth the investment. The system’s operational costs are presented above, including the cost duration, monthly expenses, and the overall cost of using the system.

**Table 4**

*Development cost analysis*

<b>Development Cost</b>	<b>Quantity Unit</b>	<b>No. of Months</b>	<b>Cost</b>	<b>Total</b>
Developers	1	1	Php 19,999.00	Php 19,999.00
System Analyst	1	1	Php 30,999.00	Php 30, 999.00
Internet Fee	1	7	Php 1,300.00	Php 9,100.00
Researcher	2	10	Php 25,000.00	Php 50,000.00
<b>Subtotal</b>				<b>Php 110,098.00</b>

Table 4 is the estimated cost-benefit analysis to consider whether the system benefits investment.

The system was evaluated by 35 respondents using a questionnaire based on ISO 2510, covering the following aspects: performance efficiency, maintainability, suitability, and usability.

**Table 5**

*Weighted average distribution of the criteria developed system*

<b>Criteria</b>	<b>Weighted Mean</b>	<b>Remarks</b>
Performance Efficiency	3.37	Strongly Agree
Maintainability	3.36	Strongly Agree
Suitability	3.19	Agree
Usability	3.31	Strongly Agree
<b>Average</b>	<b>3.30</b>	<b>Strongly Agree</b>

Table 5 shows that the overall system evaluation survey yielded an average weighted mean of 3.30, indicating that respondents rated the system

as outstanding in terms of performance efficiency, maintainability, suitability, and usability. This suggests that the system is capable of performing the specified requirements effectively.

*Performance efficiency.* The system is easy to understand. The average weighted mean for performance efficiency is 3.37, with a remark of Strongly Agree. This indicates that respondents are satisfied with the system's performance and its functionality.

*Maintainability.* The system is easy to maintain and incurs low costs. The average weighted mean for maintainability is 3.36, with a remark of Strongly Agree.

*Functional suitability.* The system functions effectively in terms of functional suitability. Respondents agreed that the developed system could serve as a future tool in their community because it works well and appears practical for use. The average weighted mean for functional suitability is 3.19, with a remark of Agree.

*Usability.* The system is easy to use. Respondents, including those unfamiliar with Virtual Reality (VR), reported that they quickly learned the system's controls within minutes. The average weighted mean for usability is 3.31, with a remark of Strongly Agree.

Based on the general evaluation, the results indicate that the VR system created by the proponents using Rec Room has the potential to teach PC building even to beginners and those new to the course. Although the system is still in the prototype stage, it already covers the basics, including assembling and disassembling the entire computer setup.

*Economic feasibility.* To evaluate the system, a cost-benefit analysis was conducted to determine whether the anticipated benefits would equal or exceed the system's projected costs. The system's advantages and limitations provide feedback regarding its costs and benefits, offering an

accurate comparison. Additionally, the ISO 2510 questionnaire-based assessment provided feedback on the system's economic feasibility and overall functionality.

*Technological feasibility.* If the project is successfully completed, it can offer several technological advantages. The system is user-friendly for beginners, and the construction of materials is simple, with components easily removed and replaced using red and blue screws. Further improvements can enhance the system's efficiency, profitability, and distinctiveness.

*Operational feasibility.* The system is operationally viable because it was designed with user-friendliness in mind. Survey results indicate that ICT students were satisfied with the system, finding it easy to use after a brief demonstration with a VR headset.

## **Conclusion**

The VR system developed using Rec Room demonstrates significant potential in teaching PC building, even for beginners or students new to the subject. Although still in the prototype stage, the system effectively covers fundamental tasks such as assembling and disassembling computer components, allowing students to practice without the risk of damaging actual parts. This approach also reduces unnecessary expenses on hardware replacement and provides a more engaging and enjoyable learning experience through a 3D immersive VR environment compared to traditional methods. Furthermore, the system met the ISO/IEC 2510 criteria for performance efficiency, maintainability, suitability, and usability, indicating that it is functional, user-friendly, and operationally feasible. Overall, the study demonstrates that VR technology can serve as an

effective and practical alternative to conventional PC assembly and disassembly techniques, offering both educational value and operational efficiency.

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# **E-Basura: A Solar-Based Automated Solid Waste Segregation Bin with Object Detection Using Arduino Uno**

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Waste segregation is an effective method for minimizing the volume of waste and ensuring that garbage is properly managed. By classifying waste as biodegradable, recyclable, or residual, segregation facilitates the correct placement and disposal of materials, making collection and recycling more efficient. However, studies have shown that waste segregation is not always applied effectively in developing countries, such as Tanzania, where garbage is often mixed, leading to difficulties in recycling and disposal (Aleena et al., 2016). This lack of segregation at the source creates inefficiencies in handling and complicates the recovery of recyclable materials. As recycling remains essential in reducing waste volume, proper segregation at all stages of waste management is necessary.

Technological innovations have introduced intelligent solutions to address this problem. For instance, Jayson et al. (2018) described the development of a Smart Bin presented at the Second International Conference on Advances in Electronics, Computer, and Communications,

which offers a practical and economical method of separating wet and dry waste. This system reduces the need for interpersonal contact while promoting efficient collection and disposal. Similarly, Angin (2018) proposed the Design and Development of the Trash Splitter with Three Different Sensors, which utilized infrared, metal, and light sensors to automatically detect and sort garbage into categories such as metal, organic, paper, and plastic. The design, based on system specifications and developed using the Arduino IDE, includes modules for detecting objects and sorting various waste types, thereby automating and enhancing waste management processes.

Advanced approaches using artificial intelligence and computer vision have also been explored. Shah et al. (2021) introduced a weakly supervised deep learning method (DCNN-GPC) for detecting and classifying waste objects from unlabeled Red Green Blue Depth (RGBD) images. This technique demonstrated that even with minimally annotated data, deep convolutional neural networks can significantly improve waste detection and classification, including identifying common items like plastic bottles, which often contribute to environmental hazards. The study emphasized the potential of AI-based systems in addressing large-scale waste segregation and management challenges.

At the policy level, Republic Act No. 9003 establishes the legal framework for solid waste management in the Philippines. This law emphasizes proper collection, storage, and disposal practices to safeguard public health and promote environmental sustainability. By enforcing structured waste management procedures, it provides guidelines that complement technological innovations in garbage segregation.

In line with these developments, the main objective of this study is to design a waste segregation system that efficiently determines the

appropriate category of garbage and directs it to the correct bin. The proposed model employs a conveyor belt system with integrated sensors to detect, identify, and separate waste materials such as plastic, plastic bottles, paper, and metal. By combining practical design with modern technology, the system aims to demonstrate that garbage segregation can be made more effective, sustainable, and economically viable.

## **Theoretical Framework**

### ***AI and Deep Learning Approaches***

Artificial intelligence and deep learning have transformed waste segregation by providing higher accuracy and adaptability compared to traditional sorting methods. Vo et al. (2019) introduced the DNN-TC model, an improvement of the ResNext architecture, which effectively classifies garbage images into organic, inorganic, and medical waste. By training on the VN-trash dataset of nearly 6,000 images, the model achieved a classification accuracy of 94% on Trashnet and 98% on VN-trash, surpassing state-of-the-art benchmarks. Such results prove that deep learning models are not only scalable but also adaptable to different datasets and waste categories. Similarly, Hu and Zhang (2021) demonstrated the practical application of TensorFlow and OpenCV in automatic garbage sorting. Their framework reduced reliance on human intervention and significantly enhanced sorting precision, making it more efficient and less hazardous compared to manual waste handling. Collectively, these studies highlight that AI-driven waste segregation is a step toward sustainable and intelligent waste management systems, with potential applications in both urban communities and industrial environments.

### ***Sensor- and Arduino-based Systems***

Alongside AI solutions, low-cost hardware-based approaches using sensors and microcontrollers have been widely explored for practical waste segregation. Durrani et al. (2019) developed the Automated Waste Control Management System (AWCMS), which uses Arduino microcontrollers, infrared sensors, GPS, and GSM modules. This system not only identifies the amount of waste in bins but also communicates the data in real-time, allowing for efficient collection scheduling and reducing unnecessary trips. Sunehra et al. (2021) presented another system using Arduino Uno that classifies waste into dry, moist, and metallic categories, with additional layers for paper and plastic segregation. This was further supported by Angin (2018), who proposed a trash splitter equipped with infrared, metal, and light sensors to separate metals, organics, paper, and plastics. These systems illustrate that sensor-driven models provide a feasible and cost-effective alternative for waste segregation, particularly in developing countries where resources are limited. While not as sophisticated as AI-based models, their affordability and simplicity make them highly practical for grassroots-level implementation.

### ***IoT-Enabled and Smart Trash Bins***

The integration of IoT (Internet of Things) technologies into waste segregation has added significant value by enabling real-time monitoring, data collection, and system automation. Pamintuan et al. (2019) introduced i-BIN, an intelligent trash bin combining machine learning and sensors to distinguish between biodegradable and non-biodegradable waste using over 2,000 samples. This system exemplifies how IoT can link waste classification with larger smart city infrastructures. Similarly, Baras et al. (2020) proposed a cloud-based smart recycling bin that achieved 93.4%

accuracy in sorting household waste, demonstrating the potential of cloud integration in ensuring centralized monitoring and data-driven collection strategies. Sohail et al. (2019) designed the Intelligent Trash Bin (ITB), which reduced waste collection costs by optimizing truck routes and minimizing human involvement through IoT-enabled sensors. Additionally, Ndakara et al. (2020) emphasized renewable energy integration by designing a solar-powered automatic waste bin that relies on ultrasonic sensors and microcontrollers for hygienic and sustainable waste management. Collectively, these innovations highlight how IoT-enabled systems combine efficiency, sustainability, and environmental consciousness, making them highly relevant for modern urban ecosystems.

### ***Incentive-Based Waste Management Systems***

While technology enhances accuracy and efficiency, behavioral compliance is equally important in ensuring effective waste segregation. Castro et al. (2020) addressed this gap by integrating Artificial Neural Networks with a reward system known as “Basura Advantage Points.” Each time a user disposed of waste correctly, the system awarded points that could later be redeemed for tangible benefits. Despite achieving only 80% classification accuracy, the study demonstrated that public participation improved significantly when incentives were introduced. This highlights the role of psychological and social motivators in complementing technological solutions. Incentive-based systems encourage individuals to change their disposal habits, create a sense of responsibility, and provide measurable rewards for environmentally friendly behavior. Such approaches are particularly effective in urban communities where behavioral change is often more challenging than technological adoption.

### ***Educational and Policy Perspectives***

Technology-driven systems alone cannot fully address waste management challenges without supportive policies and education. The Ecological Solid Waste Management Act (RA 9003) provides the legal framework for systematic collection, segregation, and disposal of solid waste in the Philippines, emphasizing both compliance and community involvement (Coracero et al., 2021; Paña-Tautho et al., 2025). Madrigal and Oracion (2017) expanded on this by stressing the importance of integrating waste segregation into school curricula and institutional practices, noting that early education fosters lifelong environmental awareness and sustainable habits. Mamarinta and Abarquez (2025) further confirmed that awareness campaigns and school-based interventions directly influence waste management practices among students and households. From a governance perspective, Effective waste management requires political will, adequate resources, and multi-stakeholder participation (Shamu et al., 2025; Debrah et al., 2021; Joseph, 2006; Salvia et al., 2021), particularly at the local government level. Soliman et al. (2025) reinforced this by showing how smart dustbin monitoring systems reduce manual labor while ensuring compliance with municipal policies. These findings underscore the importance of embedding waste management not only in technology but also in education, law, and governance frameworks to ensure holistic sustainability.

### **Research Framework**

This study gathered data through a survey involving 30 respondents. The Slovin formula was used to determine the sample size, while a random sampling method was applied to distribute the questionnaires. The survey

instrument was designed to assess four key aspects: correctness, speed, functionality, and operational ability. A four-point Likert scale was employed, with the following response categories: Strongly Agree, Agree, Disagree, and Strongly Disagree. These options provided the basis for respondents' answers to each survey item.

**Table 1**

*Characteristics of solid waste materials*

<b>Waste</b>	<b>Characteristic</b>
Paper	Made of wood pulp or another recycled paper.
Plastic Bottle	Made of polymers.
Plastic	Made of high-density polyethylene.
Metal	Made of atomic materials.

Table 1 presents the characteristics of the solid waste materials utilized in the system project. Understanding these characteristics is essential for designing an effective waste segregation system, as it allows the system to accurately detect, classify, and process different types of waste. Each material, such as paper, plastic bottle, plastic and metal, has unique physical properties, which influence how sensors and detection mechanisms respond.

**Table 2**

*Characteristics of solid waste materials*

<b>Data Set</b>	<b>Description</b>	<b>Unit of Measurement</b>
Paper	Width	Inches
	Height	Inches
Plastic Bottle	Height	Inches
	Weight	Grams
Plastic	Area	Inches
	Width	Inches
	Length	Inches
Metal	Length	Inches
	Width	Inches

Table 2 presents a set of data and the corresponding characteristics of the garbage based on the items thrown into the system. The table includes detailed descriptions of each item's length, width, height, and overall dimensions. Understanding these physical properties is essential for calibrating the system's sensors and mechanisms, ensuring accurate detection, classification, and proper placement of waste into the appropriate bins. By analyzing the dimensions of each waste material, the system can optimize its sorting process and improve overall efficiency and reliability.

### ***Experimental Design***

The experimental design of the study was developed to outline the process required to achieve the research objectives. It illustrated the logical flow of activities, from identifying the problem to evaluating the effectiveness of the proposed system. The first step in the design was to identify the problem, which focused on the challenge of properly segregating waste materials. The next step involved defining the objectives of the study and determining the appropriate recommendations that could address the identified problem. Data collection followed, as it was considered a vital step in creating a more effective system. Information was gathered both manually and from individuals with relevant expertise and background knowledge.

Once sufficient data had been collected, the researchers proceeded with the design phase, which presented the experimentation process and the integration of the gathered data into the proposed system. The data were utilized to guide procedures on how waste materials should be segregated into their proper bins. The analysis was conducted through machine learning techniques to ensure accuracy and reliability. The operational process determined whether garbage was correctly classified and directed

into the appropriate bins, which played a significant role in validating the system's performance. The results of the analysis and segregation were displayed on a screen for monitoring purposes.

To assess the effectiveness of the system, questionnaires and test runs were conducted. The questionnaires were used to collect participants' feedback regarding the system's functionality, usability, and overall performance. Gathering opinions and suggestions from respondents was considered essential, as it provided insights into possible improvements and innovative features that could make the system more unique and efficient. Moreover, challenges and limitations encountered during testing were documented to identify areas that required enhancement. Feedback gathered from respondents contributed to the refinement and optimization of the system, ensuring that it operated smoothly and effectively.

### ***Ethical Considerations***

The study also took ethical considerations into account to ensure the welfare of both the users and the community. The waste segregation system was designed and tested with the intention of providing accurate detection and proper classification of waste materials. Users were expected to receive adequate training on how to properly operate the system and respond to alerts generated during its use. The system was required to be implemented and maintained effectively to maximize its benefits and minimize potential risks.

Safety and risk reduction were prioritized to ensure that the system consistently delivered positive results. Proper testing of waste segregation functionality was emphasized to improve accuracy and reliability. Additionally, user training was highlighted as a necessary measure to ensure smooth operation and to promote system longevity. By prioritizing

effectiveness, efficiency, and sustainability, the study underscored the importance of building a system that could deliver long-term benefits to both users and the environment.

### **Modeling**

Model selection was identified as a critical factor in the system’s testing and development. It determined not only how testing was planned but also which available techniques would be applied. The researchers adopted the agile methodology for system development, as it was considered the most appropriate approach for the proposed project.

**Figure 1**

*Agile method*



The agile method allowed for iterative development, enabling the system to be constructed, tested, and improved before full deployment. This approach facilitated early identification of issues and provided opportunities for rapid resolution, thus reducing the risk of major errors during the later stages of development. By applying agile principles, the researchers ensured that the system was flexible, adaptive, and capable of addressing the needs of the study in a structured yet responsive manner. Ultimately, the

agile method contributed to building a more reliable and efficient waste segregation system.

### ***Procedures of the Different Phases***

The procedural framework of the study on solid waste detection followed a structured series of phases, each contributing to the systematic development of the proposed system.

*Design phase.* The design phase involved defining the research questions or hypotheses and establishing the objectives and aims of the study. This step also included a comprehensive review of related literature to gain a deeper understanding of existing knowledge in the chosen field and to identify research gaps that could guide further investigation. The agile methodology was adopted, beginning with an analysis of system requirements. This ensured that the system incorporated essential details, aligned with user expectations, and met stakeholder requirements. The researchers also reviewed the necessary equipment and resources to guarantee that the project could be completed within the expected timeframe. The collected information served as the foundation for moving forward to the system's design and development.

*Design development.* During this phase, a simplified conceptual design of the solid waste detector was created. This design functioned as an outline or blueprint that illustrated the primary features of the system. Although it did not yet present the complete technical details, it served as a preliminary model that allowed researchers and potential users to visualize the system's intended functions.

*System development.* In the development phase, the researchers constructed a working prototype of the solid waste detector. This stage involved programming specific activities and tasks to enable the system to

perform its intended functions. The prototype acted as a representation of the final product and provided a near-conclusive demonstration of how the system would function under real conditions.

*Testing phase.* After development, the prototype underwent rigorous testing to determine its operational effectiveness. The researchers observed potential errors, identified weaknesses, and resolved issues that could hinder performance. The testing process ensured that the solid waste detector functioned reliably and accurately, eliminating major flaws before publication and final deployment.

*Deployment phase.* In this stage, the system was considered fully functional and ready for field application. Deployment demonstrated the overall functionality of the solid waste detector, confirming that it met user requirements and performed as expected in practical scenarios. This phase also provided validation that the system was capable of delivering accurate results in real-world waste segregation tasks.

*Review phase.* The final stage involved gathering user feedback and evaluating the system's overall performance. This stage highlighted user ratings and perceptions of the system's functionality, reliability, and usability. The review process not only assessed the degree to which the system met user expectations but also provided valuable insights for future improvements. Ultimately, this phase confirmed whether the solid waste detector could be highly recommended for broader use.

## **Technical Framework**

### ***Materials***

The software and hardware were required for the development of the product. This section defines and explains how they were used in the

system's processes.

## ***Software***

Table 3 shows the software used in creating this project.

**Table 3**

*Software requirement*

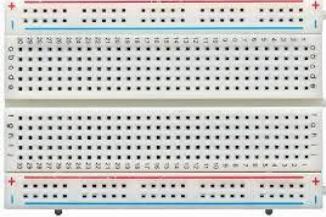
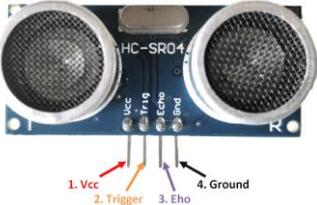
<b>Software</b>	<b>Description</b>
Arduino IDE (Code Editor)	Contains a text editor for writing codes, a message area, a text console, a toolbar with buttons for common function. Arduino IDE latest version 1.8.19
Operating System	A Microsoft Windows operating system that run into 64 bit architecture used in the development of the system.
PyCharm IDE	Is a essential tools for python developers, tightly integrated to create a convenient environment for productive Python. PyCharm Ide version – 2022.3.3

These software components were used in the system project to operate the waste segregation system effectively. They enabled the software elements to perform their tasks in coordination with the hardware components. The most critical aspect of the system was the code, which executed specific functions and ensured that the system operated smoothly and efficiently. Properly designed software played a key role in maintaining the system's performance and achieving accurate and reliable waste segregation.

## ***Hardware***

Table 4 shows the hardware used in creating this project.

**Table 4***Hardware requirements*

Hardware	Description/Specification
Desktop Computer	Core i5 500GB HDD 8 GB Ram
	<p>It is a microcontroller board.</p> <p>Specs:</p> <p>Microcontroller: ATmega328P</p> <p>Operating Voltage: 5V</p> <p>Input Voltage (recommended): 7-12V</p> <p>Input Voltage (limit): 6-20V</p> <p>Digital I/O Pins: 14 (of which 6 provide PWM output)</p> <p>PWM Digital I/O Pins: 6</p> <p>Analog Input Pins: 6</p> <p>DC Current per I/O Pin: 20 mA</p> <p>DC Current for 3.3V Pin: 50 mA</p> <p>Flash Memory: 32 KB (ATmega328P) of which 0.5KB used by bootloader</p> <p>SRAM : 2 KB (ATmega328P)</p> <p>EEPROM: 1 KB (ATmega328P)</p> <p>Clock Speed: 16 MHz</p> <p>LED_BUILTIN :13</p> <p>Length : 68.6 mm</p> <p>Width: 53.4 mm</p> <p>Weight : 25 g</p>
	<p>It is used for building a permanent or temporary circuit.</p> <p>Specs: Full-size breadboard</p> <p>830 holes</p> <p>Standard 2.54mm (0.1) spacing between two holes</p> <p>Dimensions 16.5x5.5cm</p> <p>Rating is 5Amps</p>
	<p>It is an instrument that measure the distance to an object using ultrasonic sound waves.</p> <p>Specs:</p> <p>Power Supply: DC 5V</p> <p>Working Current: 15mA</p> <p>Working Frequency: 40Hz</p> <p>Ranging Distance: 2cm – 400cm/4m</p> <p>Resolution: 0.3 cm</p> <p>Measuring Angle: 15 degree</p> <p>Trigger Input Pulse width: 10uS</p> <p>Dimension: 45mm x 20mm x 15mm</p>

Hardware	Description/Specification
<p>Jumper Wires</p> 	<p>It is an electric wire that connects circuits use for printed circuit board.</p> <p>Specs:</p> <p>Wire Quantity: 20</p> <p>Length: 300mm / 30cm</p> <p>Connector Type: Female – Male/Male-Male/Female-Female</p> <p>Color: Combined</p>
<p>Servo Motor</p> 	<p>It is an electronic device and rotary or linear actuator that rotates and pushes parts of machine with precisions.</p> <p>Specs:</p> <p>Dimensions: 40.8 x 20.1 x; 38 mm</p> <p>Weight: 40 g</p> <p>Operating Speed: 0.18sec/60degrees (4.8V)</p> <p>0.16sec/60degrees (14V)</p> <p>Stall Torque: 5kg.cm/69.56oz.in (4.8V)</p> <p>6kg.cm/83.47oz.in(6V)</p> <p>Operating Voltage: 4.8V~6V</p> <p>Control System: Analog</p> <p>Direction: CCW</p> <p>Operating Angle: 360 degrees</p> <p>Required Pulse: 500us-2500us</p> <p>Bearing Type: 2BB</p> <p>Gear Type: Plastic</p> <p>Motor Type: Metal</p> <p>Connector Wire Length: 30 cm</p>
<p>Dc Motor</p> 	<p>It is a class of electrical motors that convert direct current electrical energy into mechanical energy.</p> <p>Specs:</p> <p>Operating Voltage(V): 12.</p> <p>Rated Speed (RPM): 200.</p> <p>Rated Torque(kg-cm): 1.5.</p> <p>Stall Torque(kg-cm): 5.4.</p> <p>Load Current (A): 0.3.</p> <p>No Load Current (A): 0.06.</p>

Hardware	Description/Specification
<p>Solar Panel board</p> 	<p>A solar panel is actually a collection of solar (or photovoltaic) cells, which can be used to generate electricity through photovoltaic effect.</p> <p>Specs:</p> <p>Item Type: Solar Panel</p> <p>Material: Monocrystalline Silicon+ABS</p> <p>Product Size: Approx. 21.5x18.5cm / 8.5x7.3in</p> <p>Weight: Approx. 321g / 11.3oz</p> <p>Waterproof Rating: IP65</p> <p>Voltage: 12V</p> <p>Current: 1A Power: 24W</p> <p>Conversion Rate: 23-24%</p> <p>Output: USB</p>
<p>Conveyor Belt</p> 	<p>Belt Dimension: 43.4 x 9x9cm LWH</p> <p>Chassis Dimensions: 46 x 10.5 x 11 LWH</p>
<p>Rechargeable Battery</p> 	<p>Capacity: 2.9AH</p> <p>Voltage: 12V</p> <p>Battery Type: Rechargeable Lead Acid Battery</p>
<p>Camera</p>	<p>HD ready (720p or 1280 x 720 pixels), full HD (1080p or 1920 x 1080 pixels),</p>
<p>LED Light</p> 	<p>Width: 15 mm</p> <p>Length: 48 mm</p> <p>Color: white</p> <p>Wattage: 0,60 W</p> <p>Voltage: 12 V</p>

Table 4 specifies the hardware materials used in the system project. These components were essential for constructing the waste segregation bin. Among them, the inductive proximity and ultrasonic sensors were particularly important, as they played a critical role in detecting and

identifying waste materials, ensuring that each item was placed in the correct bin. Additional hardware components were also incorporated to enhance the overall performance and reliability of the system.

## System Design

In the system design, all requirements of the project, including both hardware and software, were incorporated into the operational framework. The system design also illustrated the overall system flow, demonstrating how each component interacted to achieve the desired functionality.

**Figure 2**

*System architecture/design of a solar-based automated waste segregation*

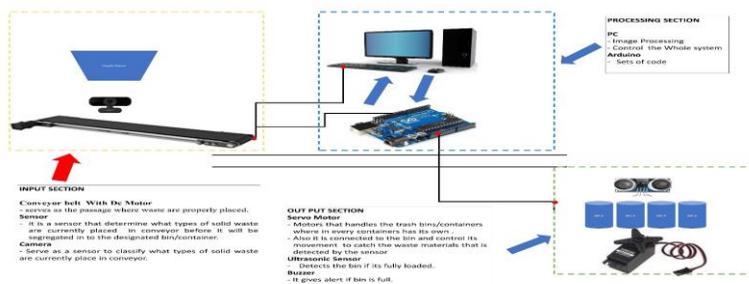
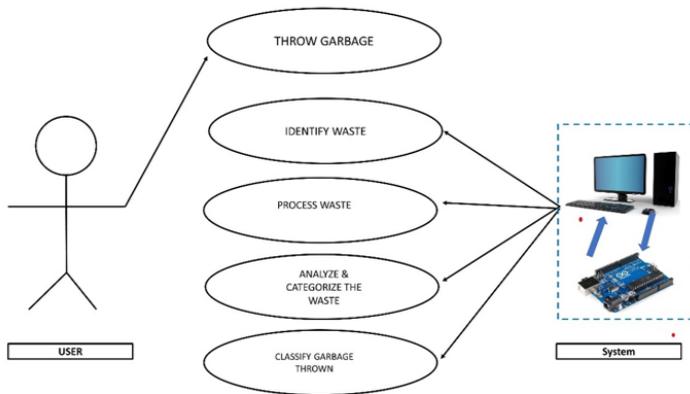


Figure 2 depicts the system architecture of the waste segregation system. The process begins when waste is placed into the funnel (one waste material at a time). The waste then moves along the conveyor belt, where the sensor detects and identifies the type of material. Based on this detection, the servo motor automatically directs the waste to the appropriate bin. The entire system plays a crucial role in waste segregation, as it is responsible for both detecting and accurately classifying the garbage.

The process is illustrated in the Use Case diagram in Figure 3, which provides a detailed overview of how the system classifies garbage.

**Figure 3**

*Use case diagram of automated waste segregation*



The system automatically identifies the waste provided by the user and executes a series of steps to analyze and process the input. These steps include detecting the waste, determining the appropriate bin for disposal, and directing the item into its correct location. This diagram highlights the sequential flow of actions that ensure accurate and efficient waste segregation.

