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Vaxi-eTrack: A Data-driven System for Infant Vaccination Management for Barangay Clinic Pico La Trinidad, Benguet

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Abstract – *Efficient management of infant immunization remains a significant challenge in rural communities in the Philippines, where vaccination processes continue to rely on manual, paper-based workflows that often result in inaccurate records, delayed scheduling, weak data security, and limited communication with parents, increasing the risk of missed or delayed vaccinations. Despite the proven success of digital immunization systems in other regions, similar technologies remain underutilized in many local community health centers. This study aims to improve the effectiveness, accuracy, and efficiency of vaccination record management, scheduling, and vaccine inventory monitoring through the development of a digital health information system known as Vaxi-eTrack. The study employed the Rapid Application Development (RAD) methodology, allowing iterative system design, active user involvement, and continuous refinement throughout the development lifecycle. The results revealed SUS scores ranging from 42.5 to 100, indicating varied user experiences but overall positive acceptance. The system achieved a strong overall mean quality score of 4.14 out of 5, with the highest rating in Security, followed by Maintainability, Compatibility, and Scalability, demonstrating strong system performance, reliability, and readiness for broader deployment. Overall, Vaxi-eTrack proved to be an effective digital solution for improving immunization tracking, record accuracy, and service delivery in community health settings, and it is recommended that the system be expanded to other barangays, enhanced with SMS or push notifications, equipped with offline functionality, and continuously evaluated to ensure long-term sustainability and improved public health outcomes.*

Keywords – *Digital Health System, Immunization Management, Community Health Technology, RAD Methodology, Vaccine Inventory*

INTRODUCTION

Immunization is one of the most effective global public health measures, preventing millions of deaths and reducing illness from vaccine-preventable diseases. Despite progress through WHO's Expanded Programme on Immunization and Gavi, gaps remain due to healthcare access issues, weak infrastructure, and vaccine hesitancy. Studies show vaccination's impact, with near elimination of infectious diseases in some regions (Talbird et al., 2022). From early variation to modern mRNA technologies, vaccination has enabled rapid responses to threats like COVID-19 and strengthened global systems (Sharma, 2022).

In the Philippines, the Expanded Program on Immunization (1976) expanded childhood vaccine access and achieved milestones such as eliminating maternal and neonatal tetanus. Supported by Republic Act No. 10152, it aims for universal immunization, but hesitancy, misinformation, and inconsistent access hinder coverage, causing outbreaks and many zero-dose

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children, especially in disadvantaged communities (UNICEF Philippines, 2022). Delayed vaccinations weaken herd immunity (Raguindin et al., 2021). Local initiatives in Benguet, like Reaching Every Purok, highlight the importance of community outreach.

Globally, digital health technologies, Electronic Health Records, mHealth, telemedicine, and mobile apps, improve delivery and engagement (Ge et al., 2022; Lv et al., 2019; Narwadiya & Rao, 2025). In the Philippines, web-based tools, Vaccine Tracking Systems, GIS monitoring, and real-time apps support scheduling, reminders, reporting, and surveillance. Innovations such as drones, thermostable mRNA vaccines, IoT sensors, AI-driven cold chain systems, and blockchain enhance logistics (Jamal, 2023; Rasool et al., 2024). Yet many local health units still rely on manual records, limiting efficiency.

Systemic limitations, poor access, hesitancy, manual data, and low digital adoption continue to hinder universal coverage in the Philippines. This is evident in Barangay Pico, La Trinidad, Benguet, where growing child populations heighten the need for accurate, timely, and technology-supported immunization (UNICEF Philippines, 2025). Strengthening digital infrastructure and community outreach is essential to ensure all children are protected.

Barangay Pico in La Trinidad, Benguet, has registered high infant vaccination numbers but still relies on manual or paper-based systems for vaccination and inventory management. This leads to double entries, misplaced records, incomplete histories, outdated contact information, missed appointments, and delays due to stock shortages. Similarly, in manual tracking, discrepancies result in slow replenishment and difficulty monitoring expiration dates, reducing coverage and efficiency.

The project focuses on digitizing infant immunization schedules, real-time vaccine inventory tracking, secure health record storage, analytics, and automated reporting to improve efficiency at the barangay level. It aligns with national digital health initiatives (RT-VaMA, IIS, VIMS) but currently lacks full interoperability with DOH and LGU frameworks. The system is designed for a single barangay unit, monitors only government-provided vaccines, and does not yet include modules for inventory request approvals or financial processes. Despite these limitations, it remains adaptable for other barangays with similar operations.