**Figure 4**

*Project system flow*

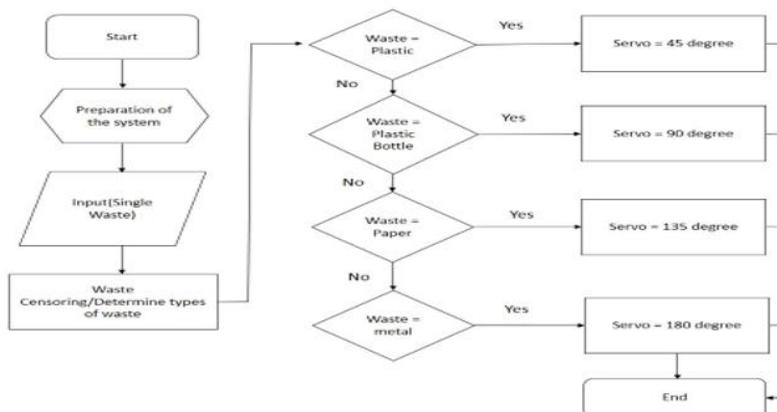
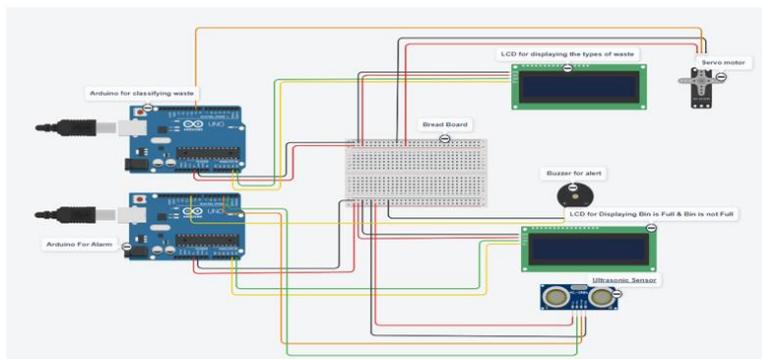


Figure 4 illustrates the system flow of the project, showing how the system functions and identifies waste materials. First, when the users

activate the system via the switch, all hardware components become operational. Waste materials, one at a time, are placed into the funnel and then dropped onto the conveyor belt. As the waste moves along the belt, the sensors detect and classify the material. Based on this detection, the servo motor automatically directs the waste into the appropriate bin, ensuring proper segregation.

**Figure 5**

*Circuit diagram of solar-based automated waste segregation*



As shown in Figure 5, the system utilizes two Arduino Uno boards to perform its functions. The first Arduino is connected to a laptop, where the code is uploaded to control the detection of solid waste materials. The second Arduino is responsible for managing the notification alert or alarm, which indicates when a bin is full. Both Arduinos are connected to a breadboard to coordinate their tasks.

The system also includes two LCD displays: the first shows the type of solid material detected, while the second indicates when a bin is full. A buzzer functions as an alarm, set to a high volume to inform users that the bin has reached capacity. An ultrasonic sensor measures the level of solid waste stored in the bin. Lastly, a servo motor, also connected to the Arduino,

performs rotational movements to position the bins correctly. The rotation is controlled by specifying precise angles in the code to ensure smooth and accurate operation.

**Figure 6**

*Detailed circuit diagram of solar-based automated waste segregation*

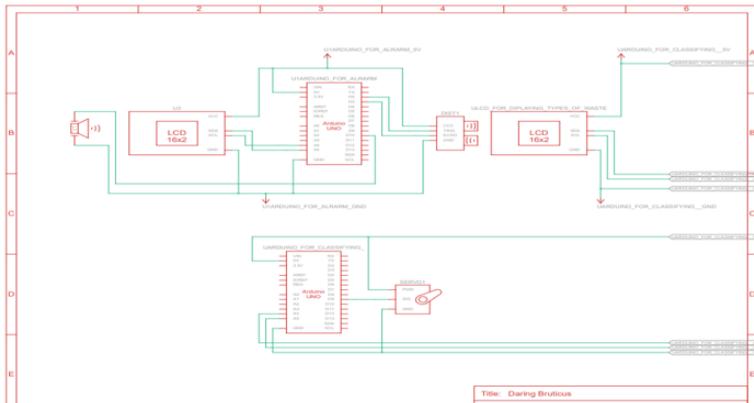


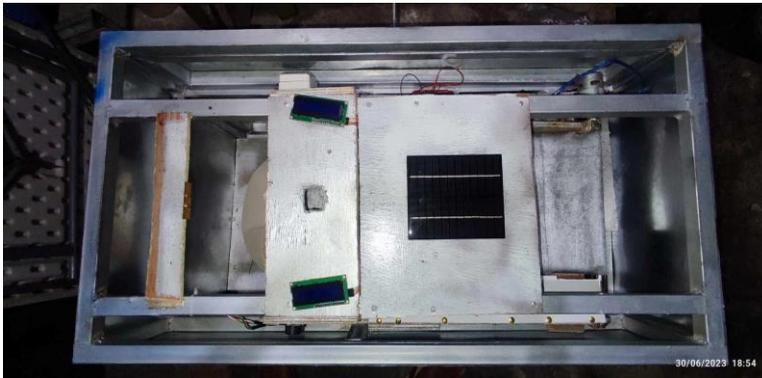
Figure 6 illustrates the detailed circuit diagram of the solar-based automated solid waste segregation system. This diagram provided users with a clear understanding of the system's operation. The main components included two Arduino Uno boards, a servo motor, a buzzer for alarms, and two LCD displays. In addition, software components were integrated to coordinate with the hardware, ensuring the proper functioning of the system. The circuit diagram played a critical role in demonstrating the function of each system component and their interaction within the overall system.

Figure 7 illustrates the completed waste segregation system. It represents the integrated output of both hardware and software components used in its development. The researchers also utilized recycled and low-cost materials to complete the project, making it a practical and cost-effective

solution. This system serves as a reference for future researchers who wish to develop innovative and impactful studies on waste segregation.

**Figure 7**

*Whole system/prototype of automated solid waste segregation bin*



**Figure 8**

*Plastic waste detected*



Figure 8 shows that the solid waste material tested was plastic. The camera successfully detected and confirmed the plastic as the targeted waste material. Based on this detection, the servo motor rotated to the specified

angle to capture and direct the plastic into the appropriate bin.

**Figure 9**

*Plastic bottle waste detected*

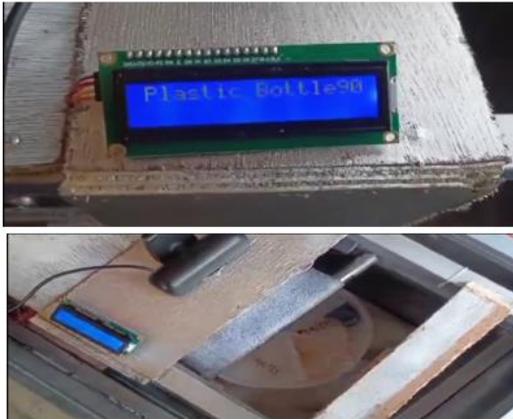


Figure 9 shows that the tested waste material was a plastic bottle. The camera successfully detected and confirmed the plastic bottle as the targeted solid waste material. The servo motor then rotated to the specified angle to capture and direct the plastic bottle into the appropriate bin.

**Figure 10**

*Paper waste detected*

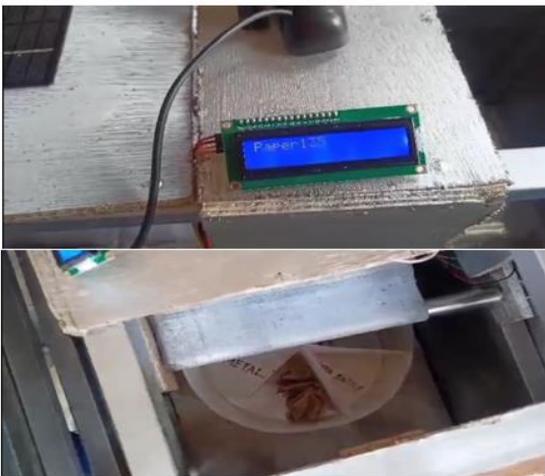


Figure 10 shows that the tested solid waste material was paper. The camera successfully detected and confirmed the paper as the targeted waste material. The servo motor then rotated to the specified angle to capture and direct the paper into the appropriate bin.

### ***System Testing***

System testing was conducted to evaluate the performance and functionality of the waste segregation system. Researchers performed manual testing to assess system quality, detect errors, and identify potential failures. Each component of the system was tested individually and collectively to ensure proper operation. The identification of errors during testing was crucial, as it informed improvements and refinements to enhance the system's performance. This approach allowed researchers to validate the system's effectiveness and prepare for subsequent testing cycles efficiently.

The system's operation was the primary focus during testing, guided by the system design specifications. The system was simulated, and the outputs were compared with expected results to validate functionality. All requirements defined in the model were used as benchmarks for testing. Validation of the system output confirmed that the proposed system operated correctly and met its intended objectives.

Regular inspection and maintenance were essential for the effective functioning of the waste segregation system. Routine checks ensured that sensors, conveyor belts, and servo motors operated correctly and remained clean, preserving system efficiency and reliability. Proper maintenance also contributed to the system's longevity and ensured that all components functioned optimally. Daily inspections and user training enhanced system performance and promoted responsible operation. Furthermore,

maintaining high-quality parts and proper handling provided by users contributed to the accuracy and reliability of the waste segregation system. Overall, these procedures ensured that the system operated smoothly, delivered consistent performance, and maximized user benefits.

### ***System Evaluation and Testing***

This section presents the overall results of the survey conducted with 30 respondents. The questionnaire assessed the system based on four key aspects: correctness, speed, functionality, and operational ability.

**Table 5**

*Weighted mean distribution of the criteria for the developed system*

<b>Criteria</b>	<b>Weighted Mean</b>	<b>Remarks</b>
Correctness of waste Segregation	3.80	Strongly Agree
Speed	3.18	Agree
Functionality	3.82	Strongly Agree
Operation Ability	3.80	Strongly Agree
Average	3.65	Strongly Agree

Table 5 presents the evaluation results of the system, which achieved an overall average weighted mean of 3.65. This indicates that the respondents generally rated the system positively in terms of correctness, speed, functionality, and operational ability, demonstrating that the system was capable of performing the required tasks.

In terms of correctness, the system performed appropriately and accurately, with waste segregation carried out flawlessly. The average weighted mean for correctness was 3.80, corresponding to the remark “Strongly Agree,” indicating that respondents were satisfied with the system’s performance.

Regarding speed, the system functioned with proper acceleration, although some observations noted minor timing inconsistencies. The average weighted mean for speed was 3.18, with the remark “Agree,” showing that the system performed satisfactorily in this aspect.

The system was highly functional and beneficial to users, serving as an effective tool for proper waste segregation. The average weighted mean for functionality was 3.82, with the remark “Strongly Agree,” reflecting its positive impact.

Finally, the system operated accurately and reliably, providing users with a clear understanding of proper operational procedures. The average weighted mean for operational ability was 3.80, with the remark “Strongly Agree,” confirming that the system performed its tasks efficiently and effectively.

The researchers employed an overall system changeover scheme to implement the prototype effectively. Although the prototype functioned properly in waste segregation, alternative methods were considered for situations where certain waste materials could not be easily detected. This contingency ensured that the system could maintain accuracy and efficiency under varying conditions.

*Economic feasibility.* Economic feasibility was evaluated by examining the system’s projected costs relative to its benefits. The assessment of advantages and disadvantages provided insight into the system’s cost-effectiveness and overall value. This analysis allowed for a comparison of the system’s performance and benefits against its implementation costs.

*Technological feasibility.* Upon project completion, feedback indicated that the materials used were cost-effective and well-designed, making the system accessible and useful to many people. The evaluation

highlighted areas where materials could be further improved to enhance the system's uniqueness and overall performance.

*Operational feasibility.* The developed system proved to be operationally feasible. It was user-friendly, allowing users to operate it effectively and with satisfaction. Evaluations and surveys confirmed that users could easily understand the system's functions, and proper demonstrations ensured that clients were able to use the system correctly. The findings demonstrated that the system could be successfully deployed and maintained in real-world conditions.

## **Conclusion**

Proper waste segregation is essential for maintaining cleanliness and environmental health, and the developed waste segregation system using Arduino Uno proved to be an effective solution for this purpose. The system successfully integrated hardware and software components, including sensors, a conveyor belt, and a real-time alert system, to detect and properly categorize waste materials. Testing results showed that the prototype performed efficiently in terms of correctness, speed, functionality, and operational ability, demonstrating its reliability and user-friendliness. The system not only facilitated proper waste management but also promoted awareness and environmental responsibility among users. Its practical design, cost-effective materials, and ease of operation ensure that it can be widely adopted in schools and other communities, offering a sustainable and impactful approach to addressing solid waste challenges.

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# Automatic Grading and Sorting Machine for Eggplant Using Machine Learning

*Erika R. Manalo, Monica M. Magnaye, Angela V. Labuguen & Merwin A. Carandang*

One of the leading crops in the Philippines is the eggplant, locally known as "talong." On average, eggplant is cultivated on 21,225 hectares annually, producing approximately 9.95 tons per hectare, which is about half of the Asian average (ISAAA, 2023). Eggplants typically have a long, slender, cylindrical shape that can be straight or slightly curved. Botanically classified under the Solanaceae family, which also includes peppers, tomatoes, and potatoes, eggplants vary in color from white to dark purple (Taher et al., 2017). Although commonly regarded as a vegetable, eggplants are technically a fruit because they develop from flowering plants and contain seeds.

Fronza (2022) studied vegetable production in Nueva Ecija, Philippines, and found that cultural practices and input requirements significantly affect vegetable output. Farmers indicated that higher production volumes result in increased profits, making grading and sorting a critical step in maximizing returns. Similarly, In Janagdong II, Sariaya, Quezon, Philippines, eggplants and other vegetables are primarily graded and sorted manually, which introduces challenges such as subjective

assessment, fatigue, inconsistency, and decreased productivity. Because eggplants are relatively easy to cultivate, many farmers prioritize planting them, making an effective grading and sorting system particularly valuable.

To address these challenges, this study developed an automatic grading and sorting machine for eggplant using machine learning. The system focuses exclusively on eggplants and utilizes image processing to classify vegetables into three categories: good, semi-good, and defective, based on size, shape, and appearance. Sensors are employed to guide each eggplant to its appropriate bin, ensuring accurate segregation. The system is designed for convenience and efficiency: eggplants are placed on a conveyor belt, pass through the camera's field of view, and undergo image processing to extract data for quality assessment. The ultimate goal is to sort eggplants continuously and reliably into their respective grade-level containers.

The benefits of automated sorting are significant when compared to manual methods. Automated systems can handle large volumes of vegetables in shorter periods, increasing processing speed and reducing delays caused by fatigue and human error. They also provide consistent and objective grading based on predetermined criteria, whereas manual sorting may vary due to individual subjectivity. Moreover, automated systems can incorporate multiple sorting criteria simultaneously, whereas manual sorting is limited to basic assessments. From a labor and cost perspective, automation reduces the need for a large workforce, resulting in operational savings and improved reliability. Additionally, automated sorting systems can collect and analyze data to monitor performance and continuously improve efficiency, an advantage not readily available with manual methods.

This study focuses on the design and development of an eggplant

automatic grading and sorting machine using machine learning. By implementing this system, labor costs can be reduced, productivity and accuracy can be increased, and the overall efficiency of vegetable grading and sorting can be enhanced, particularly in agricultural operations.

## **Theoretical Framework**

### ***Automation and Artificial Intelligence in Vegetable Sorting***

Mishra et al. (2024) highlighted that traditional manual sorting of vegetables is a labor-intensive, time-consuming, and subjective process. Inconsistencies arise because different workers apply varied criteria, which affects the quality grading and market value of the produce. Automation, supported by artificial intelligence (AI), addresses these challenges by standardizing grading procedures. By integrating Raspberry Pi and Arduino microcontrollers with sensors and computer vision, the system can detect, classify, and segregate eggplants efficiently. This reduces human fatigue and improves productivity, enabling continuous operation without breaks or decline in performance (Valtonen et al., 2025).

AI-assisted automation provides significant benefits for small and medium-scale farmers (Kumari et al., 2025; Hoque & Padhiary, 2024; Gupta & Kumar Pal, 2025; Bazargani & Deemyad, 2024; Assimakopoulos et al., 2024; Song et al., 2025; Rathor et al., 2024). It ensures that grading is uniform and objective, which can increase customer satisfaction and potentially improve profits. By using cost-effective components like Raspberry Pi and Arduino, the system becomes accessible to farmers with limited resources. The successful integration of AI and automation demonstrates that modern technology can significantly enhance traditional agricultural practices, reducing labor costs while maintaining high

standards of accuracy and reliability (Mishra et al., 2024).

### ***Image Processing and Object Recognition Techniques***

Loresco and Dadios (2018) focused on improving the accuracy of vegetable detection using image processing and object recognition. Convolutional Neural Networks (CNNs) were applied to extract essential features from eggplants, while fuzzy logic handled uncertainties such as variations in shape, orientation, and lighting. This combination allowed the system to classify vegetables accurately into grades such as Good, Semi-Good, or Defective. Keras and MATLAB provided frameworks for model training and optimization, ensuring the detection algorithms were reliable and precise. The study demonstrated that the integration of AI and image processing could overcome the limitations of manual inspection by providing objective, repeatable results.

Object recognition models enable the system to handle real-world complexities, such as overlapping vegetables or inconsistent appearances (Khan et al., 2025; Xiao et al., 2023; Jamali et al., 2025; Edozie et al., 2025). By incorporating these advanced algorithms, the sorting machine can assess multiple quality parameters simultaneously, ensuring accurate grading under diverse conditions. This capability is crucial for commercial applications where consistency and reliability are necessary for maintaining product quality and market competitiveness. The use of image processing and object recognition in agricultural automation illustrates the potential of AI to enhance operational efficiency and reduce human errors (Loresco & Dadios, 2018; Jiang et al., 2025; Song et al., 2025; Sow et al., 2024; Bhat et al., 2025).

### ***Deep Learning and Crop Detection***

Zheng et al. (2018) emphasized the role of deep learning in improving crop detection and quality assessment. Using a large dataset of 1,600 images, the system could identify multiple vegetables, including eggplants, cucumbers, tomatoes, and peppers, based on size, color, and surface defects. Deep learning techniques such as image segmentation and keypoint detection allowed precise localization and analysis of each vegetable, enabling accurate classification into quality grades. This approach ensures that even subtle differences in appearance are captured, which manual inspection might overlook.

Furthermore, the deep learning framework enables continuous improvement through model training with new data (Prapas et al., 2021). As the system processes more images, it refines its detection capabilities, increasing accuracy and reducing misclassification. This scalability makes the system suitable for commercial agricultural operations with large volumes of produce (Totin et al., 2020). By leveraging deep learning, the system ensures high standards of quality assessment, improves sorting efficiency, and contributes to more consistent product grading.

### ***Integration of Software and Hardware Components***

The successful operation of the automated eggplant grading system relies on the integration of software and hardware components. Python and TensorFlow handle image processing and deep learning tasks, while OpenCV manages real-time camera feeds. Thonny IDE provides a platform for coding and debugging on the Raspberry Pi, ensuring smooth execution of algorithms. Arduino, programmed using C++ through Arduino IDE, manages physical tasks such as motor rotation, sensor detection, and bin sorting. Together, these components enable the system to detect, classify,

and physically sort vegetables accurately and efficiently.

This integration ensures that the hardware and software communicate seamlessly, allowing the system to respond promptly to detected inputs. The Arduino executes commands for actuators, such as servo motors, based on image recognition results from the Raspberry Pi, enabling automated sorting. The combination of reliable software algorithms with responsive hardware ensures consistent operation, minimizes downtime, and enhances overall system reliability. This comprehensive integration highlights the importance of synchronizing computational and mechanical components in agricultural automation for optimal performance (Mishra et al., 2024; Loresco & Dadios, 2018).

### ***Implications for Agricultural Efficiency and Productivity***

Automated eggplant sorting offers significant improvements in agricultural productivity compared to manual methods. Manual sorting is slow, inconsistent, and requires a substantial workforce, which increases labor costs. Automated systems can process larger volumes of produce in a shorter time, maintaining consistent quality and minimizing human error. By providing objective and standardized grading, automated systems can improve market competitiveness and profitability for farmers.

Additionally, automated sorting aligns with the principles of precision agriculture, which seeks to optimize efficiency and resource utilization. Data collected during sorting, such as size, color, and defect rates, can be analyzed to inform future cultivation practices, storage decisions, and supply chain management. This enables smarter, data-driven decision-making, enhancing operational efficiency and reducing waste. Ultimately, AI-based vegetable sorting systems demonstrate the potential to transform agricultural practices, providing reliable, efficient, and cost-

effective solutions for modern farming (Mishra et al., 2024; Loresco et al., 2019).

## **Research Framework**

The data collected in this study served as the foundation for developing and evaluating the automatic eggplant grading and sorting system.

### ***Data***

Vegetable information was gathered, which includes the names and types of vegetables to be sorted. This ensures that the system can identify and classify each vegetable accurately. The categorized characteristics of the vegetables, size, color, and appearance, were documented. These characteristics are essential for the CNN algorithm, enabling the machine to accurately detect and classify vegetables based on predefined quality parameters. Finally, grading information was recorded, representing the classification outcomes after the sorting process: good, semi-good, and reject. This information provides feedback on the system's effectiveness in maintaining quality standards during sorting.

### ***Design***

The study employed a developmental research design to explore and develop innovative features for the automated sorting system. The primary goal of the study was to enhance the accuracy and efficiency of vegetable grading while ensuring that quality standards are maintained. This approach allowed the developers to observe, analyze, and refine the system iteratively, providing practical solutions tailored to the needs of local

farmers.

### ***Respondents***

The respondents consisted of farmers from Brgy. Janagdong 2 in Sariaya, Quezon, who are actively engaged in vegetable cultivation, particularly eggplants. To ensure a representative evaluation, the study used stratified sampling, categorizing respondents based on relevant characteristics to maintain diversity in feedback. Since the barangay has a total of 35 farmers, all of them were included in the study to provide comprehensive insights into the practical performance and usability of the proposed system.

### ***Instrument***

Data collection involved observations and interviews with randomly selected farmers to gather qualitative insights on current manual sorting practices, challenges, and expectations. Additionally, the system evaluation was conducted using survey questionnaires, designed based on the ISO 25010 software quality standard, with five questions per criterion. The questionnaire addressed key aspects of the system, including functionality, efficiency, reliability, and usability, ensuring that the evaluation captured both technical performance and user satisfaction.

### ***Statistical Analysis***

The researchers analyzed the survey responses using the 5-point Likert scale and average weighted mean (AWM). The ISO 25010 criteria guided the analysis, covering functional suitability, performance efficiency, compatibility, usability, reliability, security, maintainability, and portability. The Likert scale allowed respondents to indicate their level of

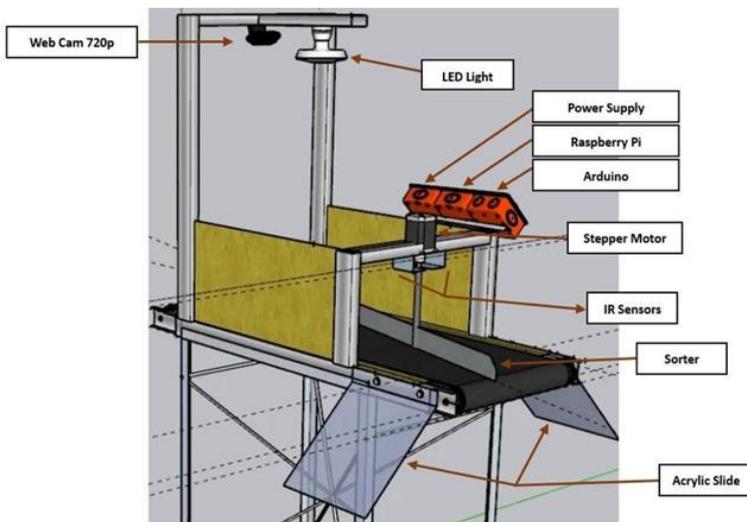
agreement with each statement regarding the system’s performance, from “strongly disagree” to “strongly agree.” This method provided quantitative insights into user satisfaction and highlighted areas for improvement in system design and operation. By applying AWM, the study was able to determine the overall effectiveness and acceptance of the proposed automatic sorting machine among the farmers.

### ***Experimental Design***

Figure 1 illustrates the initial design of the sorting machine as visualized by the proponents.

**Figure 1**

*Sorting machine sample design*



The design concept was developed after reviewing various sources, which served as the foundation for the developers. However, the concept remains flexible and open to modifications based on feedback from farmers or recommendations from industry professionals. The prototype is designed

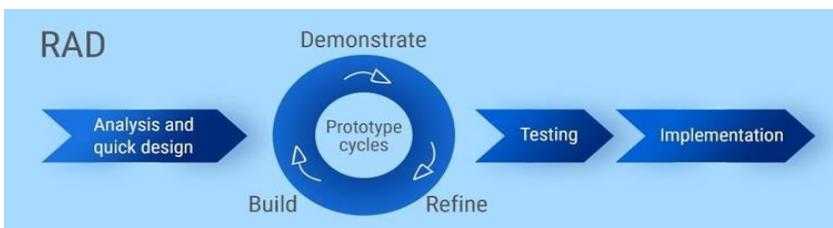
at waist height to ensure that farmers can easily access and operate the machine without bending, thereby reducing the risk of back strain. Additionally, it incorporates a sideways slide mechanism to control the momentum of falling vegetables, preventing damage during the sorting process and ensuring that the produce maintains its quality.

### ***Procedures of the Different Phases***

According to Puzhevich (2020), the Rapid Application Development (RAD) model is a variant of Agile methodology that emphasizes rapid prototype development and minimizes rigid planning. This approach allows developers to implement updates based on user feedback rather than adhering to a strict schedule. The RAD model focuses on active development activities with the goal of quickly creating a functional system.

**Figure 2**

*Rapid Application Development*



*Analysis and quick design.* In the initial phase, research and preliminary drafts for the system design were conducted. The developers carefully assessed how to apply the CNN algorithm to recognize vegetables' color, size, and quality. The entire design and process of the sorting machine were systematically outlined, ensuring that each step aligned with the desired functionality before finalizing the design.

*Build, Demonstrate & Refine.* During this phase, the prototype was developed and constructed according to the finalized design. Materials were secured, and the CNN algorithm was implemented to enable the machine to accurately identify the color, size, and quality of vegetables. Each module of the system was tested individually to verify proper functioning, and necessary modifications were made to address any deficiencies.

*Testing.* The testing phase involved rigorous debugging and evaluation to confirm that the machine met its intended purpose. The developers examined all system components and processes to ensure accuracy and reliability, preparing the prototype for deployment with minimal errors.

*Implementation.* In the final phase, the proposed system became fully operational and ready for routine use. A maintenance plan was established to guide users in resolving potential issues over time, ensuring sustained functionality and efficiency of the sorting machine.

## **Technical Framework**

This section presents the overall design of the project and evaluates its effectiveness.

### ***Materials***

The following materials were utilized in the development of the prototype.

### ***Software***

Table 1 presents the software programs utilized in developing the machine. These programs are essential for the successful functioning of the

system, particularly for image processing, model training, and hardware communication.

**Table 1**

*Software specifications*

<b>Software</b>	<b>Description</b>
Python	Python is a popular, high-level and a general-purpose programming language. It is the language used to program the Image Processing feature.
C++	An object-oriented programming language that provides clear structure to programs and allows code to be reused. This language is used to program the Arduino in order to interact with the machine components.
Arduino IDE	Arduino IDE contains a text editor for writing code, a message area, a text console, a toolbar with buttons for common functions and a series of menus. It connects to the Arduino hardware to upload programs and communicate with them.
Thonny	Thonny is an integrated development environment for Python that is designed for beginners. It is where the Image Processing is coded and debugged.
OpenCV	OpenCV (Open Source Computer Vision Library) is an open source computer vision and machine learning software library. It is used for camera logic.
Tensorflow	TensorFlow is a rich system for managing all aspects of a machine learning system. It is used for deep learning of image processing.

Python was primarily used for programming the image processing features via the Thonny IDE. OpenCV handled the camera feed and processed images of the vegetables. TensorFlow was employed to train the system's CNN model for accurate vegetable recognition. C++ was used to program the Arduino microcontrollers, and Arduino IDE facilitated the

uploading of programs to the Arduino hardware, enabling communication with the prototype's components.

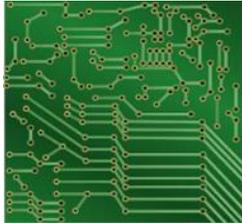
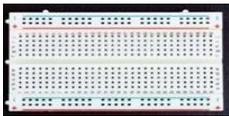
## Hardware

Table 2 presents the hardware components required for the development of the machine. Each component plays a specific role in ensuring the proper functioning of the system and facilitating the grading and sorting process.

**Table 2**

*Hardware specifications*

Hardware	Description	Specification
 <p><b>Raspberry Pi 4</b></p>	<p>Raspberry Pi is a credit-card-sized minicomputer that turns a monitor, TV, mouse, or keyboard into a full-fledged PC</p>	<p>SDRAM: 1GB, 2GB, 4GB, or 8GB LPDDR4-3200 (depending on model)            IEEE 802.11ac wireless at 2.4 and GHz, Bluetooth 5.0, and BLE            Ethernet Gigabit            Two USB 3.0 ports and two USB 2.0 ports.            40-pin GPIO header for Raspberry Pi (fully backwards compatible with previous boards)            There are two micro-HDMI ports</p>
 <p><b>Arduino Mega 2560</b></p>	<p>This software is used for writing, compiling, and uploading the code into the Arduino board. This unit comes with a USB interface so a USB cable can be used to connect the device with the computer through which you can transfer sketch (Arduino program is called a sketch) to the board.</p>	<p>The ATmega2560 is a Microcontroller            The operating voltage of this microcontroller is 5volts            The recommended Input Voltage will range from 7volts to 12volts            The input voltage will range from 6volts to 20volts            The digital input/output pins are 54 where 15 of these pins will supply PWM o/p.            Analog Input Pins are 16            DC Current for each input/output pin is 40 mA            DC Current used for 3.3V Pin is 50 mA</p>

Hardware	Description	Specification
		Flash Memory like 256 KB where 8 KB of flash memory is (SRAM) is 8 KB (EEPROM) is 4 KB
<p><b>LED Lights</b></p> 	<p>A light-emitting diode is a semiconductor device that emits light when current flows through it. Electrons in the semiconductor recombine with electron holes, releasing energy in the form of photons.</p>	<p>Long Life: LEDs can last over 100,000 hours (10+ years) if used at rated specifications No annoying flicker like from fluorescent lamps LEDs are impervious to heat, cold, shock and vibration LEDs do not contain breakable glass Solid-State, shock and vibration resistant Extremely fast turn On/Off times Low power consumption puts less load on the electrical systems increasing battery life</p>
<p><b>Circuit Board</b></p> 	<p>A printed circuit board (PCB; also printed wiring board or PWB) is a medium used to connect electronic components to one another in a controlled manner.</p>	<p>8 x 12cm (3.2 x 4.7") outside dimensions 1.6mm (0.64") thickness FR-4 double-sided construction with green solder mask Holes on 2.54mm (0.1") centers in grid pattern with grid numbered/lettered in copper on two edges of the board. Holes are plated through with same pad pattern on both sides of the board. Edge solder pads are on 2.54mm (0.1") centers HASL (SnPb) plating over copper for best solderability</p>
<p><b>Bread Board</b></p> 	<p>A breadboard, solderless breadboard, or proto-board is a construction base used to build semipermanent prototypes of electronic circuits. Unlike a perfboard or stripboard, breadboards do not require soldering or destruction of tracks and are hence reusable.</p>	<p>Distribution Strips are two Wire Size is 21 to 26 AWG wire Tie Points are two hundred Withstanding Voltage is 1,000V AC Tie points within IC are 630 Insulation Resistance is DC500V or 500MΩ Dimension is 6.5*4.4*0.3 inch Rating is 5Amps ABS plastic through color legend ABS heat Distortion Temperature</p>

Hardware	Description	Specification
 <p><b>RPi 4 Power Supply</b></p>	<p>The Raspberry Pi 15W USB-C Power Supply is designed to power Raspberry Pi 4 and Raspberry Pi 400 computers</p>	<p>is 183° F (84° C) Hole or Pitch Style is 2.54mm</p> <p>USB-C power supply specially designed and tested for the Raspberry Pi 4 Includes noise filter for added stability 18 AWG Cable UL Listed 5ft Cable Length</p>
 <p><b>Servo Motor</b></p>	<p>A servomotor is a rotary actuator or linear actuator that allows for precise control of angular or linear position, velocity, and acceleration. It consists of a suitable motor coupled to a sensor for position feedback.</p>	<p>Weight: 55g Dimension: 39.5mm x 20.5mm x 40.7mm Stall Torque: 9.4kg/cm (4.8v); 11kg/cm (6v) Op. speed: 0.20sec/60degree (4.8v); 0.16sec/60degree (6.0v) Operating voltage: 4.8~ 6.6v Gear Type: Metal gear Temperature range: 0- 55deg Servo wire length: 30cm Rotation angle: 180 degree</p>
 <p><b>Stepper Motor</b></p>	<p>A stepper motor, also known as step motor or stepping motor, is a brushless DC electric motor that divides a full rotation into a number of equal steps.</p>	<p>Size: 42.3 mm square × 48 mm, not including the shaft (NEMA 17) Weight: 350g Shaft diameter: 5 mm “D” Steps per revolution: 200 Current rating: 1.2 A per coil Voltage rating: 4 V Resistance: 3.3 Ω per coil Holding torque: 3.2 kg-cm (44 ozin) Inductance: 2.8 mH per coil Lead length: 30 cm (12”) Output shaft supported by two ball bearings</p>
 <p><b>IR Sensor</b></p>	<p>An infrared detector is a detector that reacts to infrared radiation.</p>	<p>The operating voltage is 5VDC I/O pins – 3.3V &amp; 5V Mounting hole The range is up to 20 centimeters The supply current is 20mA The range of sensing is adjustable Fixed ambient light sensor</p>

Hardware	Description	Specification
<p><b>Ultrasonic Sensor</b></p> 	<p>Ultrasonic Sensors measure the distance to the target by measuring the time between the emission and reception.</p>	<p>Power Supply: 3.3V – 5V. Operating Current: 8mA. Working Frequency: 40Hz. Ranging Distance: 3cm – 350cm/3.5m. Resolution: 1 cm. Measuring Angle: 15 degree. Trigger Input Pulse width: 10uS TTL. Dimension: 50mm x 25mm x 16mm</p>
<p><b>Buzzer</b></p> 	<p>A buzzer or beeper is an audio signaling device, which may be mechanical, electromechanical, or piezoelectric.</p>	<p>12V Active Buzzer Alarm Magnetic Long Continuous Beep Tone</p>
<p><b>LCD</b></p> 	<p>LCD (Liquid Crystal Display) is a type of flat panel display which uses liquid crystals in its primary form of operation.</p>	<p>20x4 2004 LCD Display with I2C Adapter Module for Arduino Text Color: White Back light: Blue LED Backlight Dimensions: 98mm x 60mm x 20mm</p>
<p><b>Jumper Wires</b></p> 	<p>A jump wire is an electrical wire, or group of them in a cable, with a connector or pin at each end, which is normally used to interconnect the components of a breadboard or other prototype without soldering.</p>	<p>Length: 20cm. Pitch: 2.54mm. Female to female. 3pin (2.54mm) to 3pin (2.54mm) header. Withstand voltage: 300V DC Min. Insulation resistance: <math>\geq 5M\Omega</math> Min. Contact resistance: <math>\leq 5\Omega</math> Max.s</p>
<p><b>Container</b></p> 	<p>Any receptacle or enclosure for holding a product</p>	<p>Material: Plastic Size: 32cm x 25cm</p>

The Raspberry Pi serves as the central processing unit of the system, where the image processing module is programmed and executed. The Arduino microcontroller manages the interaction and coordination between other hardware components. LED lights act as indicators to display the

machine’s operational status. The prototype frame and breadboard are used for connecting and testing the electrical components of the machine.

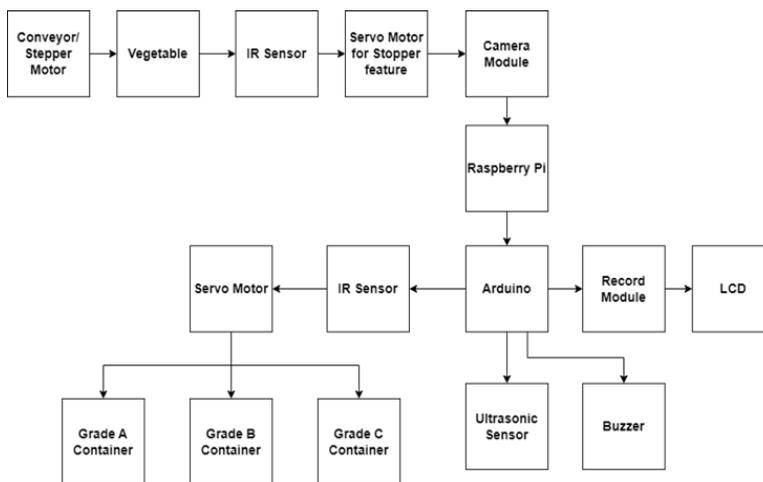
The servo motor controls the stopper mechanism of the prototype, while the stepper motor drives the conveyor system and handles the actual sorting of vegetables. The IR sensor detects the presence of vegetables on the conveyor, and the ultrasonic sensor, along with the buzzer, signals when the container is full. The LCD display provides notifications and records of the sorted vegetables, allowing the user to monitor system performance. Jumper wires connect all electrical components, ensuring proper transmission of signals and power. Finally, the container serves as the receptacle for the sorted vegetables, completing the sorting process.

### Modeling

Figure 3 illustrates the relationships between the devices and materials used in the proposed system in a simplified manner.

**Figure 3**

*Block diagram*



When the machine is powered on, the conveyor belt, driven by the stepper motor, begins operating. As a vegetable is inserted, it reaches the first IR sensor, which detects the vegetable and sends a signal to the first servo motor to activate the stopper feature. The camera module then scans the vegetable, and the CNN algorithm, programmed on the Raspberry Pi, processes the image to determine the vegetable's category. The Raspberry Pi sends this information to the Arduino, which controls the sorting mechanism. The vegetable then moves to the second IR sensor, which signals the stepper motor to guide it into the appropriate container. Simultaneously, the Arduino updates the count of sorted vegetables, stores the information in the records module, and displays the output on the LCD. This process is repeated for each subsequent batch of vegetables inserted into the machine.

**Figure 4**  
*Circuit diagram of the prototype*

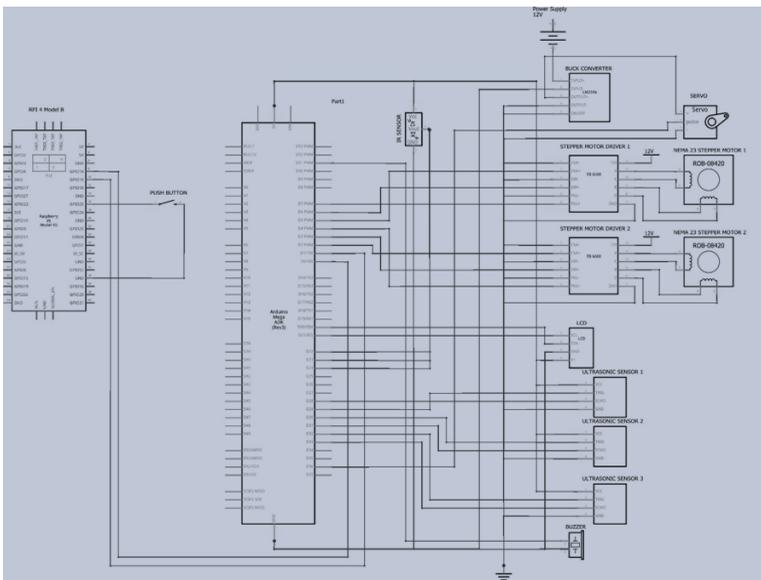
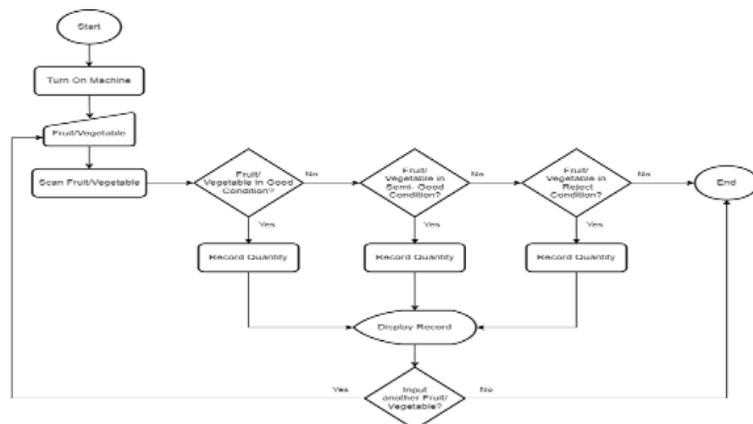


Figure 4 illustrates the overall architecture and circuit layout of the system, designed for easy installation and use. The diagram displays three infrared (IR) sensors, one servo motor, three ultrasonic sensors, two stepper motors, and an LCD connected to the board. The Arduino functions as the processor of the prototype, while the Raspberry Pi, which connects to the camera module, handles image processing. Serving as the central unit, the Raspberry Pi sends commands to the Arduino, which executes the sorting operations. The IR sensors detect vegetables and control the stopper mechanism, coordinating the sorter's movement, while the servo motor lifts and lowers the stopper. Obstacle detection is achieved through the ultrasonic sensors, which identify the vegetables and indicate when the container is full. The stepper motors control the conveyor belt and the movement of the sorter, ensuring precise handling of the vegetables. Meanwhile, the LCD module provides notifications, displaying error messages and the total count of sorted vegetables over a given period. By integrating these components effectively, the grading and sorting machine fulfills all functional requirements.

### System Design

Figure 5 illustrates the system flow of the proposed sorting machine.

**Figure 5**  
Flow chart



The process begins when the user turns on the machine and manually inputs a vegetable. The machine then scans the vegetable to determine its category. If the vegetable does not match any predefined categories, it will bypass the sorting process and continue to the next item. However, if the vegetable belongs to a recognized category, the system records the quantity of each sorted vegetable. After recording, the machine displays the updated record on the interface. The sorting process continues in a loop as long as the user continues to input vegetables; otherwise, the process concludes.

**Figure 6**

*System architecture of the prototype*

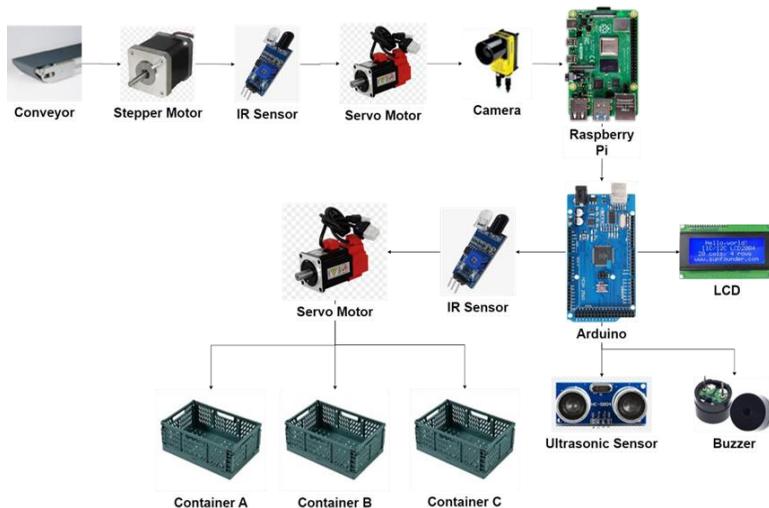


Figure 6 depicts the system architecture, illustrating the connections and interactions of the key components in the sorting machine. The process begins with the conveyor, powered by the stepper motor, which rotates to move the vegetable along the sorting path. When a vegetable is inserted, it passes the first IR sensor, which detects the item and sends a signal to the first servo motor to activate the stopper feature, ensuring the vegetable is

properly positioned for scanning. The camera then captures an image of the vegetable, and the Raspberry Pi, programmed with the CNN algorithm, determines the vegetable's category and accuracy based on its characteristics.

Meanwhile, the Arduino manages the remaining hardware components, ensuring proper coordination between motors, sensors, and indicators. The ultrasonic sensor measures the distance between the vegetable and the container, triggering the buzzer if the container is near capacity to alert the user. Finally, the second IR sensor confirms the vegetable is in the sorting area, signaling the stepper motor to move the vegetable into its designated category. This architecture ensures precise, automated sorting while maintaining real-time monitoring and user notifications.

**Figure 7**

*System structure of the prototype*

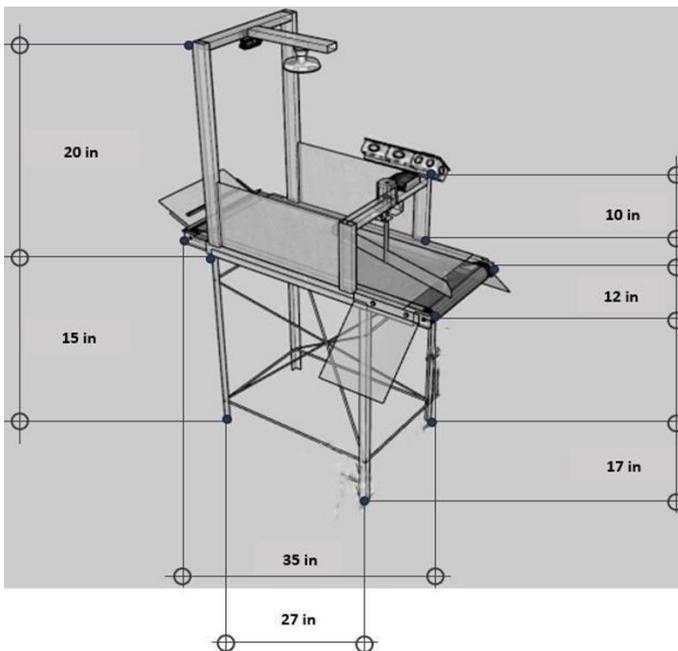


Figure 7 illustrates the system structure of the machine. Each component of the machine is clearly labeled to provide a better understanding of its functions and interactions. The prototype is designed at waist height to allow users to access the machine comfortably, eliminating the need to bend over while sorting and thereby reducing the risk of back strain. Additionally, the width of the sorting machine is adjustable based on the size of the vegetables being processed, ensuring efficient handling and smooth operation during the grading and sorting process.

**Figure 8**

*Prototype's storyboard*

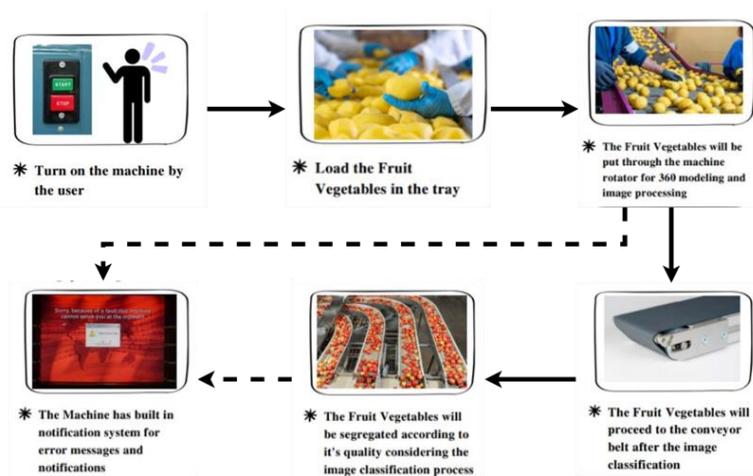


Figure 8 illustrates the step-by-step process of the proposed sorting machine, detailing the workflow from initial operation to the built-in notification system. The solid lines represent the standard flow of operations, showing how each stage progresses sequentially during the grading and sorting process. In contrast, the broken lines indicate alternative paths that occur when an error is detected, triggering the notification system

to alert the user. This design ensures that the machine operates efficiently while providing immediate feedback to address issues, maintaining accuracy and minimizing disruptions in the sorting process.

**Figure 9**

*Data flow diagram level 0*

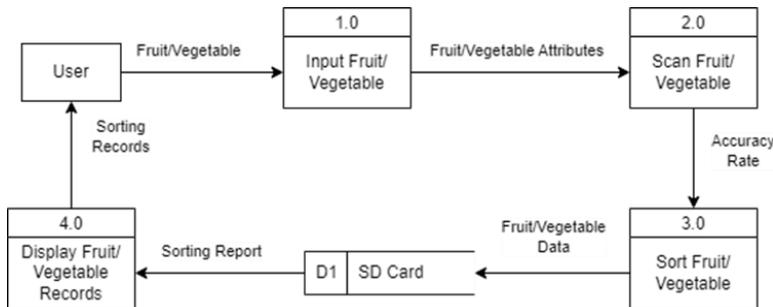


Figure 9 presents the processes and flow of data within the proposed sorting machine. Initially, the user inputs a specific vegetable into the machine, which then scans the vegetable’s attributes, such as size, color, and quality. In process 2.0, the system evaluates the scanned data and determines the vegetable’s accuracy rating, assigning it to the appropriate category for sorting. Following the sorting decision, the system records the data onto the SD Card for storage and future reference. Finally, the sorting results are displayed to the user, providing a clear summary of the processed vegetables and ensuring transparency and traceability in the sorting operation.

**Figure 10**

*Data flow diagram level 1*

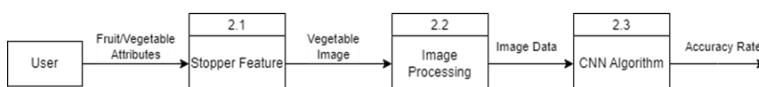


Figure 10 provides a detailed explanation of the sub process in process 2.0, specifically focusing on the scanning procedure. When the user inputs a particular vegetable onto the conveyor, the stopper feature acts as a temporary queue to position the vegetable accurately for image capturing. The camera then captures the vegetable's image, which is subsequently processed through the CNN algorithm. This algorithm analyzes the vegetable's attributes, such as size, color, and quality, to determine its category. The captured data are used to train the CNN model, improving the system's accuracy in grading and sorting the vegetables for future operations.

**Figure 11**

*Entity relationship diagram*

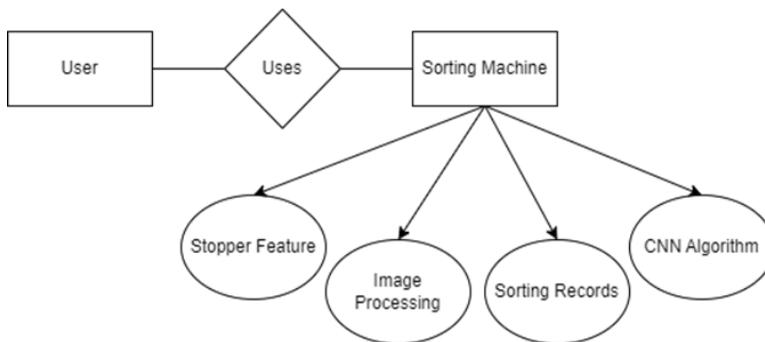


Figure 11 illustrates the functional relationship between the user and the sorting machine, highlighting how they interact during the sorting process. When the User inputs a particular vegetable into the machine, the vegetable is first detected by the system, triggering the stopper feature. This feature temporarily holds the vegetable in place and signals the start of the image processing procedure. The captured image data are then processed through the CNN algorithm, which analyzes the vegetable's attributes to ensure accurate grading and sorting. Once the vegetable is categorized, the

system automatically records the sorted item, and the Raspberry Pi communicates the necessary data to the Arduino, which executes the physical sorting actions. This coordinated workflow ensures efficiency, accuracy, and seamless interaction between the User and the machine.

**Figure 12**

*System output*



Figure 12 illustrates the output of the developed system, showing that the prototype includes a notification system that displays processes, errors, records, and the AI's confidence percentage in grading the vegetables. The system's data are stored on an SD card, making them easily accessible and viewable through the LCD monitor during the sorting process. The design was developed with the user in mind, ensuring that the system's functions and processes are easy to understand and operate.

After installing the essential software applications, the training phase of the system followed a step-by-step procedure. The first step involved gathering images to be used for training and compiling them into a single directory. Following this, the developers proceeded with the coding

phase to implement the CNN algorithm and prepare the system for accurate detection and classification.

**Figure 13**

*Validation and accuracy graph*

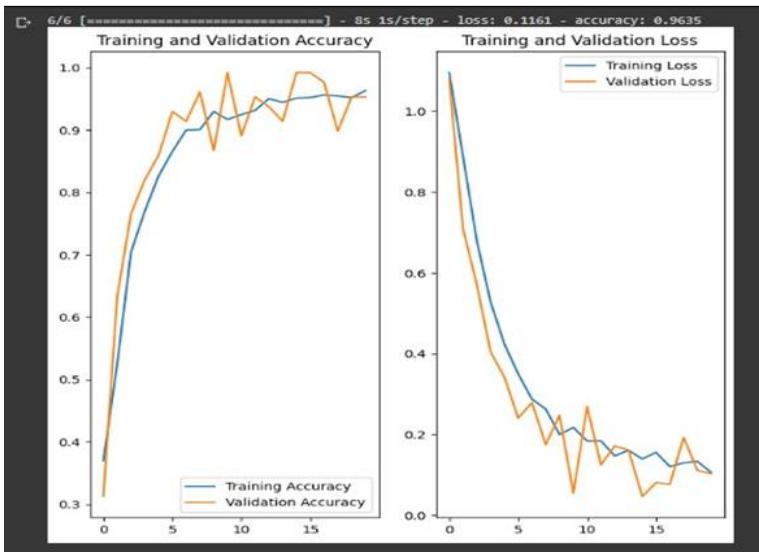


Figure 13 presents the graphical representation of validation and accuracy during training. To determine whether the model is effectively learning and generalizing the data, the validation loss should ideally be higher than the training loss. Validation accuracy helps monitor the model's generalization ability and detect overfitting or underfitting. As the model learns, validation metrics typically improve; however, if the model begins to overfit the training data, these metrics may stop improving or even start to decline.

Accuracy is a common evaluation metric used in classification tasks and indicates the percentage of correctly classified samples. It is essential to monitor accuracy on both the training and validation sets. If the model performs well only on the training data but fails to generalize to the validation data, the validation accuracy may plateau or decrease. This

suggests that the model is overfitting, memorizing the training data rather than learning the underlying patterns. A significant gap between training and validation accuracy is a strong indicator of overfitting.

The validation and accuracy graphs serve as valuable visual tools for understanding and analyzing the model's performance throughout the training process. They assist in making informed decisions about model tuning, detecting overfitting, and evaluating the model's generalization capability.