In addition to these challenges, the researchers propose Vaxi-eTrack, a health information system that automates scheduling, allows inventory management, and compliance reporting. The system aims to resolve inaccuracies, slow retrieval, and inefficient scheduling because of a paper-based dependence as reported by La Trinidad Local Government 2023; Raguindin et al., 2021; Castillon et al., 2025. It supports SDG 3 (health access) and SDG 8 (efficient work environments). Besides, Vaxi-eTrack enhances service delivery through its generation of personalized schedules, real-time monitoring of stock, and maintenance of secure digital records. Like RT-VaMA and IIS, it has integrated analytics for default detection, demand forecasting, and coverage gap detection (UNICEF Philippines, 2023). Similarly, it generates reports for local health units and the Department of Health, just like national VIMS (WHO, 2022). It is modular, scalable, interoperable, and meets the needs of SDG 9 and SDG 11 through innovation and resilient health systems.

Guided by Socio-Technical Systems (STS) Theory, this project focuses on smooth integration between staff and technology. The framework defines the roles for midwives, administrators, nurses, parents, and barangay health workers. In a technical way, it uses Appwrite for file handling, Firestore for real-time data, and local storage for offline continuity. Being a Progressive Web Application (PWA), seamless, accessible, and reliable immunization management is assured to Barangay Pico.

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Objectives of the Study

The overall aim of this study is to improve the effectiveness and precision in handling vaccination records, scheduling, and inventory management by developing a data-driven system for local health centers. This study seeks to replace the traditional manual immunization process with a digital system that enhances service delivery, data integrity, and resource optimization. Similar to the digital transition in immunization tracking systems implemented in provinces of Vietnam, where digital registries demonstrated improvements in data accuracy and service delivery efficiency (Nguyen, Vu, Dao, Tran, & Nguyen, 2021), this project aspires to introduce a comparable model tailored to the local context of Barangay Pico.

Objectives:

1.) To identify the functional and non-functional requirements of the Vaxi-eTrack System;
2.) To design the architecture of Vaxi-eTrack system;
3.) To develop Vaxi-eTrack system with data analytics capabilities; and
4.) To test and deploy the Vaxi-eTrack system.

MATERIALS AND METHODS

This section presents the materials and methods used in developing Vaxi-eTrack, a digital immunization management system designed for Barangay Pico, La Trinidad, Benguet.

Data Gathering

The researchers applied the Rapid Application Development (RAD) approach, an iterative technique emphasizing quick prototyping, user participation, and flexibility across the development life cycle (Hutabri, 2019). This method was well-suited for developing Vaxi-eTrack, an infant immunization care system, as it enabled rapid progress from requirements gathering to deployment while adapting to evolving user needs and healthcare regulations. The process is shown in Figure 1.

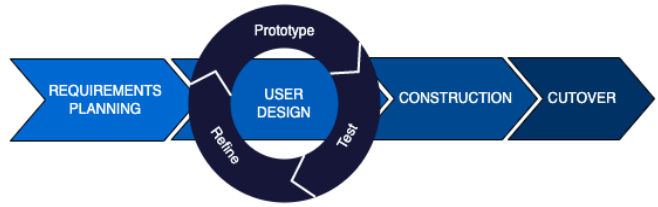

Figure 1. *Rapid Application Development (Hutabri, 2019)*

Requirements Planning

During the identification of functional and non-functional requirements, the researchers conducted structured interviews with key health personnel directly involved in immunization services. To uphold ethical standards, all data collected were treated with strict confidentiality. Participant identities were anonymized through coding, and digital files were securely stored in a password-protected Google Drive and on an encrypted USB device accessible only to the research team.

In compliance with the Philippine Data Privacy Act of 2012 (Republic Act No. 10173) and institutional ethical guidelines, records will be retained for twelve (12) months following the completion of the study to allow for verification and academic review. After this retention period, all digital files will be permanently deleted, while printed documents will be securely shredded to ensure that no sensitive information remains accessible.

These measures align with the ethical considerations of the study, ensuring informed consent, confidentiality, and strict adherence to national data privacy regulations throughout the research process.

Interview

During the interview process, the researchers conducted structured, in-person interviews guided by a prepared questionnaire. Participants were selected through purposive sampling and consisted of key health personnel directly involved in immunization services. Each interview was conducted with signed informed consent, recorded to ensure accuracy, and supplemented with written notes. The identities of all respondents were

kept confidential, and the questionnaire used is provided in Appendix B.

Document Review

In conducting the document review, the researchers performed a systematic assessment of the records and materials used in the immunization process at the Pico Barangay Health Station. This process involved examining key documents such as vaccination forms, raw vaccination logs, EMR templates, baby book records, vaccine inventory sheets, and the official vaccination schedule. Each document was analyzed to understand existing procedures, verify data gathered from interviews, and derive the necessary functional and non-functional requirements for the system. The researchers organized the review using a structured checklist, recorded observations, and compared information across documents to ensure accuracy. All reviewed materials were kept confidential and securely stored.

User Design

In the User Design phase, the researchers structured the Vaxi-eTrack system by outlining its architecture and interface to guide development. They began by creating the System Architecture, identifying core components such as modules, databases, and servers, and mapping their interactions to define the system's overall framework.