**Figure 14**

*Accuracy test*

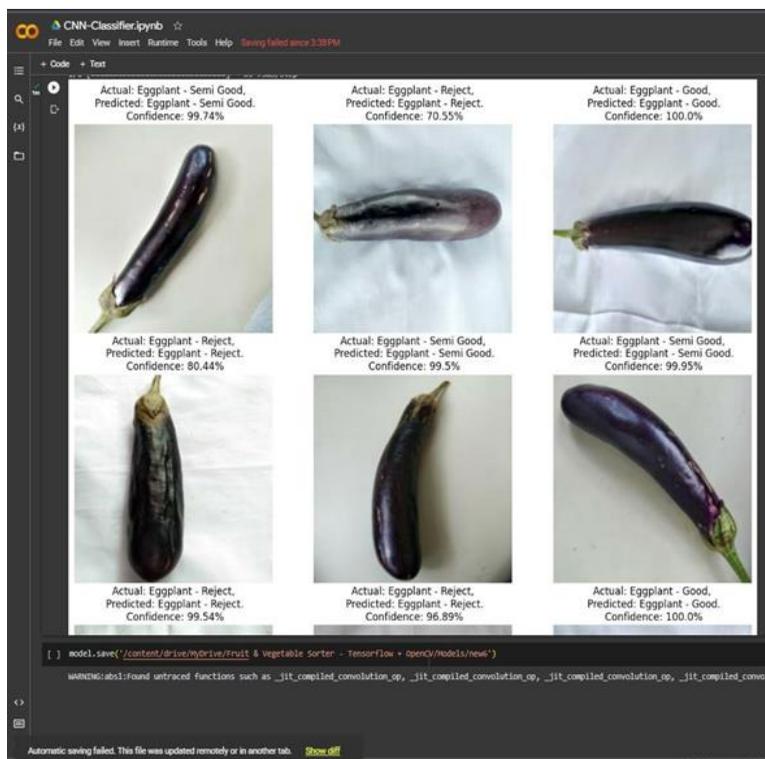


Figure 14 shows the model's confidence percentage. This phase demonstrates how the model is tested using unseen data to determine the

effectiveness of the training process. The actual image displays the real appearance of the vegetable, the Predicted Image shows the model's prediction regarding the vegetable's grade, and the confidence percentage indicates how certain the model is about its prediction.

### ***Evaluation of the System***

This section shows the results of the survey evaluation. Following ISO25010, the criteria for evaluation are functional suitability, performance efficiency, compatibility, usability, reliability, security, maintainability, and portability. Each criterion has five questions that the respondents rated.

Table 3 presents the materials, tools, and equipment used in the development of the prototype. It includes the quantity and respective prices of each item, along with the total cost of producing the system. The researchers conducted a cost-benefit analysis to evaluate the feasibility of implementing the machine.

**Table 3**

*Cost benefit analysis of the prototype*

<b>Materials, Tools &amp; Equipment</b>	<b>Quantity</b>	<b>Unit Price</b>	<b>Total Cost</b>
Raspberry Pi 4B Kit	1	12,000	12,000
-Power Supply	1		
-SD Card	1		
-SD Card Reader	1		
Arduino Mega 2560	1	1,117	1,117
LM 2596 Buck Converter	1	48	48
Buzzer	1	49.75	49.75
DIY Wires	2	224.75	449.50
Servo	1	630	630
Stepper Motor	2	2,200	4,400
Stepper Driver TB 6600	2	2,600	5,200
Web Cam 720P	1	900	900
IR Sensor	2	29	58
Bearing	4	90	360
1 x 2 Tubular	1	219	219
Angle Bar 1Meter	2	80	160
Round Bar 8MMx1/2M	7	35	259

<b>Materials, Tools &amp; Equipment</b>	<b>Quantity</b>	<b>Unit Price</b>	<b>Total Cost</b>
Stepper Shaft Coupler	2	49.75	99.5
PVC Reducer	4	25	100
PVC Coupling	8	25	200
Chain Adjuster	2	35	70
Acrylic Sheet 2mm	1	1,900	1,900
Acrylic Sheet 3mm	1	960	960
Conveyor Belt	1	378	378
10mm Bolt & Nuts	8	10	80
Cable Tie 1 pack	1	150	150
Junction Box	3	75	225
LED	3	98	294
Push Button 1 pack	1	149.75	149.75
12V DC Power Supply	1	184	184
SPDT Switch	1	49.75	49.75
Prototyping Board	1	25	25
220 ohm resistor 1 pack	3	74.67	224.01
Ultrasonic Sensor	3	39.75	119.25
PVC Pipe	1	195	195
Basket	3	10	30
Sprocket	2	120	240
Chain	1	247	247
<b>Total Amount</b>			<b>31,536.76</b>

**Table 4**

*Overall weighted mean of farmers' evaluation*

<b>Criteria</b>	<b>Weighted Average Mean</b>
Functional Suitability	3.86
Performance Efficiency	3.62
Compatibility	3.77
Usability	3.77
Reliability	3.86
Security	3.96
Maintainability	3.78
Portability	3.88
<b>Overall Weighted Mean</b>	<b>3.81</b>

Table 4 presents the overall evaluation results from the farmers. Among the criteria assessed, Security obtained the highest mean score of

3.96, followed by Portability (3.88), Functional Suitability and Reliability (3.86), Maintainability (3.78), Compatibility and Usability (3.77), and Performance Efficiency (3.62), resulting in an overall weighted mean of 3.81, interpreted as Agree.

The evaluation of Functional Suitability yielded a mean of 3.86 (Agree), indicating that the system effectively utilizes image processing and the stopper mechanism for accurate vegetable grading.

Performance Efficiency received a mean of 3.62 (Agree), suggesting that the stopper feature enhances data processing and classification accuracy while reducing manual labor and saving time during sorting.

Compatibility achieved a mean of 3.77 (Agree), showing that system notifications are beneficial, hardware and software components are well-integrated, and the machine's dimensions and stand-alone setup are convenient and free from physical defects.

For Usability, the mean score of 3.77 (Agree) indicates that the prototype is user-friendly, the interface is easy to understand, and users can conveniently monitor sorting results on the LCD screen. Sorting records are also automatically stored and accessible through the SD card.

Reliability obtained a mean of 3.86 (Agree), demonstrating that the system functions without an internet connection, accurately performs sorting, detects errors, and maintains accessible local records.

The Security criterion, with the highest mean of 3.96 (Agree), confirms that the system operates without requiring internet access or personal data, ensuring secure and accurate vegetable sorting through reliable image processing.

Maintainability recorded a mean of 3.78 (Agree), verifying that the system's notification feature effectively supports users and that the machine operates efficiently with minimal maintenance requirements after

deployment.

Lastly, Portability received a mean of 3.88 (Agree), indicating that the system is easy to install, stable in its setup, and can be improved further without the need for frequent repositioning.

## **Conclusion**

The successful design and development of the hardware to sort eggplants into Grades A, B, and C proved beneficial and effective for the sorting process. The system's physical infrastructure and functionality were fully achieved. Additionally, the study successfully collected a dataset of eggplant samples, which served as training data for grading and sorting.

As reflected in the accuracy graph and confirmed through the accuracy test, the TensorFlow and CNN algorithms were successfully trained to recognize and classify vegetables based on texture, color, and defects. Furthermore, with all test cases passed, the proposed system met all the ISO 25010 software quality criteria.

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# Arduino-based Bottle Reclassification and Vegetable or Flower Seed Equivalency Vendo Machine

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According to National Geographic (2022), agriculture is the art and science of cultivating soil, growing crops, and rearing livestock. It plays a vital role in producing the goods people use daily, such as fruits, vegetables, rice, and other agricultural commodities available in grocery stores. Agriculture relies on various production techniques to generate these essential goods. Over time, technology has become a fundamental component of agricultural production, enabling efficiency and productivity through the use of automated machines that simplify labor-intensive tasks (Abiri et al., 2023; Jiang et al., 2025; Duguma & Bai, 2025; Bazargani & Deemyad, 2024; Padhiary et al., 2025; Chen, 2025; Thilakarathne et al., 2025).

Technological advancements have significantly transformed agriculture and the environment. Machines are now widely used not only to improve productivity in farming but also to support environmental sustainability through waste management and recycling. For instance,

recycling machines that process plastic bottles help reduce environmental waste. As National Geographic (2022) further explained, agricultural products such as food, textiles (cotton, wool, and leather), paper, and timber are central to daily life, and these outputs vary globally depending on climate, geography, cultural practices, and technological capacity. Technology has undeniably revolutionized modern life, influencing nearly every sector, education, business, industry, and especially agriculture. As technology continues to evolve, it becomes increasingly integrated into daily activities and essential operations. Those who fail to adopt technological tools in production processes often find it challenging to remain competitive. Recognizing this, the present study introduces an innovative system called the Arduino-based bottle reclassification and vegetable or flower seed equivalency vending machine, which integrates environmental responsibility with agricultural development. This innovation builds upon an earlier system, Cash and Sanitize: An Arduino-Based Reverse Vending Machine with Automated Hand Sanitizer, and expands its purpose from hygiene promotion to sustainability and agricultural engagement.

The proposed vending machine aims to encourage proper plastic bottle disposal by offering seed packets as a reward. Users deposit a plastic bottle into the machine and can then choose from a selection of visible flower or vegetable seeds displayed behind a transparent glass door. After selecting a category, the machine dispenses the corresponding seed packet into the collection box. This approach not only promotes environmental awareness and recycling but also supports local agricultural activities by providing seeds for planting.

The main objective of this study is to design and implement an efficient, project-based system for collecting plastic bottles through an

automated vending machine that exchanges them for seeds. This initiative seeks to benefit farmers, gardeners, and community residents by fostering a sustainable cycle of recycling and planting, turning waste into resources that support both environmental conservation and agricultural growth.

## **Theoretical Framework**

### ***Environmental Impact of Plastic Waste***

The extensive use of plastics in household and commercial products has contributed significantly to environmental degradation. Plastic waste has become one of the most pressing global issues, affecting ecosystems, human health, and the climate (Pilapitiya et al., 2024; Islam, 2025). The United Nations (2018) reports that approximately 8 million tons of plastic waste enter the oceans annually, causing the deaths of around 1 million seabirds and 100,000 marine mammals each year. These statistics highlight the severity of plastic pollution and underscore the urgent need for innovative and sustainable waste management solutions.

Plastic pollution not only impacts marine life but also contributes to broader environmental challenges such as global warming, climate change, and the thinning of the ozone layer. Improper disposal and accumulation of plastics in landfills or natural environments create long-term ecological consequences, including soil contamination and disruption of natural habitats. As the global population continues to rely heavily on plastic products, the environmental burden of plastic waste is expected to increase unless comprehensive mitigation strategies are implemented. The literature emphasizes that addressing plastic pollution requires a combination of policy, technological intervention, and public engagement (Bertolazzi et al., 2024; Alaghemandi, 2024; Matavos-Aramyan, 2024; Pambudi et al., 2025;

Rahman et al., 2025; Tang, 2023; Rohmana et al., 2025).

### ***Technological Innovations in Plastic Waste Management***

One of the key technological solutions proposed to mitigate plastic waste is the Reverse Vending Machine (RVM), a system designed to accept plastic bottles in exchange for rewards or incentives. Zia et al. (2022) describe the RVM as a machine where users deposit empty plastic bottles for recycling. The machine performs several automated functions, including bottle acceptance, fill detection, and notifying authorities when the machine is full. By providing tangible rewards, RVMs encourage public participation in proper waste disposal and promote environmental awareness.

Recent innovations have enhanced the RVM concept by integrating automation and digital technology. Modern systems are equipped with microcontrollers and sensors that can identify users, weigh the waste, and convert the weight into redeemable points through RFID-based systems. Such automation reduces the inconvenience of manual recycling, which often requires users to transport large volumes of waste to recycling centers. Studies in Malaysia demonstrate that small-scale testing of automated recycling bins with reward systems increases participation in recycling programs, motivating citizens to engage in environmentally responsible behaviors while simultaneously creating economic opportunities through the “waste-to-wealth” concept (Tomari et al., 2017; Hassan et al., 2000). These technological solutions represent a practical and scalable method for addressing urban waste management challenges.

### ***Agricultural Development and Sustainability***

Agriculture, defined as the art and science of cultivating soil,

growing crops, and raising livestock, forms the backbone of human civilization. It encompasses all processes involved in producing food, fiber, and raw materials necessary for human life. Farming, a core aspect of agriculture, involves the careful management of crops and livestock to provide sustenance, clothing, and other essential resources. Over thousands of years, agriculture has shaped cultures, economies, and societal structures, influencing traditions and values while providing the foundation for civilizations worldwide.

In the Philippines, agriculture remains a crucial sector due to the country's abundant natural resources. However, urbanization, industrial development, and climate change have reduced the availability of arable land, disrupted crop production, and contributed to the inflation of agricultural commodities. These challenges highlight the need for innovative agricultural practices and interventions that enhance sustainability, improve access to essential resources, and ensure the availability of crops for both market and personal use. Promoting agriculture as a sustainable practice is vital not only for economic growth but also for food security and community development.

### ***Integration of Technology and Agriculture through Incentive Systems***

Technological innovations in environmental management, such as reverse vending machines, can be effectively integrated into agriculture to address both ecological and economic challenges. By exchanging recyclable materials like plastic bottles for agricultural incentives, such as vegetable or flower seeds, these systems encourage recycling while simultaneously promoting crop cultivation. This dual-purpose approach provides households, gardeners, and farmers with accessible seeds that can be used for personal consumption or commercial production, thereby

enhancing crop availability and contributing to local food security.

The Arduino-based bottle reclassification and vegetable or flower seed equivalency vending machine exemplifies the synergy between technology and agriculture. This innovation converts plastic waste into a valuable resource for agricultural use, encouraging environmental responsibility and sustainable farming practices. By linking waste management with agricultural productivity, the system creates a circular economy in which recycling supports community development, environmental conservation, and food production. Such integrated initiatives demonstrate that technological interventions can simultaneously address multiple societal challenges, making them highly relevant in modern sustainability and agricultural strategies.

## Research Framework

The data collected in this study served as the foundation for developing and evaluating the system.

### *Data*

Table 1 presents the characteristics of the primary materials used in the system project, specifically the plastic bottles and seeds.

**Table 1**

*Characteristics of the primary materials*

<b>Data Set</b>	<b>Characteristic</b>
Plastic Bottle	Made of Polymers
Seeds	Plants and Vegetables

The plastic bottles are made of polymers, while the seeds consist of

various plant and vegetable types. Understanding these characteristics is essential for the system to function effectively.

### ***Method***

The data for this study were collected through a survey administered to 30 respondents. The total number of respondents was determined using Slovin's formula, which also guided the application of a random sampling method for distributing the survey questionnaires. The survey instrument was designed to assess three key aspects: functionality, environmental impact, and profitability.

To measure respondents' perceptions, the researchers employed a four-point Likert scale, which included the following response options: strongly agree, agree, disagree, and strongly disagree. Each participant used this scale to indicate their level of agreement with each survey item. This approach allowed the researchers to quantify opinions consistently and analyze the data systematically, ensuring that the findings accurately reflect the respondents' views on the system's functionality, environmental contribution, and profitability.

### ***Ethical Considerations***

The study prioritized ethical and safe use of the system throughout the study. Ensuring the functionality, usability, and compatibility of the system was a key requirement before deployment. The system underwent thorough testing to confirm that it operates correctly and reliably, minimizing the risk of errors during user interaction.

Additionally, the system was designed to be user-friendly, with a clear manual provided to guide users in its operation. A backup mechanism

was also included to address potential technical issues and reduce inconvenience for users. Regular monitoring and verification of the system's processes were conducted to ensure that it consistently meets its intended goals. These precautions are essential not only for the researchers' accountability but also to safeguard the experience and safety of end-users, guaranteeing smooth and error-free system operation.

### ***Experimental Design***

An experimental design was developed to guide the implementation of the study. This design outlines the study's objectives and demonstrates the logical flow of the research process. The researchers employed a repeated measures design, in which the same respondents participate in each condition of the vending machine experiment. This approach ensures that each condition is evaluated consistently by the same participants, who include farmers, gardeners, and residents.

### ***Modeling***

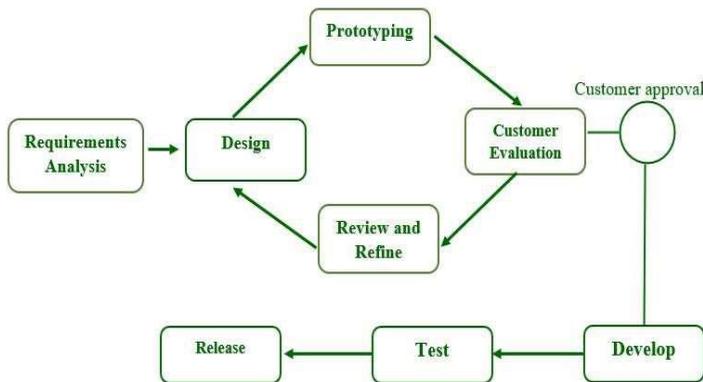
Selecting an appropriate model is a critical factor for the system's effectiveness, as it determines how testing is conducted and which techniques are most efficient. For this study, the researchers employed the prototyping method to develop the system. This approach allows for constructing a preliminary version of the system, which can be tested and refined before final production.

The prototyping method is particularly effective because it enables the identification and resolution of potential issues early in the development process. By iteratively testing and improving the system, the researchers can ensure that the final product is functional, reliable, and user-friendly. This method not only enhances the quality of the system but also reduces

the likelihood of errors during deployment.

**Figure 1**

*Prototyping model*



### *Procedures of the Different Phases*

*Design.* The design phase focuses on creating the overall blueprint of the Bottle Reclassification Vending Machine. This includes outlining the system architecture, interface, and other specifications required to develop an effective and functional prototype. The design provides a clear concept of how the system will operate and serves as a guide for the development team.

*Prototyping.* In the prototyping phase, the system is constructed and refined. A well-defined prototype is created, tested, and evaluated to ensure it meets the intended objectives. This prototype serves as a reference for future system improvements and provides a practical demonstration of the machine’s functionality.

*Customer evaluation.* The customer evaluation phase assesses the satisfaction and usability of the prototype among potential users. Feedback from users helps the researchers understand the system’s benefits and

identify areas for improvement. This phase also provides insights for future studies and encourages innovation in similar systems.

*Review and evaluation.* During this phase, the system undergoes a final review and evaluation. Researchers assess the system's overall performance, functionality, and reliability. The results of this evaluation are used to compile all gathered information and inform any necessary adjustments before the final development stage.

*Development.* The development phase involves building a fully functional system based on the refined prototype. The researchers focus on ensuring that the vending machine operates efficiently and demonstrates improved performance compared to the initial prototype. This phase represents the tangible realization of the system's design and functionality.

*Testing.* In the testing phase, the Bottle Reclassification Vending Machine is thoroughly examined to ensure it operates correctly. Researchers identify potential errors, monitor system performance, and implement corrective actions to prevent issues. This phase guarantees that the system functions reliably and meets quality standards before release.

*Release.* The release phase marks the deployment of the finalized system. The machine is made available for practical use, demonstrating its benefits and performance to end-users. This phase ensures that the system can be implemented effectively and contributes to environmental sustainability and agricultural support through proper plastic bottle reclassification and seed distribution.

## **Technical Framework**

The development of the product requires the integration of data, hardware, and software components. Each component plays a critical role

in the overall functionality of the system.

### ***Materials***

Hardware includes all physical devices and equipment necessary to run the system, such as sensors, microcontrollers, and actuators, which enable the system to interact with the environment and execute tasks. Software encompasses the programs, algorithms, and interfaces that control the hardware, process data, and facilitate user interactions. Together, these components work in harmony to ensure the system performs its intended functions effectively and efficiently.

### ***Software***

Table 2 shows the software used in creating this project.

**Table 2**

*Software requirement*

<b>Software</b>	<b>Specification</b>
Arduino IDE	Arduino-ide_2.0.2_Windows_64bit Size 157 MB (165,608.048 bytes)

The project requires specific software materials to operate the machine effectively. These software components work in conjunction with the hardware to ensure the system performs all its intended tasks. Central to the system are the programming codes, which execute the specific operations necessary for the machine to function correctly. These codes coordinate the hardware components, process the input data, and manage the overall workflow, making them essential for the accurate and reliable operation of the vending machine.

## Hardware

Table 3 shows the hardware used in creating this project.

**Table 3**

*Hardware requirements*

Parts	Function	Specification
<b>Arduino Mega 2560</b> 	It serves the brain of the projects.	5 Volts
<b>IR Break Sensor Beam</b> 	A Sensor that detects if its plastic bottle	5 Volts
<b>Servo Motor</b> 	It serves the door of the machine if it is accepted or not	5 Volts
<b>Solar Panel and Rechargeable Battery</b> 	A electric device that makes the whole machine works.	Battery : 12V 20H Solar Panel : 50Watts 12V
<b>LM2596</b> 	A component that gives the other devices 5 volts instead of 12 volts	12 volts
<b>LCD</b> 	It display what the machine detects and the total points	5 Volts
<b>Micro Push Button</b> 	A button that triggers the stepper motor to dispense a seed with the right number of points	5 Volts
<b>Stepper Motor</b> 	This device rotates to get their reward when the push button is pressed	5 Volts
<b>Loadcell</b>	A device this measure the weight of the plastic bottle	5 Volts

Parts	Function	Specification
 <b>Ultrasonic Sensor</b> 	A sensor that detects when a plastic bottle can place inside the PVC	5 volts

Table 2 lists the hardware materials required for the development of the bottle reclassification vending machine. Among these, the ultrasonic sensor is particularly essential, as it plays a critical role in ensuring the system performs accurately. The sensor detects the presence and placement of plastic bottles, allowing the vending machine to store them correctly and operate efficiently.

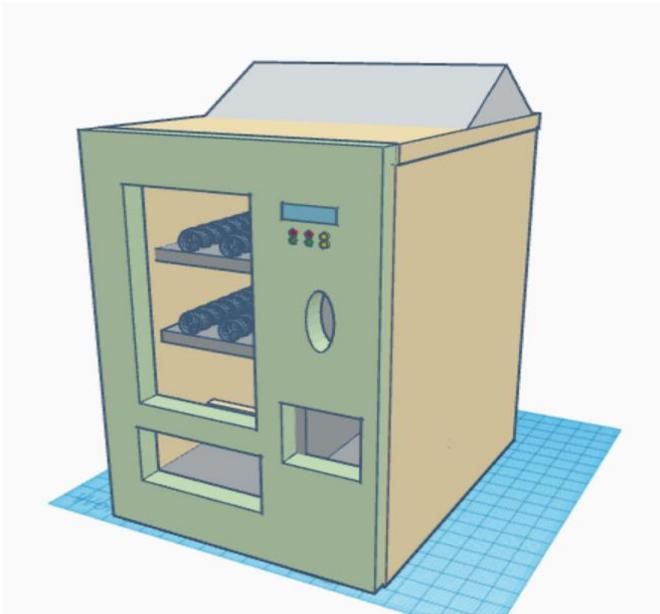
In addition to the ultrasonic sensor, other hardware components are also necessary to enhance the system’s functionality and reliability. These materials work together to support the mechanical operations, data processing, and overall performance of the vending machine, ensuring that it meets the intended objectives of bottle reclassification and seed distribution.

### ***System Design***

Figure 2 illustrates the main 3D prototype of the study. The prototype measures 4 units in height and 5 units in width. The machine is powered either by a solar panel or a battery, which is placed on the top of the unit. The vending machine features six buttons corresponding to six different seed options, six springs for dispensing the seeds, and a pipe where users insert plastic bottles for reclassification. This design ensures that the system is functional, user-friendly, and capable of performing its intended tasks efficiently.

**Figure 2**

*The main prototype*



**Figure 3**

*Project system flow*

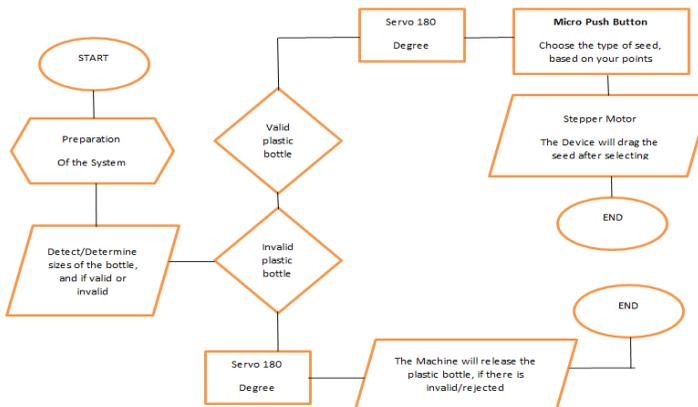


Figure 3 illustrates the system flow of the bottle reclassification vending machine, demonstrating how the system operates. Initially, users insert small, medium, or large plastic bottles into the machine. The sensor then evaluates each bottle to determine whether it meets the required

specifications. Bottles that are severely damaged, misshapen, filled with liquid, or too heavy are rejected and not accepted by the machine.

Plastic bottles that are intact, empty, and within acceptable size limits are accepted and processed. Once the bottle is validated, the user can select their preferred seed by pressing the corresponding seed button. After the selection is made, the machine dispenses the chosen seeds, completing the transaction. This flow ensures that only suitable bottles are collected while providing users with a seamless and rewarding experience.

**Figure 4**

*Detailed circuit diagram*

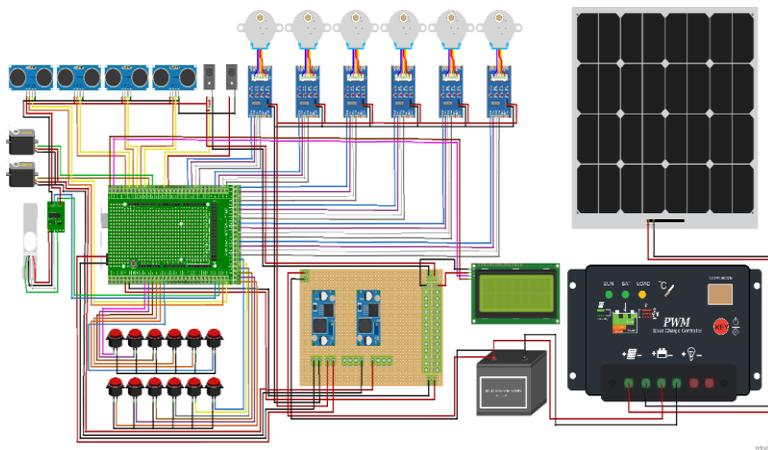


Figure 4 illustrates the overall circuit layout and the system flow of the bottle reclassification vending machine. This layout enables users to fully control and operate the system. The machine incorporates four sensors, servo motors, an Arduino Mega 2560, stepper motors, and other essential components. The sensors play a critical role in detecting the size and presence of plastic bottles, while the other components support various movements and operations required for the system to function efficiently. This integrated circuit design ensures coordinated performance across all

parts of the vending machine.

**Figure 5**

*LCD Display shows the accumulated points for plastic bottles*



Figure 5 illustrates how the system calculates and displays points for each plastic bottle deposited, with different bottles corresponding to varying point values. The accumulated points are shown on an LCD screen, allowing users to track the total points they have earned by recycling plastic bottles through the machine. This feature provides immediate feedback and encourages user engagement in responsible recycling practices.

Figure 6 illustrates a prompt indicating that the machine is dispensing a pack of seeds selected by the user using the points they have accumulated. Users can choose their preferred seed pack by pressing the corresponding buttons, with each button linked to a different type of seed. This feature allows users to redeem their points easily while selecting the seeds they desire, making the system interactive and user-friendly.

**Figure 6**

*Machine dispensing pack of seeds*



**Figure 7**

*Machine displays the size of the plastic bottle*



Figure 7 demonstrates that the machine is capable of reclassifying plastic bottles based on their size, ensuring that the points awarded to users correspond accurately to the type of bottle deposited. The system uses ultrasonic sensors to measure the height of each inserted bottle, allowing the machine to distinguish between small, medium, and large bottles. This precise classification ensures fairness in the points system and enhances the accuracy and reliability of the vending machine.

**Figure 8**

*Development system*



Figure 8 illustrates the operational process of the system. The user begins by inserting a plastic bottle into the PVC pipe. Once the bottle is dropped, the ultrasonic sensor detects its size and determines the corresponding number of points. The accumulated points are then displayed on the LCD screen. After viewing their available points, the user can press the designated push button to dispense a seed pack of their choice as a reward. This process demonstrates the system's efficiency in integrating bottle classification, point calculation, and seed dispensing into a single automated workflow.

### ***Testing***

The study employed system testing to assess the efficiency and functionality of the vending machine. Performance results were evaluated

after the system completed its operations to confirm and validate its processes. Manual testing was used to examine each feature and ensure that all components operate correctly. This approach allowed the researchers to identify errors, verify quality, and make necessary adjustments. Testing each system component individually ensures that all parts work together harmoniously, while the analysis of error data provides insights for system improvement and more efficient future testing.

The initial step in testing was to ensure proper system operation in line with the design specifications. Simulated system operations were conducted to validate the workflow and functionality. System requirements were also reviewed during this phase to ensure that all criteria were met. The final step involved output validation, confirming that the proposed system performs its intended functions accurately and efficiently.

### ***System Evaluation and Testing***

This section presents the overall results of the survey conducted with 30 respondents. The questionnaire was designed to evaluate three key aspects of the system: functionality, environmental impact, and profitability. Responses were measured using a Four-Point Likert Scale, with the options: strongly agree, agree, disagree, and strongly disagree.

**Table 9**

*Weighted mean distribution of the criteria for the developed system*

<b>Criteria</b>	<b>Weighted Mean</b>	<b>Remarks</b>
Functionality	3.44	Strongly Agree
Environmental	3.58	Strongly Agree
Profitable	3.41	Strongly Agree
<b>Average</b>	<b>3.47</b>	<b>Strongly Agree</b>

The overall evaluation of the system shows an average weighted mean of 3.47, indicating that respondents rated the Bottle Reclassification Vending Machine positively across the assessed aspects: functionality, environmental impact, and profitability. This suggests that the system is capable of performing the tasks it was designed for efficiently.

In terms of functionality, the program installed on the hardware operates correctly and is user-friendly. Respondents reported ease of use when interacting with the hardware, resulting in a Strongly Agree rating for functionality with 3.44.

Regarding the environmental impact, the system was rated positively for its contribution to sustainable practices. The average weighted mean for environmental performance is 3.58, with respondents strongly agreeing that the machine promotes eco-friendly behavior.

For profitability, the system was also evaluated as effective in helping users save money by providing seeds in exchange for recycled plastic bottles. The average weighted mean in this category is 3.41, with respondents giving a Strongly Agree remark, indicating that the system provides economic benefits in addition to its environmental and functional contributions.

*Economic feasibility.* Economic feasibility evaluates whether the anticipated benefits of the system outweigh the project costs. A cost-benefit analysis was performed to assess the value of the system, considering both its advantages and disadvantages. The analysis also provided feedback on the potential impact of the system on its users, demonstrating that the proposed vending machine can offer practical benefits while remaining economically viable.

*Technological feasibility.* The project demonstrates technological feasibility through its successful implementation. Users provided positive

feedback regarding the system's design and functionality, including suggestions such as improving the machine's appearance and tagline for greater attractiveness. Overall, the system's goal of providing points for recycled bottles in exchange for seeds was well-received by users, showing that the technology meets its intended purpose.

*Operational feasibility.* The developed system is operationally feasible because it is designed to be user-friendly and easy to understand. Survey results indicate high user satisfaction, and the inclusion of a procedural video further aids in guiding users through the machine's operation. The system's simplicity and clarity make it accessible for various users, including farmers, gardeners, and community residents.

## **Conclusion**

The Arduino-based bottle reclassification vending machine successfully addressed both environmental and agricultural needs by providing a system that converts plastic bottles into points redeemable for seeds. The machine accurately detects and classifies bottles of different sizes using ultrasonic sensors, ensuring that each bottle corresponds to the appropriate points and seed type. The prototype demonstrated functionality, user-friendliness, and operational efficiency, earning positive feedback from respondents in terms of functionality, environmental impact, and profitability. By incentivizing recycling and promoting the use of seeds for planting, the system not only encourages sustainable practices but also supports agricultural productivity for farmers, gardeners, and community residents. This innovative project highlights the potential of technology to contribute meaningfully to environmental preservation and community development.

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# An IoT Solar Bird Repellent with Image Processing

*Gizel L. Dael, Benjie C. Ila, Shaira E. Coronel & Joy Camille R. Ibon*

Rice (*Oryza sativa*) is one of the most widely cultivated crops globally, with about 90% of total production coming from Asia (Fukagawa & Ziska, 2019; Schneider & Asch, 2020). The Philippines ranks eighth among Southeast Asian rice producers (FAOSTAT, 2020). However, ensuring future food security remains one of the greatest challenges facing farmers today. Rapid population growth, climate change, farmland fragmentation and degradation, pest infestation, lack of stakeholder integration, uneven urbanization, and political instability threaten sustainable food production (Maja & Ayano, 2021; Sahoo et al., 2025; Godde et al., 2021; Çakmakçı et al., 2023). Over the next 35 years, global food output must increase by at least 60% to meet the demands of the growing population (DA Communications Group, 2022; Isakova, 2022).

Rice farmers encounter numerous challenges, including insufficient irrigation systems, labor shortages, lack of postharvest facilities, limited capital, fluctuating rice prices, high input costs, and persistent pest and disease infestations (Cao et al., 2023; Gamage et al., 2024). Among these issues, birds have become one of the most damaging pests. Many species, such as pigeons, doves, parakeets, munias, sparrows, and weaver birds, feed

on grains and fruits and can cause severe crop losses. Birds begin consuming rice grains from the ripening stage until harvest, leading to unfilled panicles and yield reduction. Large flocks can destroy crops, damage storage facilities, and contaminate nearby areas. A significant number of farmers experienced crop loss due to bird attacks (Micaelo et al., 2023; Zhong et al., 2025; Anderson et al., 2013).

In Sariaya, Quezon, Philippines, farmers identified Maya birds (*Passer montanus*) as one of the primary rice-eating pests. These birds cause substantial crop damage during the ripening stage of rice. Farmers have traditionally employed various deterrent methods such as installing nets, building scarecrows, or using clappers to produce noise across the fields. However, these conventional methods are no longer effective because birds have quickly adapted to them. Several studies have confirmed that traditional scarecrows provide only short-term relief and lose their deterrent power over time.

As technology evolves, researchers have explored the development of more effective, technology-based bird deterrents. Devices incorporating sensors such as Passive Infrared (PIR) sensors, Piezo ultrasonic sensors, cameras, and microcontrollers like Arduino Uno and Raspberry Pi have been developed to detect and repel birds automatically. Some systems use wind power, infrared imaging, RFID, Wi-Fi, and LoRa technologies to trigger high-frequency sounds or visual cues that deter birds. Electronic bird-repellent systems using acoustic and visual stimuli effectively frightened and confused birds (Chen et al., 2024; Amenyedzi et al., 2025), prompting them to relocate to quieter areas. These technologies have even been applied in airports to prevent bird congregation near runways and reduce the risk of aircraft collisions.

Technological advancement has also transformed the agricultural

industry by enhancing automation and efficiency. Sensors, actuators, and microcontrollers now play an integral role in monitoring and controlling agricultural processes. Studies highlight that the application of technology in agriculture accelerates harvesting, minimizes manual labor, and improves productivity (Aijaz et al., 2025; Sanyaolu & Sadowski, 2024; Getahun et al., 2024; Vărzaru, 2025; Nautiyal et al., 2025). In recent years, research has expanded to include the observation of bird behavior and attacks in both wind farms and rice fields (Villegas-Patracă et al., 2012; Yordanov et al., 2025; Tesfahunegny et al., 2020; Marques et al., 2021). Hasanudin et al. (2020) noted that the use of actuator and sensor-based systems for environmental monitoring is steadily increasing, offering opportunities to develop innovative pest-control solutions.

Despite global progress in agricultural technology, limited research in the Philippines focuses on developing bird-repellent systems for rice fields. This study focuses on developing an IoT-based solar bird-repellent system integrated with image processing technology to help farmers protect their rice fields without harming birds. The system employs a camera to capture real-time images, allowing its recognition module to identify bird species and trigger a speaker that emits specific sound frequencies to drive them away. Designed primarily to counter rice-eating species such as the Eurasian Tree Sparrow (*Passer montanus*), locally known as Maya, and the Mayang Paking, the system addresses a major agricultural challenge in the Philippines, where these birds cause significant crop losses by attacking in flocks during the rice-ripening stage. The Maya is characterized by its chestnut crown, black chin and throat, white cheek patches, and brown-black wings, while the Mayang Paking features a reddish-brown body, silvery-blue bill, and black head, both species known for feeding on grains and gathering in large groups, exacerbating crop destruction (Animalia,

2023). Utilizing components such as a Raspberry Pi, camera module, tweeter speaker, and photovoltaic panels, the project aims to create a sustainable and efficient prototype that enables farmers to safeguard their crops through an innovative, eco-friendly approach.

## **Theoretical Framework**

### ***The Threat of Birds to Rice Production***

In the Philippines, the Eurasian Tree Sparrow (*Passer montanus*), locally known as the Maya, is one of the most common rice-eating birds found in paddy fields. These birds feed on rice grains from the ripening stage until harvest, often causing unfilled panicles and substantial grain loss. Flocks of sparrows can knock grains off stalks, depleting yields significantly. Studies have shown that birds can affect up to 75% of local rice production in some regions (Angkaew et al., 2023; Htay et al., 2022). Birds have become one of the primary pest concerns for farmers worldwide, not only damaging crops but also contaminating fields and residential areas with their droppings, which pose health risks. Among the most problematic species are crows, which damage both agricultural and residential areas.

To mitigate bird attacks, farmers have historically relied on traditional deterrent methods such as scarecrows, hawk kites, colored lights, lasers, flashing devices, and chemical repellents. However, these methods have proven increasingly ineffective as birds quickly adapt to them. Scarecrows, often constructed from bamboo and old clothing, were once common in Sariaya, Quezon, but their effectiveness has declined over time. Farmers in the region continue to rely on manual deterrence techniques, as no advanced technological bird repellents are yet in use.

Despite technological advancements, bird pest management remains

time-consuming and costly. Developing effective systems requires resources that are often unavailable to small-scale farmers. Kendall et al. (2022) emphasized that in many developing countries, farmers still rely on outdated and inefficient manual deterrence methods, despite the availability of emerging electronic solutions.

### ***Emergence of Electronic and Sensor-Based Bird Repellents***

Advances in agricultural technology have enabled the development of electronic bird-repellent systems. These devices typically incorporate microcontrollers, sensors, cameras, solar panels, and sound emitters to deter birds using high-frequency noise. Arowolo et al. (2022) explain that birds can detect ultrasonic frequencies around 29 kHz, beyond the human hearing range of up to 20 kHz. Ultrasonic sounds above 20 Hz can irritate birds, prompting them to leave the area.

Researchers have discovered that specific predator calls, particularly those of falcons (*Buteolagopus*), are especially effective in frightening pest birds. Baral et al. (2019) and Uzma et al. (2021) found that the falcon's sound produced the strongest repelling effect against crows, especially when played in 60-second bursts followed by 360-second pauses. These studies emphasized that the frequency, volume, and duration of the sound are critical in determining a repellent's effectiveness. Importantly, these systems are designed to be environmentally friendly, humane, and cost-efficient compared to chemical deterrents or netting systems.

### ***Technological Innovations in Bird Repellent Systems***

Recent developments in the field have focused on automation and intelligent systems that detect, identify, and repel birds in real time. Singh et al. (2021) developed a modified scarecrow equipped with a Passive

Infrared (PIR) sensor and a flapping mechanism. When birds entered the field, the system detected their presence, moved its arms, and activated a buzzer to scare them away. Similarly, Murthi et al. (2021) proposed a design incorporating an LCD, infrared (IR) sensors, a relay, and ultrasound generators powered by solar panels, laying the groundwork for sustainable, autonomous deterrent systems.

Machine learning and image processing have further advanced bird detection systems. Arowolo et al. (2022) developed a bird-detection model using a convolutional neural network (CNN) running on a Raspberry Pi 4. Equipped with a 0.3-megapixel camera and solar-charged lithium batteries, the system could detect birds within 10–15 meters and automatically trigger varying sound frequencies to prevent bird habituation. Similarly, Priya et al. (2020) designed a system that used a 360-degree rotating camera and a piezo ultrasonic sensor to detect birds and emit a 60 kHz ultrasonic signal powered by Python-based OpenCV image processing.

Machine learning allows devices to analyze visual data, recognize bird species, and adapt deterrence mechanisms accordingly. According to Brown (2021), machine learning enables computers to learn from data, such as numbers, images, or text—without explicit programming, forming the foundation of artificial intelligence applications like image-based bird detection.

### ***IoT and Connectivity in Agricultural Pest Management***

The integration of the Internet of Things (IoT) into agriculture has revolutionized pest management. IoT-based systems connect sensors, cameras, and actuators to enable real-time monitoring and automation. Modern agriculture now utilizes technologies such as GPS, drones, moisture sensors, and robotics to enhance productivity and sustainability

(Mishra et al., 2020).

In one innovative project, Golla and Gullipalli (2020) collaborated with the Bioseco company to develop a LoRa- and Wi-Fi-based bird monitoring and deterrence system. The design featured an Arduino Uno, LoRa transceiver, piezoelectric buzzer, and LED indicators. Data collected from sensors were transmitted via the ESP8266 Wi-Fi module to both a web interface and mobile application, allowing users to monitor and control the system remotely. The system successfully detected and tracked birds up to 500 meters away, demonstrating the potential of IoT and LoRa technology in long-distance agricultural monitoring.

## Research Framework

### *Data*

According to Hamed et al. (2021), since species differ in their sensitivity to various sound frequencies, data on sound limits for different pest birds were used during the application of sonic waves to control birds in this experiment, as indicated in Table 1.

**Table 1**

*Species-specific sensitivities to frequencies, peak sensitivity, and range of sensitivities.*

Species	Lower Limit (HZ)	Most Sensitive (kHz)	Upper Limit (kHz)
Dove ( <i>Spilopelia senegalensis</i> )	50	1.8-2.4	11.5
Crow ( <i>Corvus cornix</i> )	300	1-2	8
Pigeon ( <i>Columba livia</i> )	20	1-2	10
House Sparrow ( <i>Passer domesticus</i> )	675		11.5

According to Levitt et al. (2022), the birds were disturbed at frequencies ranging from 28 kHz to 60 kHz. Accordingly, Dmello et al.

(2025), a locally built solar-powered electronic device, successfully produced ultrasonic waves that were amplified, broadcast at a sufficiently loud volume, and automatically varied in frequency between 15 kHz and 25 kHz.

During the testing stage of the developed system, the researchers discovered that the frequency and predator sounds were not effective in driving away the Maya. Based on related literature and previous studies, the most effective sounds for repelling birds are predator sounds, such as those of a falcon. These types of sounds have been successfully used to drive away crows and pigeons. Therefore, during sound testing, it was found that the sounds of guns, missiles, and cannons are effective in driving away the Maya.

To prevent the birds from becoming accustomed to the system, it emits five random sounds. Testing showed that when the sounds are startling, the birds fly away, which is why gunshot, cannon, and missile sounds were chosen. The system can identify birds at a distance of approximately 60–70 meters, while the emitted sound can reach approximately 100–120 meters. When a bird is detected, the system emits a sound, and the bird can react from 100–120 meters away. However, at this distance, the birds respond slowly and may require multiple sound emissions before leaving. When the interval alert mode is activated, the speaker emits a sound every five minutes to maintain the deterrent effect.

### ***Design***

The study employed a developmental research design to conduct this study. This approach was used to identify solutions to the stated problems, justify findings, and fulfill the study's objectives. Similarly, a quantitative design was utilized through computational, statistical, and

mathematical tools to gather, present and analyze the survey results. It is conclusive in nature, as it aims to quantify the problem and determine its prevalence by producing findings that can be generalized to a larger population.

### ***Respondents***

The respondents of the study consisted of rice farmers and IT experts, all selected through random sampling. This method ensured that each member of the population had an equal chance of being included in the sample. A total of ten (10) rice farmers from a selected barangay and five (5) IT experts participated in the study. The chosen barangay was selected as the site for the system testing.

### ***Instrument***

A structured questionnaire was used as the primary data collection instrument. The questionnaire consisted of thirty-three (33) closed-ended questions, each designed to gather specific information relevant to the study's objectives. A 5-point Likert scale was applied, allowing respondents to express their level of agreement or disagreement with the given statements. This format facilitated quantitative analysis and ensured consistent responses across participants.

### ***Statistical Treatment***

To analyze and interpret the collected data, the study employed appropriate statistical procedures. The total scores on the Likert scale were computed by multiplying the frequency of each response by its corresponding scale value. The mean score was then calculated by dividing the total score by the total number of respondents. The Likert scale is a

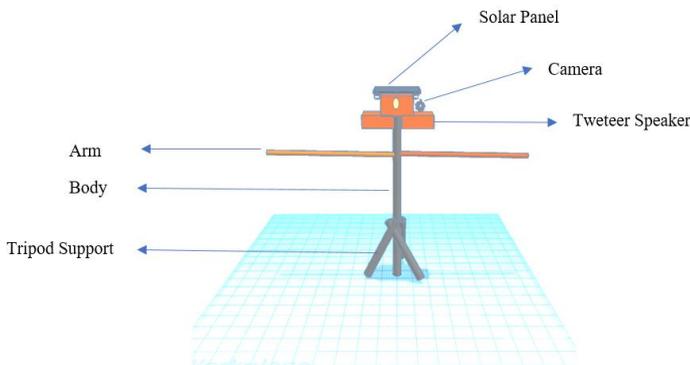
widely used method for gathering quantitative data, as it allows for clear interpretation and easy presentation of results through tables, charts, and graphs. The 5-point Likert scale, in particular, provides a balanced measure of opinions, capturing both positive and negative sentiments as well as neutral responses, thus offering a clear understanding of the respondents' true perceptions.

### ***Experimental Design***

Figure 1 illustrates the preliminary model on which the system was developed.

**Figure 1**

*An illustration of experimental design*



Tinkercad was used to create this 3D representation, providing a visual framework for the proposed design. This model remains open to modification based on potential enhancements and suggestions received after its presentation. The purpose of creating this initial design is to visualize and refine how the final system might look and function in future iterations.

## ***Agile Methodology***

The Agile methodology is a project management approach that divides a project into multiple phases, emphasizing continuous collaboration, iteration, and improvement. It follows an iterative process, meaning each cycle enhances the previous one through evaluation and refinement. This ongoing focus on quality and adaptability ensures that the final product is both efficient and effective.

**Figure 2**

*Agile methodology framework*



### ***Procedures of Different Phases***

*Planning.* Planning is the initial stage in developing a functional and reliable system. The group first discussed the feasibility of creating the proposed system and identified roles and responsibilities among members. Specific tasks, such as data gathering and manuscript preparation, were assigned to ensure an organized workflow and a smooth development process.

*Analyze.* After planning, the next step was to analyze the collected

data and materials. The researchers carefully examined whether the data were accurate, relevant, and suitable for the development of the system. This phase ensured that only valid and useful information would inform the design and functionality of the project.

*Design.* Following the analysis, the design phase began, where the conceptual framework of the system took shape. A simple, user-friendly layout was prioritized without compromising functionality. Software tools were utilized to create a 3D model that served as the visual and structural foundation for constructing the device.

*Develop.* During development, the physical assembly of the device was carried out. Each component was connected carefully to prevent short circuits or hardware malfunctions. This phase required precision and an understanding of how each part interacts with the others to ensure the system operated as intended.

*Testing.* The testing phase involved evaluating the system's functionality to identify and correct any bugs or defects. The team conducted a thorough assessment to confirm that the system performed efficiently. Any issues discovered were promptly fixed before moving to the deployment stage, ensuring that the device met the desired performance standards.

*Deployment.* Once testing was successfully completed, the system was deployed in an actual working environment. This phase marked the transition from development to real-world application. The deployment process also provided valuable insights into system performance, functionality, and usability.

*Feedback.* After deployment, feedback was gathered from users and evaluators. Both positive and negative comments were carefully considered to identify areas for improvement. This feedback loop is an essential

component of the Agile methodology, allowing the system to evolve through continuous enhancement and refinement based on real-world experiences.

## Technical Framework

### *Materials*

The materials used in developing the IoT-based solar bird-repellent system with image processing include the following:

### *Software*

**Table 2**

*List of software*

<b>Name</b>	<b>Description</b>
Python	It is used to code image recognition.
VS Code	It is used to code Python Language.
OpenCV Library	It is used for camera logic.
Tensorflow	It is used for the deep learning of image recognition.
Google Colab	It is used to train machine learning.
Anaconda Software	It is a virtual environment so that the libraries in the computer are not damaged while coding object detection.
Geany IDE	After the code is deployed in the Raspberry Pi, it is used to code Python.

Table 2 presents the software materials used for the system's detection module, specifying the programming languages and tools employed to train the machine learning model.

### *Hardware*

Table 3 provides a comprehensive overview of the hardware

components utilized in the development of the system, detailing each material’s functional role in the project. Each hardware element has been carefully selected to ensure compatibility, efficiency, and reliability in performing its designated tasks.

**Table 3**

*List of hardware materials*

<b>Name</b>	<b>Description</b>
Raspberry Pi 3b+	This is the central hardware component of the system. It will process the images received from the camera.
CCTV Bullet Camera	The camera serves as the system's human eye and accepts the current situation of recording the entire video.
Solar Charger Controller	Charge controllers, also referred to as charge regulators, control voltage and/or current to keep batteries from overcharging. It regulates the voltage and current from the solar panels to the battery.
LDR Sensor Module	The LDR sensor module detects light intensity. It is connected to the board's AO and DO-designated analog and digital output pins. The LDR's resistance falls off in direct proportion to the brightness of the light when there is light.
OD Gel Battery	Gel batteries serves as the storage of power.
Solar Panel	It is used to convert light from the sun into electricity to load the battery. PV modules can also be utilized in battery-less systems.
Horn Tweeter Speaker	A tweeter speaker is used to produce high frequencies to the limit of our human hearing range.
Amplifier	The amplifier serves as the controller of the volume of the sound.
Round Metal Tubes	In this project, a round metal tube is used to make a scarecrow structure.
USB Flash drive	It serves as the storage of data.

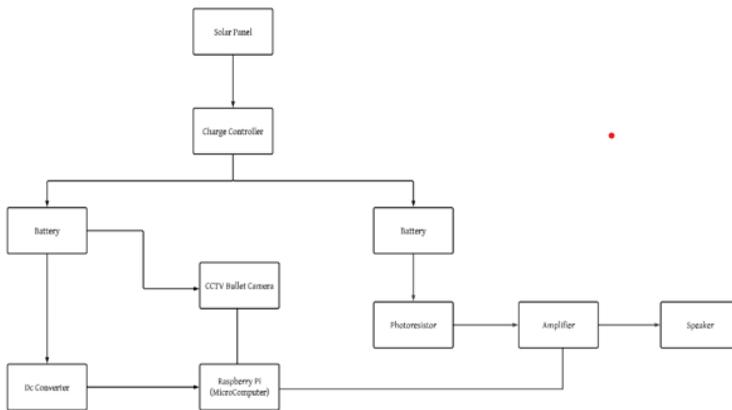
### ***Modeling***

Figure 3 illustrates the connections between the hardware components. The 18V solar panel charges the battery through a charge controller, which prevents overcharging. The DC converter then steps down the battery voltage to 5V before supplying power to the Raspberry Pi. The

CCTV Bullet Camera is connected directly to the microcomputer for monitoring purposes. Additionally, the photoresistor is connected to the battery and functions as a switch, enabling the automatic shutdown of the amplifier and speaker at night and their automatic activation in the morning.

**Figure 3**

*Diagram of block hardware*



**Figure 4**

*Circuit diagram of the developed system*

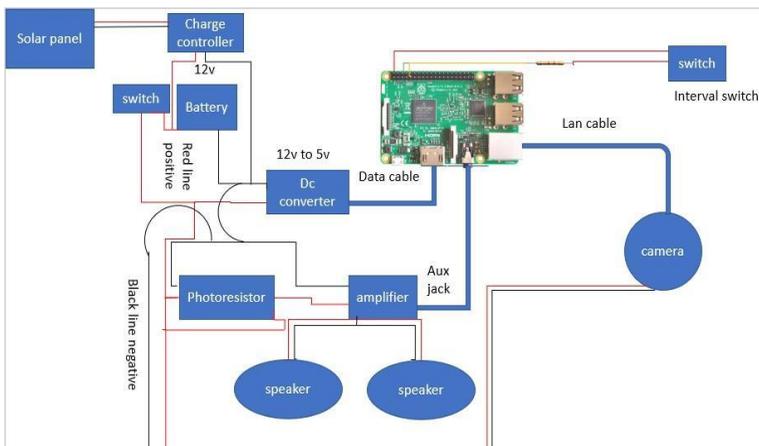


Figure 4 illustrates the connections for the audio amplifier, interval switch, camera, DC converter, and Raspberry Pi (RPI) and serves as a

reference for wiring the hardware components. The solar panel connects to the solar charge controller, which in turn connects to the battery, with the positive wire routed through a switch. The negative terminal of the battery is directly connected to the DC converter, camera, and amplifier. The output of the DC converter is connected to the power input of the RPI.

The RPI connects to the camera via a LAN cable and to the amplifier via a jack cable, while the speaker is connected directly to the amplifier. Additionally, the 5V positive output of the RPI is connected to the interval switch, and the GPIO 17 pin, along with the negative terminal, is connected to the output of the interval switch through a resistor. This setup ensures proper power distribution and communication between all hardware components, enabling the system to operate efficiently.

**Table 4**

*Interval Switch Mode of Raspberry Pi*

2	5v positive	Red
6	negative	Black
11	GPIO 17	Green

**Figure 5**

*Color-coded graphic of the Raspberry Pi GPIO*

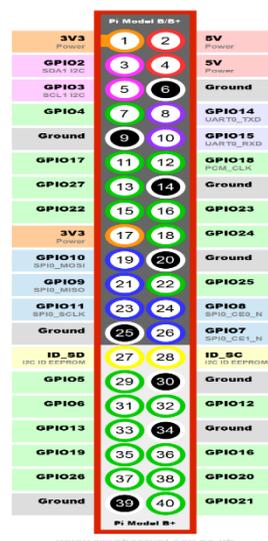


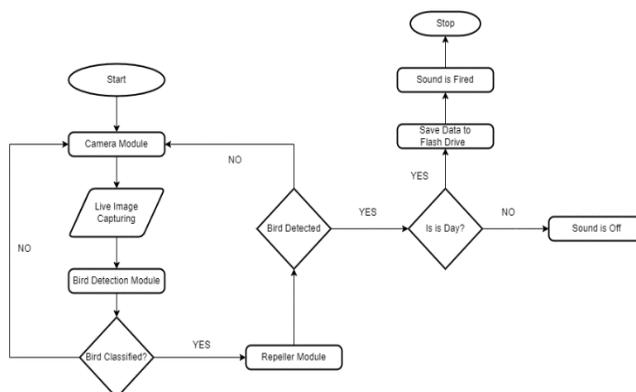
Figure 5 presents a color-coded graphic of the Raspberry Pi GPIO, showing the pin numbers, GPIO numbers, and pin types. This diagram serves as a convenient reference for wiring and identifying the proper connections on the Raspberry Pi.

The term "GPIO" refers to the pins used to connect the Raspberry Pi board to external input and output devices. A GPIO (general-purpose input/output) port can handle both incoming and outgoing digital signals. The Model B+ has a 40-pin GPIO layout, similar to the previous model. On the Model B+ board, there are 9 fixed ground pins (0V), 2 fixed 3.3V pins, and 2 fixed 5V pins. The 5V pins receive a direct supply from the mains adapter and can be used to power other 5V devices in addition to the Raspberry Pi. The 3.3V pins are used to test LEDs and provide a stable 3.3V supply for external components.

### System Design

Figure 6 presents the system process in a flowchart. The camera module serves as the system's "eye," capturing the current scene. The camera takes an image every 30 seconds, which is then processed by the bird detection module to determine whether a bird is present. After processing, the image is automatically deleted.

**Figure 6**  
Flowchart of the system camera detection mode

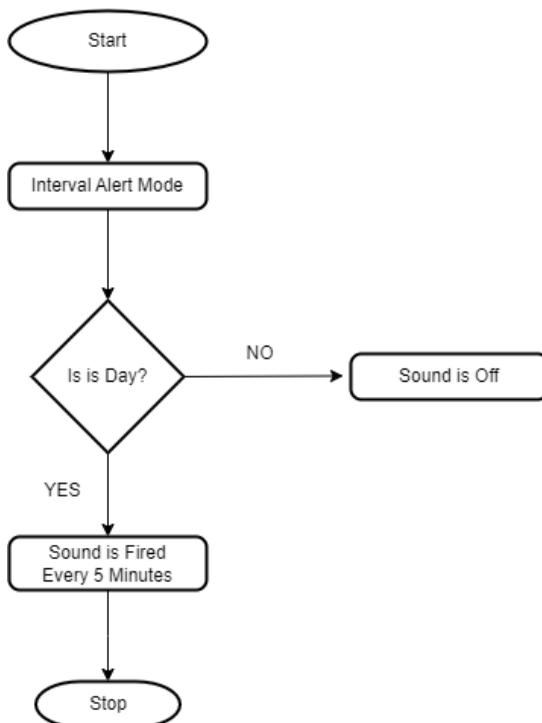


If a bird is detected, the repeller module is activated, the data is saved to a flash drive, and the speaker emits a sound. The speaker operates during the daytime and automatically turns off at night. If no bird is detected in a captured image, the image is deleted automatically, the speaker remains silent, and the bird detection module proceeds to process the next captured image.

Figure 7 illustrates the interval mode process in a flowchart. When the interval mode is active, the camera is turned off, and the speaker emits sound every five minutes. The speaker operates during the daytime and automatically turns off at night.

**Figure 7**

*Flowchart of the system interval alert mode*



**Figure 8**

*System architecture*

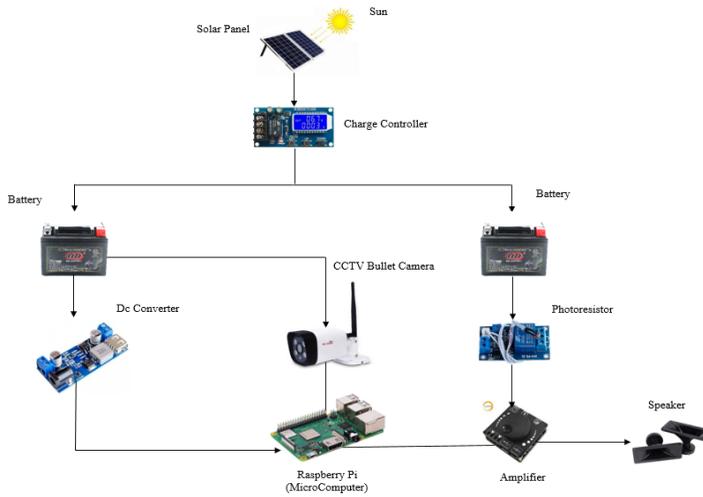


Figure 8 shows that the bird-repellent system comprises a single-board computer, camera, and speaker. Both the speaker and camera are connected to the Raspberry Pi to enable communication, allowing the exchange of data. The camera captures images and sends information to the Raspberry Pi, while the speaker produces loud sounds to scare away birds. The Raspberry Pi serves as the system's central processor, analyzing images from the camera and sending signals to the speaker to activate the deterrent sounds.

The system is powered by gel batteries, which are charged via solar panels, with the charging current regulated by a charge controller. A photoresistor is incorporated to automate the system, turning off the amplifier and speaker at night and switching them on in the morning. This integration ensures that the system operates efficiently while conserving power during periods of inactivity.

**Figure 9**  
System structure

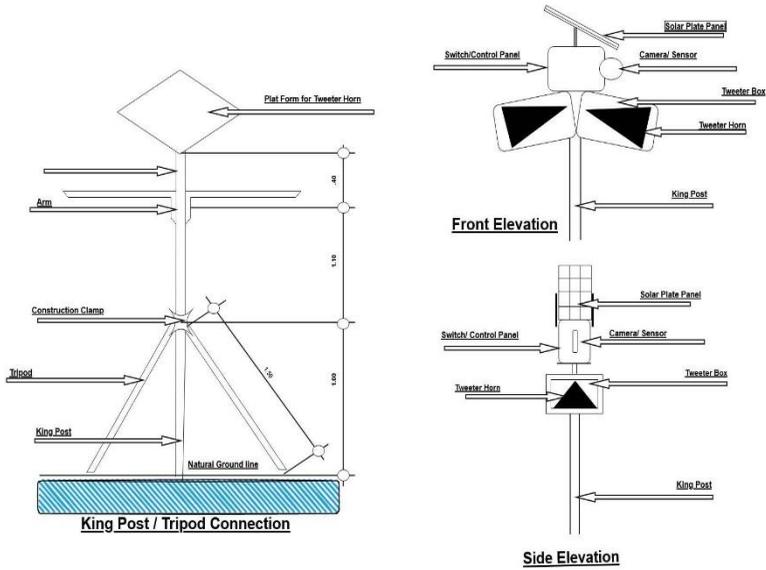


Figure 9 illustrates the assembly of the system, providing a clear guide for researchers to implement and understand the connections between each component. Multiple views of the system are presented to facilitate analysis of its physical layout once constructed. Additionally, each part of the system is labeled, making it easier to identify components and comprehend their placement within the overall setup.

**Figure 10**  
Labelling  
of birds





**Figure 12**

*Graph of downward trend in Tensorboard*

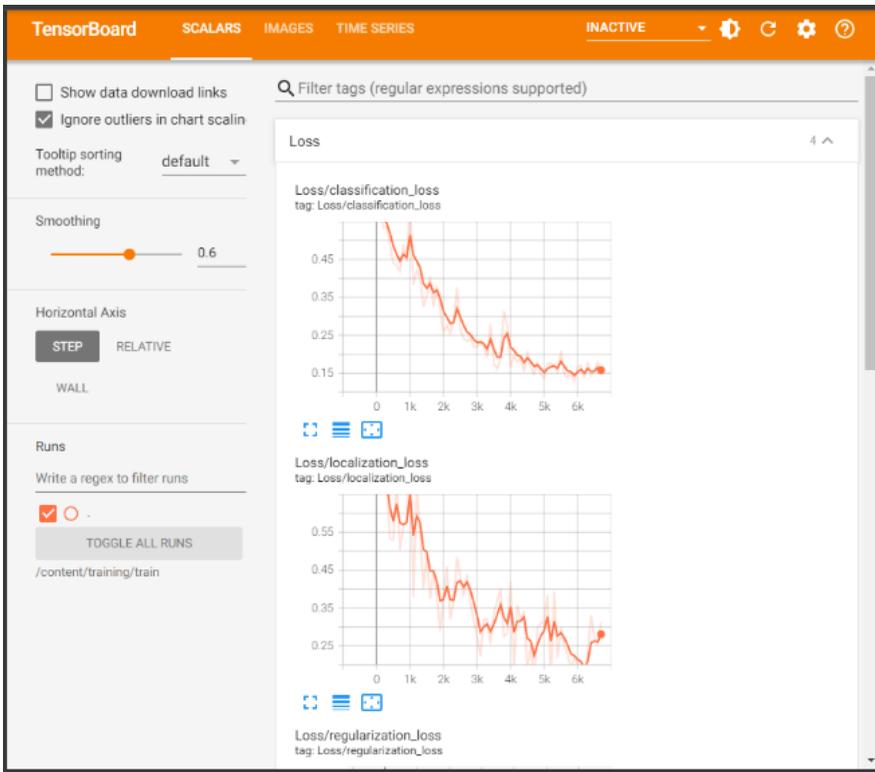


Figure 12 shows TensorBoard, a tool that provides essential measurements and visualizations during the machine learning workflow. TensorBoard’s extensive built-in functionality allows users to quickly understand the behavior of their model. It can monitor various metrics, including accuracy, root mean squared error, and log loss.

The model is then converted to TensorFlow Lite, which enables faster detection and is fully compatible with the Raspberry Pi. This conversion ensures efficient deployment of the trained model on the system’s hardware while maintaining performance.

**Figure 13**

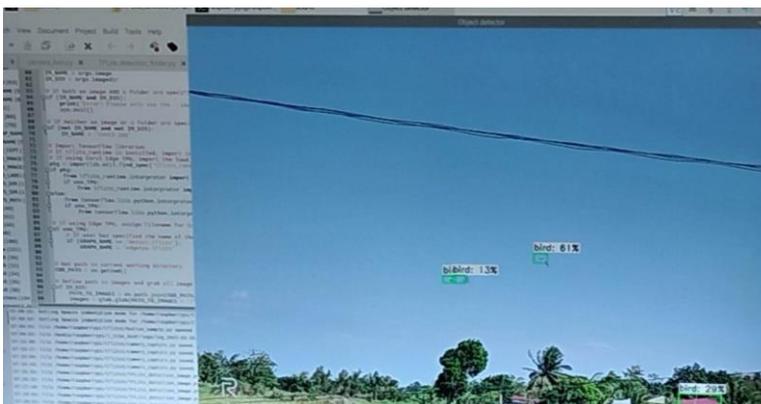
*Testing TensorFlow lite model*



Figure 13 illustrates the testing of the model. The results of bird detection show accuracy rates of 61% and 13%, respectively. The detection module was able to identify the bird even when it appeared as a small dot; however, the success rate in such cases was only 13%.

**Figure 14**

*Image processing*



As illustrated in Figure 14, the system captures an image, and the

detection module identifies whether a bird is present; if so, the speaker emits a sound. During testing, the researchers found that the detection module could reliably identify birds only within a distance of 60–70 meters from the system. When birds are farther away, the likelihood of detection decreases. The camera has a 2MP HD resolution, which limits image clarity, particularly for distant birds.

**Figure 15**

*Result of image processing*



The image processing function of the system utilized TensorFlow and Google Colab. TensorFlow was primarily used for training and inference of deep neural networks. With TensorFlow, best practices for performance monitoring and model retraining were implemented to ensure the detection module remained accurate and efficient.

The image demonstrates that the image processing function is operational. The detection module successfully identified the bird in the image, achieving confidence levels of 99%, 92%, and 77% for different detections.

**Figure 16**

*The developed system*



The IoT solar bird repellent with image processing is more reliable for driving away birds in rice fields than traditional scarecrows. The developed system effectively deters birds and can serve as a practical alternative to conventional methods. It reduces the effort required to manage birds, as they no longer need to travel back and forth across the fields to scare them away manually.

The researchers conducted extensive sound testing to observe the reactions of the sparrow (Maya). Various sounds, including frequencies, predator sounds, and startling sounds, were tested in a controlled environment. While the Maya showed signs of panic when exposed to frequency and predator sounds in this controlled setting, these sounds were ineffective in a real-world environment, such as a rice field. In open paddy fields, the sound dispersed before reaching the birds, resulting in little to no reaction. Among the tested sounds, the Maya responded most effectively to the sounds of guns, cannons, and missiles.

**Figure 17**

*Testing the sound with Maya in a Cage*



Observations also showed that the birds remained calm while inside the cage under normal conditions. However, when the system emitted gunshot, cannon, or missile sounds, the birds became visibly agitated, jumping, restless, and attempting to escape the cage. Based on these observations, the researchers concluded that the Maya are strongly affected by and react to these specific startling sounds.

Cattle are subjected to a variety of stressors, including thermal and chronic stress. For dairy cows, reducing stress is particularly important, as maximizing milk yield is a top priority. The metabolic and psychological strain on high-yielding cows can lead to decreased milk production and milk with lower protein and fat content. One significant source of stress is noise. Abrupt or loud noises can negatively affect milk production, making it essential to raise cattle in a quiet environment. Exposure to noise at 80 dB has been shown to reduce feed intake, increase agitation, and elevate heart rates in cows (Table 5). Additionally, noise can disrupt reproductive function, affecting the estrus cycle and conception rates.

**Table 5***Impact of the noise of varying intensity on cattle*

Noise Volume [dB]	The Effects of Noise
80 dB	Excessive anxiety, increased heart rate, reduction in feed intake
90-95 dB	Anxiety, frequent bowel movements, muscle tension, increased heart rate, reduction in rumen contractions food retention
≥100 dB	Morphological and biochemical changes in the blood (increase in blood glucose levels, development of leukocytosis)

Table 6 presents the materials, tools, and equipment used in the project, along with their respective prices and total cost. Conducting a cost–benefit analysis helps decision-makers make informed judgments about the system’s economic feasibility and allocate resources effectively. The study found that developing the IoT-based solar bird-repellent system required a higher initial investment compared to a traditional scarecrow, which is inexpensive since its materials are locally sourced. However, traditional scarecrows have become less effective because birds easily adapt to their static presence. In contrast, the proposed system, though costly at first, offers a long-term and sustainable solution through its durable components such as the Raspberry Pi, camera, solar panel, and battery, which can last for several years with minimal maintenance. Furthermore, it reduces farmers’ labor and time, as it automatically detects and repels birds without the need for manual intervention. Therefore, despite its higher cost, the system proves to be a more efficient, durable, and cost-effective investment for modern rice farming in the long run.

**Table 6***Cost and benefit Analysis*

	<b>Description</b>	<b>Quantity</b>	<b>Price</b>
1	1 ¼ Pipe (Post)	1	980
2	2 meters Pipe (Arm)	1	185
4	ABC Silicon Sealant Clear	1	280
5	Adjuster PC	1	15
6	Angle Bar 3/16	1	320
8	Black Screw	132	140
9	Bosny Spray Paint	2	340
10	BreadBoard	1	59
11	Clamp	3	270
12	Cutting Disc (HardiFlex)	1	250
13	Cutting Disc (Metal)	2	160
14	Double Sided Tape	1	19
15	Double Wire	1	22
16	Epoxy Primer Gray	1	270
17	Flat Bar	1 1/2	320
18	Glue Gun	1	200
19	Glue Stick	9	38
20	Hardi Sanepa 10x10 ft.	1	435
21	Heatsink	1	15
22	Jumper Wire	1	19
24	Light Control Switch	1	83
26	Manpower		2,000
27	Memory Card 16GB	1	400
29	Mini Amplifier	1	347
30	MOSFET	1	35
31	Nut and Bolt	4	40
32	OD Battery	1	550
33	Paint Brush	1	35
35	Regulator	1	15
36	Relay Module	1	39

	<b>Description</b>	<b>Quantity</b>	<b>Price</b>
37	Resistor	2	10
39	Shipping Fee		141
40	Socket	6	60
41	Solar Charger Controller	1	230
42	Solar Panel	1	669
43	Soldering Iron	1	160
44	Soldering Lead	1	60
46	Switch	2	96
47	Terminal	4	20
48	Thinner	1	45
49	Tweeter Speaker	2	1,300
50	Welding Rod	1	150
51	Wire	1	44
52	USB 32GB	1	500
53	Ethernet Cable	1	150
54	Raspberry Pi	1	4,000
55	Google Collab	1	600
56	CCTV Rover	1	3,000
<b>Total Amount</b>			<b>19,116</b>

Despite the higher cost, the bird-repellent system represents a worthwhile investment for farmers. The system is durable, with components designed to last several years. For instance, the Raspberry Pi can last 7 to 10 years, the camera and battery up to 5 years, and the solar panel up to 25 years. This longevity makes the system a sustainable and cost-effective solution over time, providing reliable bird control for paddy fields.

### ***Evaluation of the System***

Table 7 shows that the system received an overall mean score of 4.1 from IT experts and farmers, with a verbal interpretation of “Excellent.”

Among the quality attributes, Functional Suitability scored the highest with a mean of 4.47 (“Very Excellent”), indicating that the system functions correctly and meets farmers’ expectations.

**Table 7**

*Overall mean score*

<b>ISO 25010 Characteristics</b>	<b>Mean Score</b>	<b>Interpretation</b>
Functional Suitability	4.47	Very Excellent
Reliability	3.55	Excellent
Performance Efficiency	4.33	Excellent
Usability	4.36	Very Excellent
Security	3.92	Excellent
Compatibility	2.7	Poor
Maintainability	3.26	Neither/Nor Excellent
Portability	4.23	Very Excellent
<b>Overall Mean Score</b>	<b>4.1</b>	<b>Excellent</b>

The system was also found to be reliable in driving away birds and accessing recorded data, with a mean score of 3.55 (“Excellent”), showing general satisfaction with its dependability. Performance Efficiency achieved a mean score of 4.33 (“Very Excellent”), reflecting that the system performed well during demonstrations. For Usability, the system received a mean score of 4.36 (“Very Excellent”), suggesting that farmers found it easy to operate and that the camera and sound effectively deterred birds even from a distance. Security scored 3.92 (“Excellent”), indicating satisfaction with the system’s originality and protective features.

In contrast, the system did not meet the Compatibility requirement, scoring 2.7 (“Poor”), indicating that farmers were dissatisfied with its ability to exchange information. Similarly, Maintainability scored 3.26 (“Neither/Nor Excellent”), suggesting uncertainty among farmers regarding

whether system components could be reused or easily adapted to future changes.

Finally, the system met the Portability requirement with a mean score of 4.23 (“Very Excellent”), showing that farmers were satisfied with its ease of installation and its ability to replace traditional scarecrows in rice fields.

## **Conclusion**

Based on the evaluation by IT experts and farmers, the overall functionality of the system is working effectively. Respondents agreed that the system performs its intended functions well, although compatibility with other systems remains limited. Overall, the system received an “Excellent” rating across the ISO 25010 characteristics. Therefore, the researchers concluded that the system is reliable for driving away birds in the rice fields.

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# Automated Fish Pond Feeding and Detection of Water Turbidity

*Leandro D. Burog, Niel Brent D. De Villa & Louiege R. Rivarez*

Fish has become increasingly popular as a source of protein and essential nutrients over the past few decades. Consequently, the aquaculture sector has emerged as a potential solution to meet this growing global demand (Subasinghe et al., 2009; Garlock et al., 2022). However, sustainable fish farming faces several challenges, including maintaining optimal water quality, employing efficient feeding methods, and minimizing environmental impacts (Mansour, 2025; Karimanzira, 2025; Bohnes et al., 2022; Abdikadir et al., 2024; Cortes et al., 2025). Understanding the causes and consequences of fish kill incidents and fish health-related hazards in fishponds resulting from underfeeding and overfeeding practices is crucial. Researchers must evaluate feeding practices, monitor feeding rates, assess feed composition, and analyze fish growth and health parameters to develop effective guidelines for optimized feeding strategies (Hossain et al., 2025; Huang et al., 2025; Thornburg, 2025). Awareness campaigns, educational programs, and technological innovations can further promote responsible feeding management, improve efficiency, and mitigate risks.

Automatic fish feeders are widely recognized by aquarists as practical devices that can supply a calculated amount of food several times per day, promoting fish health and reducing food waste. These feeders, which range from simple battery-powered models to complex electronic systems (El Shal et al., 2021), can operate at any time of day or night. They provide fish with a consistent food supply, ensuring proper nutrition and growth. This is especially convenient for aquarists or fishpond owners who may not always be available to feed their fish manually. Automated fish feeders can be programmed to dispense food at predetermined times, allowing users to customize feeding schedules to the specific needs of their fish and maintain appropriate nutrition levels for growth and well-being.

Feeding fish manually can be time-consuming and physically demanding, particularly under extreme weather conditions, and determining the correct amount of food can also be challenging. The development of an automated fish feeding system aims to reduce the time and labor associated with traditional feeding methods. Through automation, fishpond operators can increase productivity, lessen human error, and ensure consistent feeding. By adopting aquaculture practices, communities can establish their own fish farming operations, improve their livelihoods, and become more self-sufficient in producing valuable seafood products. This provides economic opportunities, enhances resilience, and contributes to local economies while improving fish health, growth rates, and yield.

Decisions regarding the acceptance or rejection of technology can be difficult because technology continuously evolves, particularly in ICT-related applications. Several theories and models have been developed to better understand technology usage, but the Technology Acceptance Model (TAM) remains one of the most recognized in explaining factors that influence users' acceptance of modern technologies. TAM helps in

understanding the usefulness and usability of new systems. In this study, the concept of perceived usefulness (PU) is relevant, as fishpond owners believe that using an automated feeding system benefits both fish and owners compared to traditional methods. Another important aspect is perceived ease of use (PEOU), which reflects users' ability to accept and operate electronic devices effectively for fish feeding purposes.

A missed feeding schedule in a fishpond can have serious consequences for the health and survival of the fish. Fish require consistent and appropriate amounts of food to thrive, and failure to follow a feeding schedule can lead to underfeeding or overfeeding, both of which can cause health and water quality issues (Assan et al., 2021). Depending on the pond's size, automated fish pond systems can adjust feeding schedules accordingly. Smaller ponds, less than 1,000 square meters, may require two to four feedings per day, while medium-sized ponds ranging from 1,000 to 5,000 square meters may need two to six feeding cycles daily. When creating a feeding plan, careful consideration must be given to fish species, size, age, and environmental conditions. Automated fish pond systems using Arduino technology allow precise control over feeding schedules to ensure proper fish development and resource efficiency.

The health of fish in ponds also depends on water turbidity. Clean water with a turbidity or visibility range of 40–60 cm is considered optimal for fishponds, as it promotes good fish growth. Turbidity caused by plankton is generally beneficial because it indicates a healthy environment and abundant food sources for fish (Rodrigues et al., 2023). However, poor water quality can lead to fish kills and health-related hazards. Maintaining appropriate water conditions is therefore critical for fish survival and development. Researchers emphasize the need for proper water testing, filtration systems, regular water changes, and treatment applications when

necessary (Yusoff et al., 2024; Yavuzcan Yildiz et al., 2017; Liu et al., 2024).

Water turbidity refers to the concentration of dissolved materials, such as salts or minerals, in the water (Hidayana et al., 2024). The ideal turbidity level varies depending on the species being cultured. Most freshwater fish thrive in water with a turbidity of 1.000 to 1.025 g/cm<sup>3</sup>, although specific preferences may vary by species. Proper turbidity levels are vital for maintaining buoyancy, regulating oxygen availability, and ensuring overall fish health (Raghavendra et al., 2025; Adjovu et al., 2023).

The main objective of this study is to assess the functionality of the automated fish pond feeding and detection of water turbidity using Arduino UNO. This system aims to eliminate common problems in fishpond culture by improving feeding efficiency, maintaining ideal water quality, and enhancing the health and productivity of cultured fish.

## **Theoretical Framework**

### ***Fishpond***

Feeding management plays a vital role in ensuring the health, growth, and overall well-being of fish in aquaculture systems. Insufficient food availability can lead to aggressive behavior among fish as they compete for limited resources whereas restricted feeding not only triggers aggression but also hinders carp from reaching their full growth potential (Oh et al., 2007; Duan et al., 2025; Gao et al., 2022; Duan et al., 2011). To mitigate these challenges, producers must implement effective feeding management strategies that ensure fish receive adequate nutrition, thereby promoting optimal growth and reducing aggressive interactions during feeding periods.

Automatic fish feeders are central to achieving consistent and reliable feeding management. These devices ensure that fish receive the correct amount of food at regular intervals, helping them meet their dietary requirements and grow healthily. According to Karimanzira (2025), providing the appropriate amount of feed is crucial for maintaining water quality, as both overfeeding and underfeeding can negatively impact aquatic environments. Overfeeding leads to waste accumulation and deteriorating water conditions, while underfeeding results in malnutrition and poor fish health. Establishing a regular feeding schedule, such as feeding at the same time each day, promotes healthy feeding behavior and ensures fish receive balanced nutrition for growth and development.

Moreover, automatic fish feeders provide numerous advantages for both aquaculture and aquarium management. They offer convenience, precision, and flexibility in feeding schedules, which are particularly beneficial for aquarists with busy lifestyles or fish located in remote or deeper areas of ponds and oceans. El Shal et al. (2021) describe how automatic fish feeders, ranging from simple battery-powered devices to sophisticated electrical systems, deliver measured amounts of food at predetermined intervals. This not only guarantees consistent nourishment but also reduces food waste and maintains better water quality. Fantatto et al. (2024) further note that these systems can be customized to accommodate the nutritional needs of different species, ensuring optimal feeding conditions and promoting the health of aquatic populations.

### ***Water Turbidity and Feeding Control***

Proper feeding management also contributes to maintaining water clarity and preventing excessive turbidity (Hridoy et al., 2025). Hence, controlling both the quantity and timing of feed is essential for balancing

fish health with water quality. Excess feed decomposes into waste that deteriorates water conditions and may cause oxygen depletion, while insufficient feeding limits growth potential. Automatic fish feeders help regulate these factors by dispensing precise portions of food, ensuring that fish obtain adequate nutrients without overloading the aquatic environment. In this way, they support both healthy fish growth and the sustainability of aquaculture systems.

Automatic feeders can be used at any time, not only when the owner is absent. Many aquarists use them as part of a regular feeding routine to provide measured amounts of food several times per day. This practice benefits fish health, minimizes waste, and ensures steady water quality. As Karningsih et al. (2021) highlighted, modern automatic feeders offer flexibility, allowing aquarists to design feeding programs that cater to the unique needs of different species. Such systems provide reliability and convenience, making them ideal solutions for maintaining healthy aquatic ecosystems.

### ***Fish Feeder Prototypes and Innovations***

Several innovations have advanced the development of automated fish feeding systems. Noor et al. (2019) introduced a Microcontroller-Based Fish Feeder designed for aquariums, featuring timed feeding setups and controlled feed release. The system, operated by a PIC microcontroller, accommodates different feed types such as pellets, flakes, and powders, ensuring accurate and consistent feeding. Similarly, Susilawati et al. (2023) highlighted the benefits of such systems in preventing overfeeding and maintaining water quality. These feeders enable users to establish exact feeding times and portions, which are crucial for maintaining optimal fish nutrition and pond hygiene.

Karningsih et al. (2020) developed a self-feeding device designed for individuals with busy lifestyles who struggle to feed fish regularly. The portable and low-maintenance system provides multiple advantages but is limited to indoor use due to susceptibility to adverse weather conditions. In contrast, Niez et al. (2025) designed and tested an Automatic Fish Feeder system for aquaculture applications to address inefficiencies in manual feeding. This automated solution eliminated major issues related to hand feeding, saving time and effort for aquarists and fish farmers alike. Mohamed et al. (2024) supported this development, affirming that automated feeding provides a practical and efficient method that enhances feeding consistency and convenience in aquaculture operations.

In addition to these technological advances, Nave (2025) underscored the importance of establishing a self-sustaining forage base in ponds and aquariums. By creating ecosystems capable of naturally supplying the nutritional needs of fish, producers can reduce dependence on artificial feeding systems while promoting long-term ecological balance. Integrating plants, animals, and microorganisms into such systems supports the health and sustainability of the entire aquatic environment.

## **Research Framework**

### ***Data***

The system evaluation data were collected through a survey involving ten respondents. The total number of respondents was determined using Slovin's formula, and questionnaires were distributed using a random sampling technique. The questionnaire was developed based on the Technology Acceptance Model (TAM), which includes four key constructs: Perceived Ease of Use, Perceived Usefulness, Attitude Toward the

Prototype, and Intention to Use the Prototype. The researchers utilized the weighted mean formula to analyze the data. A Four-Point Likert Scale was employed, consisting of the categories Strongly Agree, Agree, Disagree, and Strongly Disagree. Each scale point was assigned a corresponding mean range, which was used to interpret the evaluation results.

### ***Experimental Design***

The experimental design for automatic fish feeders involves setting up controlled conditions, such as an aquarium or fish tank, where the performance of the feeders can be accurately assessed. This process includes selecting the specific automatic fish feeder technologies to be evaluated and establishing the parameters and guidelines for the experiment. Researchers first determine the type and quantity of feed to be used in the trials to assess the sensitivity and accuracy of the various feeder systems. They then define the feeding parameters, such as the amount of food to be dispensed, as well as the frequency and duration of feeding cycles, to ensure consistency and reliability in testing.

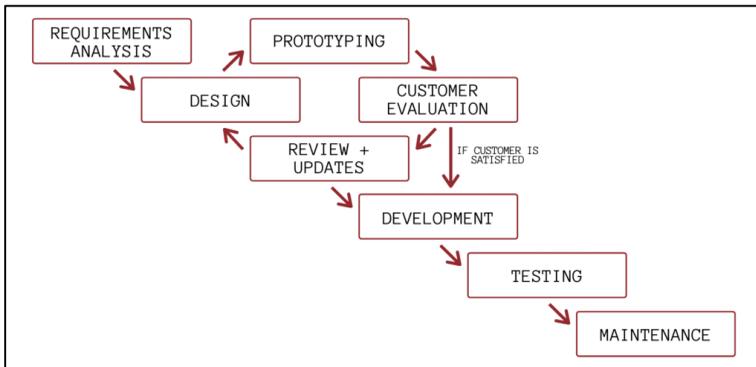
Once the experimental setup and procedures are established, testing can begin. The automatic fish feeders are activated under controlled conditions, and the behavior of the fish is carefully observed. The data collected from these trials are then analyzed to evaluate the feeders' precision, sensitivity, and overall effectiveness. This experimental design allows researchers to systematically assess different automated fish feeder technologies by constructing controlled environments, selecting appropriate devices, establishing standardized guidelines, and conducting performance evaluations to determine their efficiency and reliability.

## Modeling

The choice of development model plays a crucial role in the testing and evaluation process. It determines the scope, timing, and methodology of testing, influences regression testing strategies, and shapes the overall testing framework. These structured approaches, known as development models, provide systematic procedures for system design, implementation, and testing. Over time, various software and system development life cycle models have been formulated to meet differing project requirements and achieve desired outcomes effectively.

**Figure 1**

*Prototyping model*



The study employed the prototyping paradigm to actively test and enhance the functionality and performance of the automated fish pond feeding system. This approach involves constructing and evaluating a prototype of the system, incorporating Arduino-based sensors to detect water turbidity and control feeding operations.

*Planning and design phases.* The planning and design phases begin with identifying the research question or hypothesis and defining the study's specific aims and objectives. A thorough literature review is conducted to

assess the current state of knowledge, identify gaps, and determine areas requiring further investigation.

*Requirements gathering and analysis.* A methodical approach is adopted to ensure the effective deployment of the system. Requirements gathering involves conducting interviews and collecting user feedback to understand the needs and expectations of potential users. Equipment and materials are carefully evaluated to guarantee timely availability. The system is designed using Arduino technology to enable precise automated feeding, while sensors are integrated to provide real-time monitoring of water turbidity.

*Design phase.* In the design phase, a preliminary and conceptual layout of the fish-feeding system is created. This basic design serves as a rough sketch that outlines the system's components and functionality, providing stakeholders with an overall understanding of the intended system without being fully comprehensive.

*Prototyping phase.* During prototyping, the researchers develop a preliminary working model of the system. This includes selecting hardware components, designing circuitry, integrating turbidity sensors and feeding mechanisms, and developing the software code for the Arduino UNO. The prototype undergoes initial testing to verify basic functionality, and iterative refinements are made based on the results.

*User evaluation.* The prototype is then presented to users for initial evaluation. At this stage, feedback is collected regarding the system's strengths and weaknesses. This input helps the development team refine the prototype. If the users are satisfied with the initial design, the team may proceed to the next development stage. Otherwise, the feedback informs updates and adjustments to improve system performance.

*Review and updates.* When user feedback indicates areas for

improvement, the researchers analyze the suggestions and implement necessary modifications. A revised prototype is produced, incorporating client recommendations and addressing identified deficiencies. This iterative cycle ensures that the system meets user requirements effectively.

*Development phase.* The development phase involves detailed system design, hardware integration, and software implementation. Researchers finalize the placement of components, integrate sensors and actuators, and program the Arduino UNO to control feeding operations and detect water turbidity. A functional prototype is created and tested rigorously to validate system performance.

*Testing phase.* Comprehensive testing is conducted to assess both the automated feeding mechanism and the Arduino sensors for water turbidity detection. Experiments under various conditions evaluate the system's accuracy, reliability, and overall functionality, ensuring it meets performance expectations.

*Maintenance phase.* The maintenance phase ensures the system remains functional and efficient over time. This involves regular inspections, system checks, software updates, and component upkeep. Continuous monitoring allows for timely resolution of issues and optimization of system performance.

## **Technical Framework**

This section describes the key components of the automated fish-feeding system. Central to the system is the feeding technology, which enables automatic and controlled feeding according to preset schedules. The system utilizes Arduino sensors, which are responsible for regulating feed delivery and monitoring water turbidity in real time. These components

work together to ensure precise feeding, maintain water quality, and support optimal fish health and growth.

### *Software*

Table 1 presents the software requirements for the developed system, outlining the different software tools used to construct the system using Arduino UNO. These software components work together to process sensor data, execute control decisions, and enable users to monitor and manage the system effectively. The specific software required may vary depending on the system’s needs and typically includes tools such as an integrated development environment (IDE) for coding and a web browser for monitoring or interface purposes.

**Table 1**

*Software specifications*

<b>Software</b>	<b>Description</b>
IDE Platform	The Arduino Integrated Development Environment - or Arduino Software (IDE) - contains a text editor for writing code.
Operating System	A Microsoft Windows operating system that runs on a 32-bit or 64-bit architecture used in the development of the system
Web browser	Chrome (recommended) or any web browser installed.
Blynk App	Platform for iOS or Android smartphones that allows users to remotely control devices like Arduino, Raspberry Pi, and NodeMCU.

## Hardware

Table 2 presents the planned hardware requirements for the system, listing the components needed to build the automated fish pond feeding system using Arduino UNO.

**Table 2**  
*Hardware specifications*

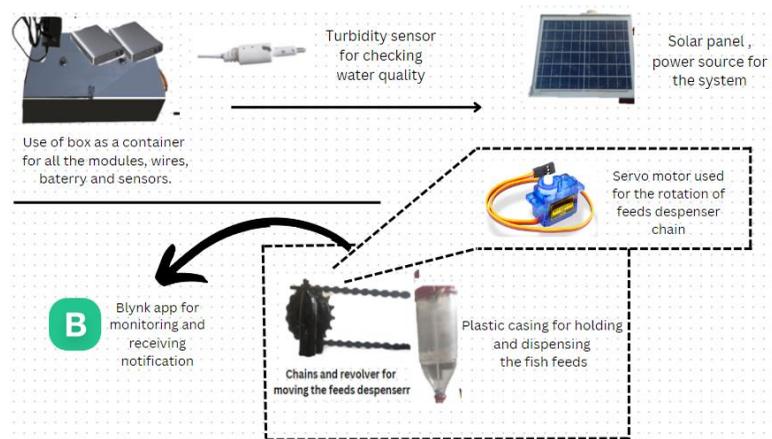
Hardware	Specification
<b>ARDUINO UNO</b> 	microcontroller board based on the ATmega328P (datasheet).USB 2.0 Cable Type A/B
<b>NODEMCU ESP8266</b> 	The NodeMCU ESP8266. The open-source NodeMCU firmware and development board.
<b>SERVO MOTOR MG996</b> 	The MG996R is a metal gear servo motor with a maximum stall torque of 11 kg/cm. RC servos the motor rotates from 0 to 180 degree.
<b>DS1302 RTCMODULE</b> 	The DS1302 real time clock module is a cheap module with high accuracy that can be used in different projects.
<b>TURBIDITY SENSOR</b> 	5V operating voltage sensor can detect water turbidity linearly within the test range 1.873 NTU to 1011.93 NTU.
<b>LOADCELL HX711</b> 	The HX711 is a precision 24-bit analog-to-digital converter (ADC) intended for scales.
<b>SOLAR PANEL</b> 	12V with Clip Flexible Power Solar Panel Battery Panels Modules Charger

The hardware includes an Arduino microcontroller to process sensor data and make control decisions, a servo motor for rotational feed dispensing, and various modules to support system operation. Additionally, a solar panel provides power, and a load cell ensures accurate measurement and efficient system performance. Together, these components enable the full automation of fish pond feeding using the Arduino UNO platform.

### *System Design*

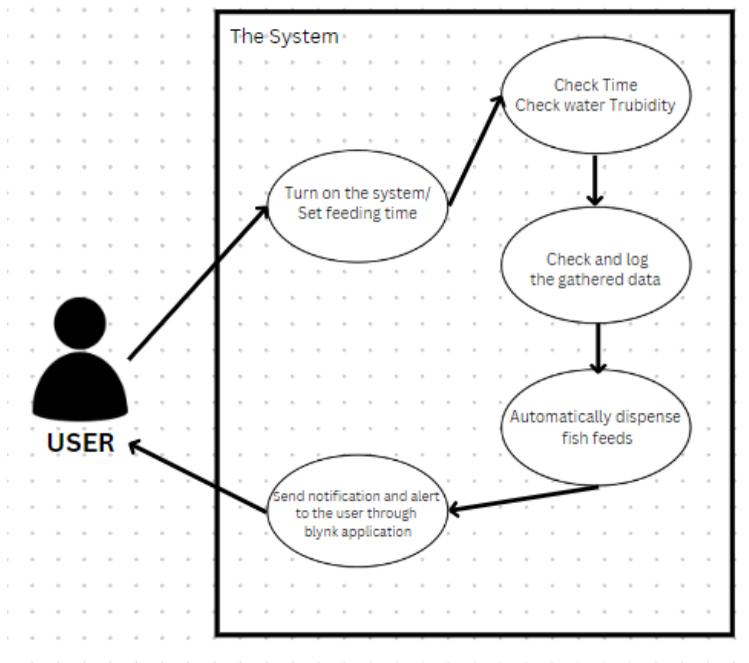
As shown in Figure 2, the fish-feeding system operates through a series of steps to ensure proper functionality. After completing the coding process, all sensors and modules are initialized in a connected state. Once initialized, the sensors begin monitoring the environment to detect any potential restrictions or limitations. The microcontroller then analyzes the sensor outputs and compares them against predetermined specifications to verify that the system is operating correctly. This process ensures that the system functions as intended, with accurate monitoring and control of feeding operations.

**Figure 2**  
*System architecture design of the prototype*



**Figure 3**

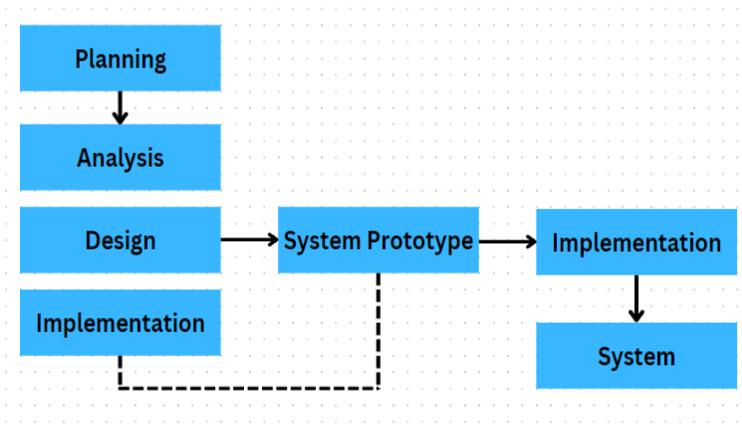
*Use case diagram of the prototype*



As illustrated in Figure 3, the fish pond feeding and water turbidity detection system reduces the need for direct human intervention by increasing automation in pond management. During initial installation, the system undergoes an initialization process that sets up all necessary components and parameters. Once operational, it continuously collects essential data on fish feeding behavior and water turbidity levels. This information is then transmitted to users via Wi-Fi notifications, providing timely updates and critical insights. By automating monitoring and reporting tasks, the system minimizes human involvement, allowing users to focus on other important activities while ensuring optimal fish health and water quality.

**Figure 4**

*Implementation flow chart of the prototype*



In Figure 4, the initial setup process is critical for the proper operation of the fish feeding system. Once the sensors and components are activated, the system begins scanning the area to detect potential restrictions or obstructions. This step allows researchers to identify issues early and make necessary adjustments to enhance system performance. Continuous monitoring, evaluation, and adjustment are essential throughout development and deployment, enabling researchers to fine-tune components and optimize the system to ensure it operates at peak efficiency.

**Figure 5**

*Circuit diagram of the prototype*

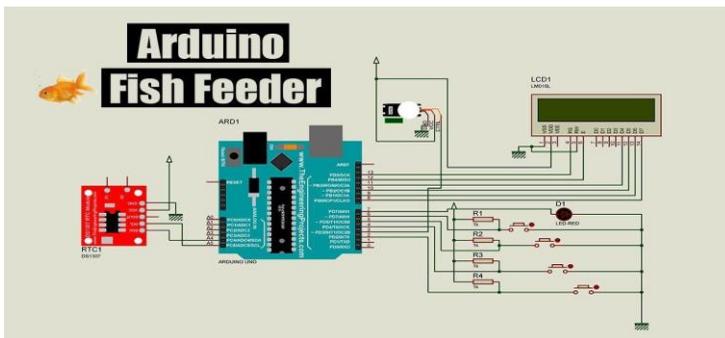


Figure 5 illustrates the circuit diagram of the automatic fish feeder system, providing a comprehensive overview of the system's layout, components, and their interactions. The system is designed for simplicity and convenience, ensuring easy setup and operation. Its portable and lightweight construction allows for installation in a variety of settings. Additionally, the user-friendly interface enables users to operate and monitor the system efficiently, requiring minimal technical expertise.

**Figure 6**  
*Storyboard of  
the Prototype*

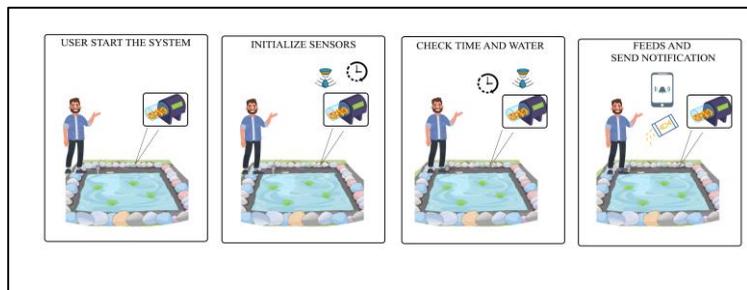


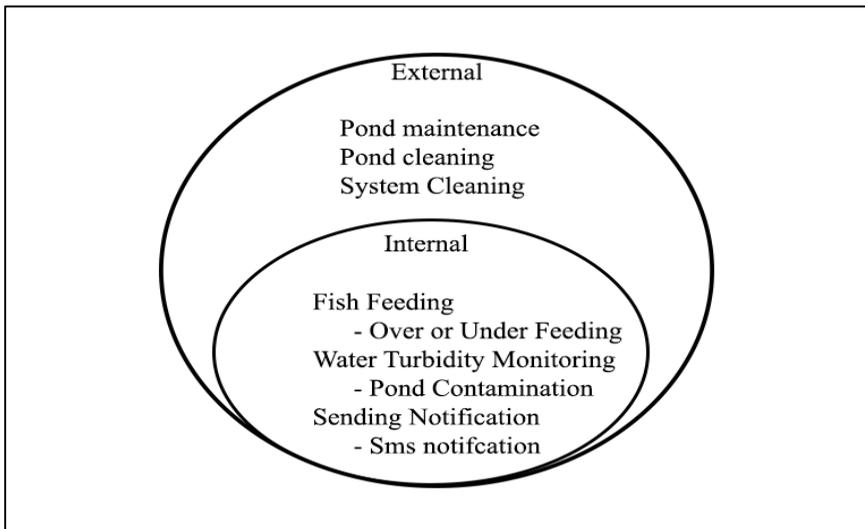
Figure 6 illustrates the workflow of the fish feeding system, from system startup to the user receiving the necessary information. The system is designed to fully automate fish feeding in ponds, addressing issues caused by inconsistent feeding schedules, such as water contamination and health problems in fish. Compact, sleek, and aesthetically designed, the device is easy to install in aquariums or ponds. It features configurable feeding schedules, an automated food dispenser, and a visible display showing the feeding timetable.

By providing regular and consistent feeding, the system promotes better digestion and strengthens the immune systems of the fish, contributing to overall health. Its user-friendly design allows fish owners to easily adjust feeding schedules and refill the dispenser, ensuring efficient operation. The workflow demonstrates how the system manages automated

feeding while delivering timely updates and relevant information to the user.

**Figure 7**

*System boundary of the prototype*

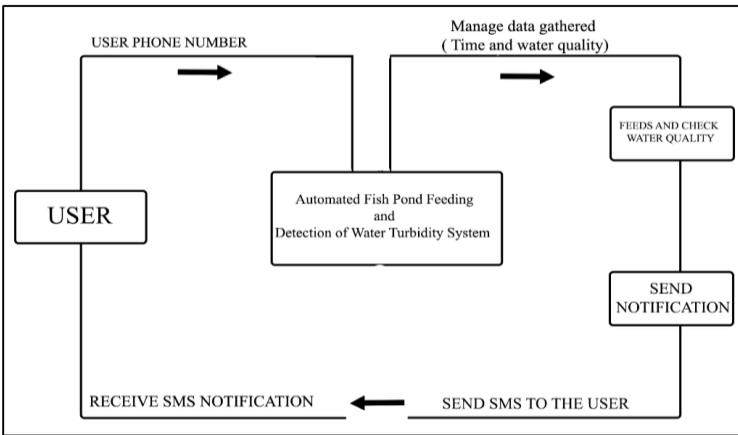


In Figure 7, the scope of the fish feeding system is defined by its system boundary, which encompasses both internal and external components. Internal components include the fish feeding device, the food dispenser, and the configuration of feeding schedules, while external components involve pond maintenance, pond cleaning, and system upkeep. Defining this boundary is essential for understanding the system's impact on its environment, guiding the design, development, and maintenance processes, and identifying potential limitations or risks associated with its implementation.

Figure 8 illustrates how information is transmitted and processed within the system. It begins when the owner inputs their phone number and sets the feeding schedule through the system device.

**Figure 8**

*Dataflow diagram of the prototype*



The system processes this information to control the food dispenser, releasing the specified amount of food into the fish pond at designated times. Simultaneously, the system monitors water quality in the pond and provides feedback to the owner via Wi-Fi notifications. This data flow is essential for maintaining a consistent and automated feeding process, promoting the health and well-being of the fish, and keeping the owner informed about feeding activities and water conditions.

**Figure 9**

*System Activity of the Prototype*

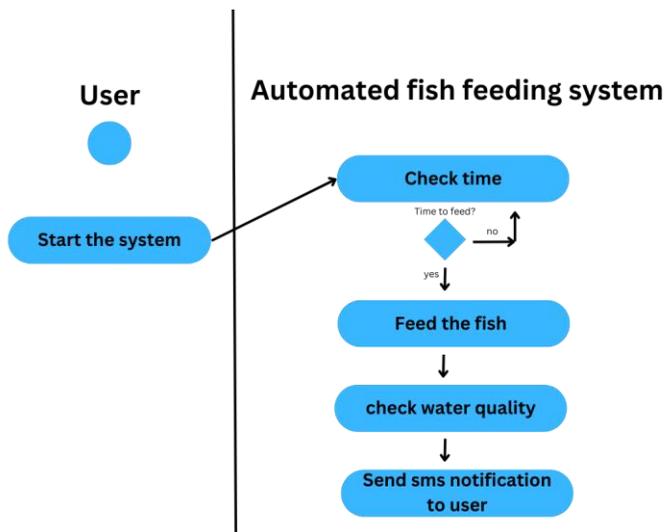


Figure 9 illustrates the various tasks involved in an automated fish feeding system, providing a comprehensive overview of its operation from start to finish. The process begins with the initialization of all components, including the feeding mechanism, sensors, and controllers responsible for monitoring the environment and managing fish feeding. Once initialized, the sensors collect data on the pond environment, such as water temperature, pH levels, and other relevant parameters.

Following data collection, system requirements and specifications are analyzed, leading to the design and construction of a prototype. The prototype is then tested to ensure it meets the desired criteria before installation and operation. Long-term maintenance procedures are also established to ensure consistent performance. Overall, the automated fish feeding system functions cohesively to provide fish with the necessary nutrients while maintaining optimal health and environmental conditions.

**Figure 10**

*The developed system*

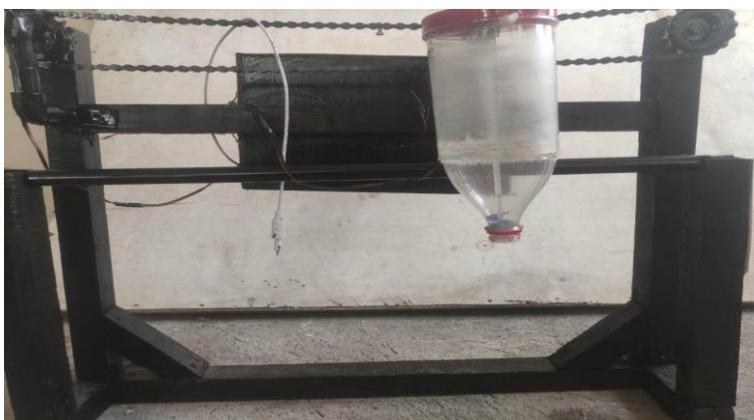


Figure 10 shows the developed system. Users reported that the system was easy to use and intuitive, facilitating its integration into their

fish pond operations.

### ***System Evaluation***

This section presents the survey results collected from ten respondents. The questionnaire was based on the TAM, which includes the constructs of Perceived Ease of Use, Perceived Usefulness, Attitude Toward the Prototype, and Intention to Use the Prototype. A Four-Point Likert Scale was employed, consisting of the categories Strongly Agree, Agree, Disagree, and Strongly Disagree, from which respondents could select their answers for each question.

**Table 3**

*Weighted mean distribution of the criteria for the developed system*

<b>Technology Acceptance Model</b>	<b>Weighted Mean</b>	<b>Remarks</b>
Perceived ease of use (PEOU)	3.27	Agree (A)
Perceived usefulness (PU)	3.38	Strongly Agree (SA)
Attitude toward Prototype	3.43	Strongly Agree (SA)
Intention to use Prototype	3.15	Agree (A)
<b>Average</b>	<b>3.30</b>	<b>Strongly Agree (SA)</b>

Table 3 presents the average weighted mean of the system assessment survey, which is 3.30, indicating that respondents strongly agree regarding the system's performance. This demonstrates that the fish pond feeding and detection of water turbidity system effectively fulfills the stated requirements. The high weighted mean reflects strong user approval and acceptance, suggesting that the system aligns with user needs and is likely to achieve the stated objectives. Overall, this positive reception indicates that the system meets or exceeds user expectations.

Respondents perceive the system as user-friendly and easy to

interact with, highlighting its intuitive design. The interface allows users to navigate and operate the system without encountering significant difficulties, promoting seamless interaction and operational efficiency. This positive perception reflects the successful application of user-centered design principles, ensuring that the system meets the expectations and needs of its users while providing a convenient and satisfying experience.

The system's mobile app further enhances usability and operational control. Respondents reported that the app allows them to remotely control the feeding process, streamlining operations and enabling precise, timely feeding. This functionality contributes to improved fish health and growth, demonstrating the practical utility of the system in real-world pond management.

The respondents' attitudes toward using the system indicate a seamless and satisfying daily experience. Users find it easy to operate due to its intuitive interface and controls, while automated feeding eliminates the need for manual intervention. The system's reliability and accuracy ensure that fish receive appropriate nutrition and that water quality is continuously monitored.

Respondents also recognize that the system helps identify potential challenges early and allows for timely adjustments to enhance overall effectiveness. Users expressed their intention to use the system daily. This confirms that the system provides a practical, automated solution for pond feeding, ensuring consistent nutrition for the fish while offering convenience and efficiency. By integrating automation and real-time water turbidity monitoring, the system effectively supports the regular operation and management of fish ponds.

*Economic feasibility.* The economic feasibility of the system was assessed to determine whether its expected benefits outweighed or met the

anticipated costs. An analysis of both advantages and disadvantages was conducted to evaluate the system's overall viability. The study provided insights into the system's costs and benefits by considering its strengths and limitations. Input on the system's efficiency and economic practicality was collected through a TAM-based questionnaire survey. This assessment method offered a reliable means of comparing the system's actual performance against expected outcomes, helping to determine its economic viability.

*Technological feasibility.* The technological feasibility of the system was evaluated. This assessment examined the compatibility and capabilities of the Arduino UNO microcontroller with the required sensors, actuators, and communication protocols for automating fish pond feeding and monitoring water turbidity. The robust hardware and software ecosystem of the Arduino UNO, along with its extensive library support and active community, provided an excellent foundation for developing and integrating the system. Comprehensive testing and validation confirmed the system's reliability and accuracy under real-world conditions. This research demonstrated that using Arduino UNO was both effective and sustainable for automating fish feeding and detecting water turbidity, confirming its technological feasibility.

*Operational feasibility.* Operational feasibility focused on the practicality and ease of use of the system in real-world settings. Factors such as user acceptance, simplicity of operation, and integration with existing fish pond management practices were considered. The system's user-friendly interface allowed pond owners and operators to navigate and interact with it efficiently. Automation of fish feeding and real-time water turbidity detection streamlined pond management, increased productivity, and reduced the need for manual labor, demonstrating the system's strong

operational feasibility.

## **Conclusion**

The development of a hardware design using Arduino UNO for automated fish feeding and water turbidity detection represents a significant improvement in fish pond management. This automated approach enhances overall pond management, increases productivity, and reduces the need for manual labor. Furthermore, a comprehensive assessment of the proposed prototype confirmed its compliance with the safety standards established by the Bureau of Fisheries and Aquatic Resources (BFAR). Evaluation of factors such as electrical components, structural integrity, and material safety verified that the system meets the required safety criteria. The Technology Acceptance Model (TAM) assessment highlighted strong user acceptance and adoption of the prototype. These findings suggest that the prototype has considerable potential for widespread implementation in fish pond operations.

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# Water and Fertilization Management Prototype for Eggplant

*Hasan Rase, Mark De-Imoy, Marlon C. Malakas & Yvhan Dave R. Morales*

Water and fertilization are critical components in farming, as different crops and plants require specific watering and fertilization schedules to thrive. Effective water and fertilization management can significantly support farmers, particularly when implemented through automated hardware systems (Aijaz et al., 2025; Lakhier et al., 2024; Xing & Wang, 2024; Et-taibi et al., 2024; Kaur et al., 2024). Such technology reduces manual labor, provides more time for farmers to manage their crops, and ensures consistent plant care.

According to Ricciardi et al. (2018), smallholder farmers, particularly older individuals in developing countries, produce the majority of the world's food. However, older farmers are less likely to adopt new technologies that could sustainably increase agricultural productivity while safeguarding the environment. This underscores the importance of encouraging younger generations to engage in agriculture. Technological solutions, such as automated systems, can help bridge the gap created by an aging farming population. For instance, in Japan, Hiroki Iwasa, a former IT

engineer with limited farming experience, developed computer-controlled greenhouses that manage every aspect of the growth environment, including humidity, carbon dioxide, nutrients, water, and temperature (Kaneko, 2017). This approach highlights how technology can make farming more appealing and efficient for younger farmers while ensuring optimal crop growth.

The present study focused on developing a water and fertilization management system specifically for eggplant cultivation, targeting small vegetable farmers. The prototype consists of a water pump that automatically switches on and off and includes a timer setting to regulate both the duration and frequency of water delivery. By automating irrigation and fertilization, the system reduces manual labor and ensures consistent plant care. Irrigation, defined as the application of water at required intervals and amounts, is essential not only for farm productivity but also for promoting proper seed germination, maintaining soil fertility, and supporting plant growth and development (Kelley et al., 2025).

Fertilization strategies also play a key role in crop productivity. Moncada et al. (2020) states that fertilized spring seedlings and transplants are initially treated with soluble fertilizers mixed with water, later transitioning to granular vegetable fertilizers as the plants grow. Optimal water management combined with crop-specific fertilizer rates can increase productivity while reducing non-point source nutrient pollution, making it both environmentally sustainable and economically beneficial (Hashemi et al., 2024; Feng et al., 2020; Abd-Elrahman et al., 2022).

Globally, smallholder farmers provide the food relied upon by up to 70% of the world's population, yet they remain financially vulnerable and increasingly affected by climate variability (Joshi, 2024). While traditional irrigation methods have long been used to water crops, modern technology

allows for more efficient and precise watering and fertilization, easing farmers' workload and enhancing crop management. Recent studies by Mohammadi et al. (2019) show that root water and nitrate uptake under optimal irrigation conditions (So treatment) exceeds that of conventional methods, with application efficiency improving by 9–15% depending on the treatment. This underscores the value of automated water management systems in maximizing resource use.

The primary objective of this study was to develop a functional prototype for water and fertilization management of eggplant, enabling small vegetable farmers to efficiently manage irrigation and nutrient application while reducing labor and increasing productivity.

## **Theoretical Framework**

### ***Water Management***

Water is a fundamental resource in agriculture, essential for crop growth and livestock production. With global population growth accelerating, efficiently managing available water resources has become crucial to meeting the increasing demand for food. Effective water management remains a significant challenge, but recent technological advancements have improved monitoring and management practices in agriculture (Parra-López et al., 2025; Alharbi et al., 2024; Antu et al., 2024). Applications of the Internet of Things (IoT), wireless sensor networks, and cloud computing have enabled smarter, more automated approaches to agricultural water management. By addressing water management holistically, these technologies aim to maximize water use efficiency, enhance crop yield and quality, and reduce the need for extensive human intervention (Abdelmoneim et al., 2025; Mansoor et al., 2025; Nsoh et al.,

2024).

Uhlenbrook et al. (2022) emphasizes that knowledge of water availability and usage is critical not only for agriculture but also for environmental management, societal needs, navigation, and transportation. Accurate forecasting of water supply and demand has long been a challenge worldwide. By predicting incoming water volumes in reservoirs, farmers and managers can make informed decisions regarding water distribution and usage. A systems-based perspective further enhances water management by considering the interactions between subsystems, the dynamic changes over time, and the broader impacts of interventions. This approach prevents the isolation of water management subsystems, allowing farmers to optimize irrigation through automation while remotely monitoring and controlling their farms, thereby improving efficiency and responsiveness.

### ***Fertilizer Management***

Fertilization is another critical aspect of farming that directly impacts crop productivity and environmental quality. Proper fertilization ensures that crops receive adequate nutrients during peak growth periods, based on the soil's inherent nutrient-supplying capacity. Mismanagement of fertilization can lead to economic losses, soil degradation, and contamination of groundwater and surface water. Over-fertilization, in particular, can cause eutrophication, whereby excess phosphorus in freshwater promotes algal blooms that deprive other species of oxygen and sunlight, disrupting aquatic ecosystems (Xing et al., 2025).

Fertilizer application practices often vary among regions and even among farmers within the same area. In irrigated plantations, fertilizers are most effective when applied 12–24 months before or after the peak growing

season. However, in regions where subsidies encourage high fertilizer usage, nutrient overabundance is common, leading to environmental degradation and reduced water quality. Achieving a dynamic balance in nutrient application is therefore essential for sustainable agricultural productivity and environmental protection.

### ***Related Prototypes***

*Crop irrigation and fertilization using purified wastewater.* A pioneering prototype developed by ENEA and the University of Bologna, in partnership with the Hera Group and Irritec, integrates purified wastewater for crop irrigation and fertilization (ENEA, 2022). This system conserves water, provides nutrients that can partially replace chemical fertilizers, and enhances the sustainability of the water purification process. The prototype, part of the Value CE-IN project funded by the Development and Cohesion Fund and the Emilia-Romagna Region, was tested at the Cesena purification facility on 120 crops, including 66 peach trees and 54 industrial tomatoes. This innovation demonstrates how wastewater can be repurposed to increase resource efficiency and reduce the environmental footprint of agriculture.

*Embedded system for greenhouse irrigation and fertilization.* Mite-Baidal et al. (2019) developed a prototype that leverages embedded systems and hardware-software codesign to automate greenhouse irrigation and fertilization. The system reduces manual labor while improving efficiency and precision. Soil moisture sensors trigger irrigation or fertigation through nebulizers, ensuring plants receive the right amounts of water and nutrients. The system also measures soil nitrogen, phosphorus, potassium, and other mineral levels, while a solar panel provides sustainable energy. An ultrasonic sensor monitors water levels in tanks for optimal rationing.

Farmers access real-time data via a smartphone application, with all information stored on a cloud server for record-keeping and analysis. This prototype automates critical processes, reduces costs, and allows farmers to provide optimal care for greenhouse crops while maintaining detailed daily records.

## **Research Framework**

This section describes the methods employed in conducting the study, including the research design, methodology, and the technical aspects involved in system modeling.

### ***Design***

This study employed an experimental research design, which provides a structured framework of protocols and methods developed to conduct scientific investigations involving two sets of variables. In this setup, the first set of variables remains constant and serves as the basis for comparing changes observed in the second set. This approach allows researchers to test hypotheses systematically and objectively. Moreover, the use of an experimental design enables researchers to carry out their research aims with greater clarity, transparency, and control over influencing factors.

### ***Respondents***

The study utilized a quota sampling method to ensure an unbiased selection of participants and improve the generalizability of the findings. Quota sampling is a non-probability sampling technique wherein researchers select participants who accurately reflect the characteristics of the target population. Participants are chosen based on specific traits or

attributes relevant to the study.

A total of 15 vegetable farmers from Sariaya, Quezon, Philippines, were selected as respondents. The researchers recognized that additional data could further enhance the comprehensiveness and validity of the study's results. Among the respondents, the majority were 41 years old and above (40%), followed by those aged 36–40 years (33.33%). In terms of farming experience, most had been engaged in farming for 2–3 years (60%), while 33.33% had four years or more of experience in the field.

### ***Instrument***

The primary research instrument was a questionnaire designed to gather data on farmers' perspectives regarding water and fertilizer efficiency. Respondents rated their familiarity with the sub-variables using a Likert scale. The third section of the questionnaire assessed the prototype machine's quality, focusing on its functional suitability, usability, reliability, and maintainability. This section aimed to measure respondents' satisfaction with the developed prototype's performance.

The Likert scale was used to quantify the participants' responses, providing a standardized way for them to indicate their level of agreement or disagreement with each statement. This approach facilitated the collection of numerical data suitable for statistical analysis, allowing the researchers to identify patterns and trends in participants' perceptions of the prototype machine's quality and usability.

Before distribution, the questionnaire underwent two validation procedures: content validation and concurrent validation. Content validation involved the review and feedback of three experts, an MIT professor, an IT instructor, and an ICT NCII competencies assessor, to ensure that the items were clear, relevant, and aligned with the study's

objectives. These validation processes established the reliability and accuracy of the instrument, thereby enhancing the credibility, rigor, and integrity of the study's findings.

### ***Statistical Treatment***

The data collected were analyzed using frequency, percentage distribution, weighted arithmetic mean, and ranking. These statistical tools allowed the researchers to summarize responses, interpret trends, and draw meaningful conclusions from the gathered data.

### ***Ethical Considerations***

The study adhered to the ethical principle of informed consent, ensuring that all respondents participated voluntarily. Participants were provided with sufficient information about the study's purpose, procedures, and potential implications to make an informed decision about their involvement. The researchers emphasized that participation was entirely voluntary, free from any form of coercion or undue influence, in accordance with standard ethical research practices.

### ***Modeling***

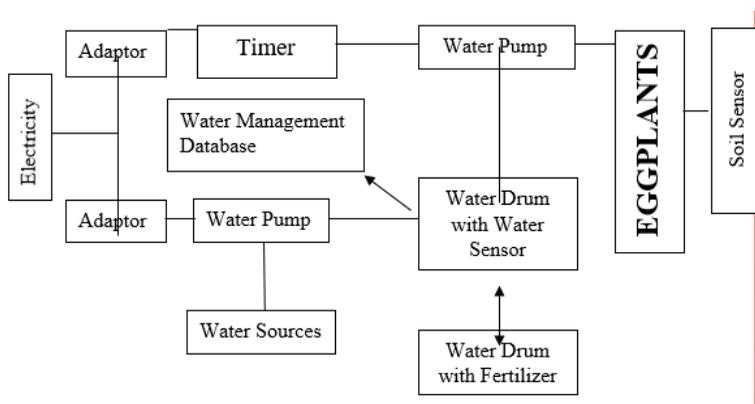
Figure 1 presents the flow diagram of the developed hardware. The diagram illustrates the process of the automated water and fertilizer management system designed for vegetable farmers. The system operates using a switch timer connected to an electrical source, which automatically activates the machine. Through this timer, farmers can set the specific duration for which the water pump will operate and the length of time allotted for fertilization of the eggplants.

Once activated, the system records in its database the date, time, and

duration of the water pump's operation. The electrical power is then transferred to the water pump motor, enabling the distribution of water through the connected pipes. The water drum is equipped with a water level sensor that monitors the water volume. When the water level reaches a critical point, the pump connected to the water source automatically activates to refill the drum. Once the desired water level is reached, the pump automatically shuts off to prevent overflow.

**Figure 1**

*Flow diagram*



The fertilizer drum is connected to the water pump through a hose, allowing the system to mix and distribute fertilizer as needed. When the eggplants require fertilization, the system channels the water-fertilizer mixture through the pipes, ensuring that the plants are efficiently watered and nourished. This automated process reduces manual labor, conserves resources, and promotes consistent plant growth.

### ***Procedures of the Different Phases***

*Machine design.* The machine developed for the water and

fertilization management of eggplants for vegetable farmers is a prototype model. It operates through a switch timer, a device that can automatically turn on and off various types of electrical equipment at preset times. Using this instrument, farmers can set the duration for which the water pump operates and the time allotted for fertilizing the eggplants.

*Analysis.* The machine operates using a switch timer connected to a power source. Farmers set the desired duration for irrigation and fertilization, after which the timer automatically activates the system. The power is then transferred to the water pump motor, which drives the flow of water through the connected pipes.

The water drum plays a crucial role in regulating water supply. Its water sensor detects when the level is critically low, triggering the source pump to refill the drum automatically. Once the optimal level is reached, the pump switches off. Meanwhile, the fertilizer drum releases fertilizer through a hose connected to the pump when needed, ensuring that water and nutrients are evenly distributed to the eggplants.

The soil sensor continuously monitors the moisture level in the soil. When the soil becomes sufficiently wet, the sensor automatically shuts off the water pump to prevent over-irrigation. This process ensures efficient use of water and fertilizer, reduces manual labor, and promotes healthier plant growth through precise and automated control.

*Testing.* The testing phase aimed to measure the functionality and performance of the water and fertilization management prototype to determine its effectiveness and reliability. After the development of the machine, the researchers conducted a series of demonstrations and operational tests to verify whether all components functioned as expected. Each hardware component was individually tested to ensure compatibility and proper integration within the system.

In addition, the researchers simulated real-world scenarios to evaluate how the machine would perform under typical farming conditions. These test cases allowed the researchers to identify potential issues, assess operational efficiency, and confirm that the system could perform its intended tasks, automated watering and fertilization, effectively and consistently.

The testing approach involved systematic verification and validation of the machine's operation. The researchers first implemented the prototype in a controlled environment to detect possible technical problems and make necessary adjustments. This proactive approach allowed them to identify and fix issues promptly, thereby improving the overall performance and stability of the system.

Furthermore, the researchers considered potential risks associated with electrical and mechanical components, as well as regulatory and safety aspects of the design. A well-defined testing plan was followed to ensure that any malfunctions, incompatibilities, or safety hazards were immediately addressed. This ensured that the prototype met both functional and safety standards before being deployed for actual use.

*Deployment and Maintenance.* The researchers developed a comprehensive implementation plan for the deployment of the machine prototype. The deployment phase included a review and approval process to verify that the system operated as intended after completing all required testing stages. Once all evaluations were successfully passed, the prototype was deemed ready for real-world application by the end users.

The deployment of a hardware prototype provided valuable user feedback prior to large-scale implementation. Users were encouraged to test the prototype and provide insights into its usability and effectiveness. Based on these comments, the researchers made necessary refinements before final

acceptance. This iterative process continued until the users, primarily the farmers, were satisfied with the prototype’s performance and functionality.

Regarding maintenance, the researchers emphasized the importance of preparing solutions for potential technical issues that may arise after deployment. Ensuring the farmers understood how to manage minor problems was crucial to prevent panic or misuse. Post-deployment, the researchers conducted an evaluation of the hardware’s performance to confirm that all systems were functioning efficiently and to plan for future improvements.

## Technical Framework

This section describes the technical framework of the study, encompassing the design, structure, and functional flow of the system, as well as the interactions between its hardware and software components.

### Materials

**Table 1**

*Hardware specifications*

Hardware	Specification
Adapter	12V AC Adapter Charger Power
Timer	SINOTIMER AC 12V Digital TIMER SWITCH
Water Pump	Pressure Diaphragm Self Priming Water Pump 6L per minute 12v
Water Hose	Transparent Silicone Rubber Hose
Nozzle	BB Plastic Stopper nozzle
Water Container	Water container 150 liters
Water Sensor	Arduino Nano
Wire	Jumper wires
Mixer	Mini Washing Machine
Soil Sensor	Arduino Uno

*Adapter.* The adapter was used to connect the system to the main

electrical source, allowing the switch timer and water pump to operate efficiently.

*Switch timer.* The researchers used a switch timer capable of automatically turning on and off various electrical equipment at preset times. This was the first essential component required for the machine's operation, as it controlled the activation and deactivation of the water pump and fertilization process.

*Water hose connector.* A water hose connector was utilized to securely connect hoses to different pressurized air and water outlets. This coupling ensured stable and leak-free connections between the hoses and other components of the system.

*Water pump motor.* The water pump motor is an electromechanical device that generates pressure to move water from one point to another. It is an essential part of the system's water control mechanism, responsible for transferring water efficiently from the source to the distribution pipes and ultimately to the plants.

*Water hose.* A transparent silicone rubber hose was used to transport water between plants. The transparency of the hose allowed the researchers to observe the flow of water during operation, ensuring consistent distribution across the system.

*Water sensor.* A water sensor was installed to monitor the water level in the storage container. This sensor detects when the tank requires refilling, enabling the automatic activation of the source pump when water levels fall below the critical threshold.

*Water container.* A 150-liter water container served as the main water reservoir for the system. It stored the water used for both irrigation and fertilization processes throughout the experiment.

*Washing turbine.* A mini washing machine turbine was repurposed

to mix the fertilizer with water inside the drum. This component ensured proper blending of the fertilizer solution before it was distributed to the plants.

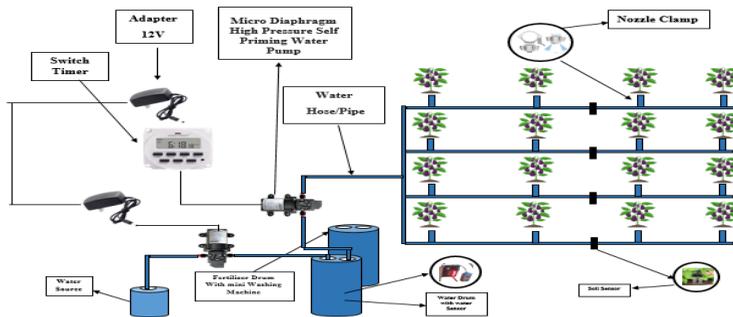
*Arduino Uno.* The Arduino Uno microcontroller was used to operate the soil moisture sensor. It monitored the soil's moisture content and automatically turned off the water pump when the soil was sufficiently wet, optimizing water usage and preventing over-irrigation.

### **Modelling**

Figure 2 illustrates the machine design of the prototype

**Figure 2**

*Machine design of the prototype*



The machine developed for water and fertilization management of eggplants is a prototype model designed specifically for vegetable farmers. The system operates using a switch timer, a device that can automatically turn on and off various electrical equipment at preset times. Using this timer, farmers can set the duration for which the water pump operates and the time allotted for fertilizing the eggplants.

The water drum is equipped with a water level sensor that monitors the water volume. When the water level drops to a critical point, the pump

connected to the water source automatically activates to refill the drum. Once the desired water level is reached, the pump automatically shuts off to prevent overflow. The fertilizer drum is connected to the water pump via a hose, enabling fertilizer to be applied to the plants as needed. Additionally, a soil moisture sensor is integrated into the system to automatically switch off the water pump when the soil is sufficiently wet, preventing overwatering and conserving resources.

In terms of design, the prototype has a rectangular shape, measuring 45 inches in length and 30 inches in width, providing a compact and functional layout suitable for small to medium-scale vegetable farms.

**Figure 3**

*The circuit diagram*

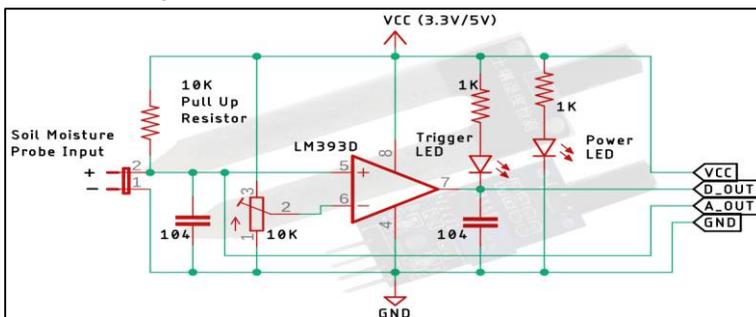


Figure 3 shows the circuit diagram. The circuit diagram depicts the electrical flow within the soil sensor, demonstrating how the sensor detects soil moisture and sends signals to automatically activate or deactivate the water pump to maintain optimal soil conditions.

Figure 4 shows the water sensor used in the system. The purpose of the water sensor is to automatically refill the water container from the main water source. When the sensor detects that the water level has dropped (the sensor sinks), the water pump activates to refill the container. Once the

water level reaches the required height (the sensor floats), the water pump automatically stops, preventing overflow and ensuring consistent water availability.

**Figure 4**

*Water sensor*



**Figure 5**

*Soil sensor and switch timer*



Figure 5 shows the soil sensor and switch timer used in the system. The soil sensor is designed to prevent excessive watering by detecting the

soil’s moisture level and automatically stopping the water pump when the soil is sufficiently wet. The switch timer allows farmers to control the operation duration of the water pump. It has three settings: ON, which manually turns on the water pump; AUTO, which automatically controls the water pump based on the preset schedule; and OFF, which manually disables both the soil sensor and the switch timer, stopping the system entirely.

**Figure 6**

*Water management database*

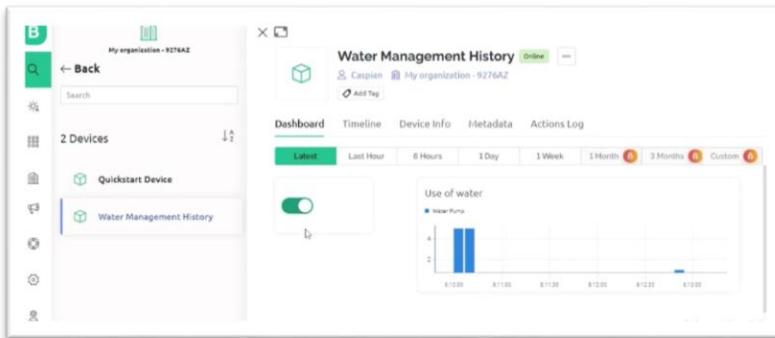


Figure 6 illustrates the water management database, which logs the exact date and time of each water pump operation, allowing for accurate monitoring and analysis of irrigation activities.

**Figure 7**

*Fertilization Management Database*

Date & Time	
05/09/2023 03:00 pm	
Description	
1 Kilo of Dr. Earth Fertilizer	
<a href="#">Insert</a> <a href="#">Create Table</a> <a href="#">Delete Table</a> <a href="#">Fetch Record</a>	
Note: Table must be created first before inserting or performing any action.	
Record	
5	2023-06-08T15:00   1 Kilo of Dr. Earth Fertilizer   <a href="#">Delete</a>   <a href="#">Update</a>
4	2023-06-08T15:00   1 Kilo of Dr. Earth Fertilizer   <a href="#">Delete</a>   <a href="#">Update</a>
3	2023-06-01T15:00   1 Kilo of Dr. Earth Fertilizer   <a href="#">Delete</a>   <a href="#">Update</a>
2	2023-06-30T15:00   1 Kilo of Dr. Earth Fertilizer   <a href="#">Delete</a>   <a href="#">Update</a>
1	2023-05-28T15:41   1 Kilo of Dr. Earth Fertilizer   <a href="#">Delete</a>   <a href="#">Update</a>

Figure 7 illustrates the fertilization management database, tracking both the timing of fertilizer application and the quantity used, providing an accurate record of resource usage for effective farm management.

**Table 2**

*Data analysis*

<b>Time and Date</b>	<b>Water consumption</b>	<b>Fertilizer consumption</b>
2023-05-28 / 15:41	16 liters of water used by the machine	1 kilo of Dr. Earth Fertilizer
2023-05-30 / 15:00	16 liters of water used by the machine	1 kilo of Dr. Earth Fertilizer
2023-06-01 / 15:00	16 liters of water used by the machine	1 kilo of Dr. Earth Fertilizer
2023-06-03 / 15:00	16 liters of water used by the machine	1 kilo of Dr. Earth Fertilizer
2023-06-05 / 15:00	16 liters of water used by the machine	1 kilo of Dr. Earth Fertilizer

Table 2 displays the recorded data on the date and time of water pump and fertilizer usage, including the quantity of water and fertilizer applied to the plants.

**Table 3**

*Risk analysis*

<b>High</b>	<b>Average</b>	<b>Low</b>
Short Circuits	Poisoning	Soil sensor ate by rats
Pump getting explode	Electrocuted	Soil sensor gets burn
	Water sensor gets stock by tree branch	
	Over heating	

Table 3 presents the risk analysis of the system. High-risk factors include the possibility of a short circuit and the potential explosion of the water pump. Moderate risks involve hazards such as poisoning from fertilizer exposure, electrocution, blockage of the water sensor by tree branches, and overheating. Low-risk factors include the soil sensor being

damaged by rats or being burned due to prolonged exposure to sunlight.

**Table 4**

*Cost benefit analysis*

<b>Materials, Tools &amp; Equipment</b>	<b>Quantity</b>	<b>Price</b>	<b>Total</b>
Water Sensor	1	350	350.00
Adapter	3	300	300.00
Switch Timer	1	450	450.00
Water Pump	2	380	760.00
Water Hose	1 (10 meters)	100	100.00
Water Hose connectors	25	500	500.00
Water Container	2	150	300.00
Water Turbine	1	250	250.00
Arduino Uno	1	680	680.00
Soil Sensor	1	70	50.00
<b>Total Costs</b>		<b>Php 3,740</b>	

As shown in Table 4, the Water and Fertilization Management Prototype was developed at a total cost of Php 3,740, covering all necessary materials, tools, and equipment. The most significant contributors to the cost were the water pump (Php 760), Arduino Uno (Php 680), and water hose connectors (Php 500), which are essential components for the automation and connectivity of the system.

The relatively low overall cost demonstrates that the prototype is affordable and feasible for small-scale vegetable farmers. By investing in this system, farmers can potentially reduce labor costs and improve efficiency in watering and fertilization. The cost-effectiveness of the prototype, combined with its functionality and automation features, makes it a practical solution for improving farm productivity while remaining budget-friendly.

**Table 5**

*Water efficiency overall mean score*

<b>Indicator</b>	<b>Mean</b>	<b>Interpretation</b>
Water Efficiency	3.89	Strongly Agree
Fertilizer Efficiency	3.81	Strongly Agree
<b>Overall Prototype Machine</b>	<b>3.85</b>	<b>Strongly Agree</b>

As indicated in Table 5, the overall assessment of the prototype’s efficiency yielded a mean score of 3.85, also verbally interpreted as “strongly agree,” demonstrating that the system performs effectively in both watering and fertilization management.

In terms of water efficiency, the respondents generally strongly agreed that the prototype effectively manages water usage, with an overall mean score of 3.89, which is verbally interpreted as “strongly agree.”

For fertilizer efficiency, the weighted mean was 3.81, indicating that most respondents were familiar with the system’s fertilization process and found it effective.

**Figure 8**

*Overall mean score of hardware prototype machine*

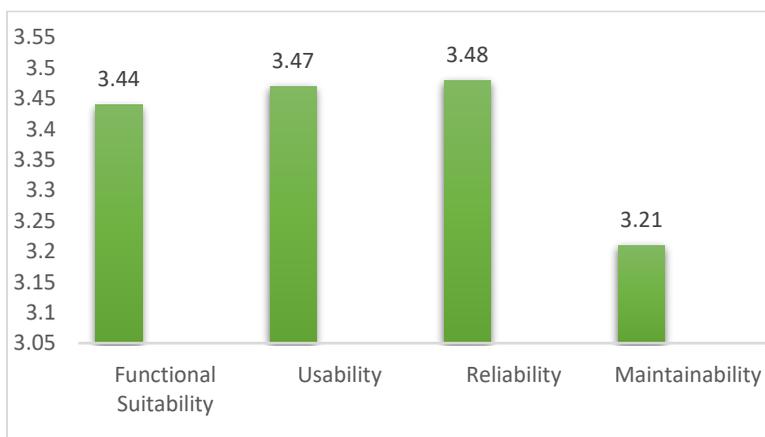


Figure 8 presents the overall mean score for the hardware prototype, which was 3.4, verbally interpreted as “strongly agree.” This indicates that the respondents generally found the prototype to be effective and satisfactory. Most of the sub-variables received strong agreement ratings, reflecting positive perceptions of the machine’s performance, usability, and reliability.

In terms of functional suitability, the prototype received an overall mean score of 3.44, suggesting that the respondents agreed that the machine performs its intended functions effectively. For usability, the mean score was 3.47, indicating that the system is user-friendly and easy to operate. The reliability of the prototype was rated at 3.48, reflecting respondents’ confidence in the machine’s consistent performance during operation. All these scores fall under the “strongly agree” category, demonstrating that the prototype meets the expectations of the users in terms of functionality and practical application. However, in terms of maintainability, the prototype received the lowest overall mean score of 3.21, which is verbally interpreted as “agree.” This suggests that while the machine is generally effective, some respondents perceived potential challenges in maintaining or servicing the hardware. This finding highlights an area for improvement, emphasizing the need for clearer maintenance guidelines, easier access to components, or enhanced durability to ensure long-term usability.

Overall, the results demonstrate that the hardware prototype is well-designed, reliable, and user-friendly, but addressing maintainability concerns could further enhance its overall effectiveness and acceptance among farmers.

## **Conclusion**

Compared to traditional methods, the prototype allows for faster and more consistent watering and fertilization of plants, minimizing manual labor while improving resource management. The system's automated features enable farmers to schedule irrigation and fertilization, reducing the risk of over- or under-application. The hardware prototype was deemed acceptable and effective based on the evaluation conducted by the researchers. These results indicate that while the system performs its intended functions effectively, is easy to use, and operates reliably, there is still room for improvement in maintainability to enhance long-term usability and user satisfaction.

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