Next, Use Case Diagrams were developed to capture system functionality, showing how different actors interact with the system. These were followed by Activity Diagrams, which detailed the workflows and decision points for each process based on the use cases. To visualize data movement, System Flow Diagrams were constructed, highlighting inputs, outputs, and component interactions.

The researchers also prepared a UML Diagram to define system classes, attributes, operations, and relationships, representing both structural and behavioral aspects. Finally, an Iterative Development Process was employed using Figma to build and refine a prototype of the interface and key features. This prototype was presented to clients for feedback, preceded by an orientation to ensure meaningful input.

Construction

The researchers used various modern web technologies to develop the Vaxi-eTrack system. These technologies enabled the team to efficiently build the system's core functionalities and ensure smooth, reliable performance.

Cutover

The cutover phase marked the transition from development and implementation of Vaxi-eTrack, encompassing both testing and deployment activities to ensure the system was functional, reliable, and user-friendly for healthcare workers. This phase validated that the platform met the requirements gathered during earlier stages and was ready for operational use in a community health setting. A project Gantt chart was also created to outline the schedule and sequence of activities.

Testing

Three types of testing were carried out to ensure that the system was reliable and usable, Unit Testing, where core functionalities were checked by having health workers answer prepared questions; Usability Testing, where the ease of use and user experience were checked through standardized questionnaires; and User Acceptance Testing, where users and clients performed tasks and provided feedback to confirm if system requirements and expectations set were met.

Along with deployment, several supporting documents and plans were prepared: a User Manual detailing system functionalities in stepwise instructions with screenshots, an Installation Manual that specified requirements and detailed procedures for proper setup and configuration, a Network Plan that determined the cloud hosting requirements of the system based on testing results, and lastly, a Long-Term Plan that outlined scalability regarding the cloud-based architecture of the system, the database structure, and the modular system architecture.

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RESULTS AND DISCUSSION

This chapter provides a comprehensive overview of the results from each phase of the Vaxi-eTrack system development. It begins with the identification of functional and non-functional requirements, outlining the essential features and quality standards needed to ensure reliability, efficiency, and security. The user design phase follows, detailing how different users interact with the application through navigation flows, interface layouts, and user experience considerations. The construction phase then describes how design specifications were translated into a working application through step-by-step development and implementation. Finally, the cutover phase demonstrates the system's performance in real-world use, including usability testing, functionality verification, and overall readiness for deployment in the healthcare setting.

Functional Requirements

Table 1 presents the functional requirements that define the essential system behaviors and capabilities necessary to support infant immunization processes in Barangay Pico. These requirements ensure that Vaxi-eTrack performs all critical tasks expected of a digital immunization management system.

Table 1. Functional Requirements

Categories	Requirements	Definition
User Management	Admin	The Admin has full access to all system functions, including secure login, user account management (add, edit, deactivate, reset), report generation, child archives, system backup and recovery, and viewing system logs for tracking login activity and record edits. While the Admin can perform all tasks, specific responsibilities are delegated to subroles to streamline operations.
	Health Worker	Responsible for recording and updating vaccination data, managing child immunization profiles (including adding, modifying, and deleting records), and using reminder functions to notify parents about upcoming vaccinations.
	Assistant	Handles vaccine inventory management, including recording and updating stock entries, tracking expiration dates, and managing batch numbers.
	Parent	can securely log in to the system to view their child's immunization record.

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Immunization Report	Automated report generation	The system generates vaccination schedules based on DOH guidelines.
	Reminder Alerts	Sends alerts for upcoming and missed immunization dates.
Vaccines Inventory Management	Track Available Vaccine Stock	Monitors current stock levels and expiration dates.
	Stock Alert	Notifies staff when vaccine supply is low or nearing expiry.
Data Recording and Reporting	Real-Time Data Entry	Allows health workers to update immunization records after administration.
	Efficient Data Processing	Handles updates without delays.
Security	Data Confidentiality	Protects sensitive patient information via authentication and authorization.
Usability	User-friendly Interface	Designed for users with intuitive design.
	Easy Navigation	Simple menus and intuitive workflows for faster task completion.
Reliability & Availability	Stable System Operation	The system remains functional during immunization hours without failures.
	Data Backup and Recovery	Prevents data loss in case of system or power interruption.
Scalability	Expandable Records Support	Can store an increasing number of infant profiles and vaccination logs.
Compatibility	Multi-platform Accessibility	As a Progressive Web Application (PWA), it will be accessible through web browsers and fully functional on Android and iOS devices, as well as desktop platforms, ensuring users can access the system anytime and on any

Non-Functional Requirements

Table 2, Non-functional requirements described the system's quality attributes, ensuring that performance, security, usability, and reliability standards were met. These characteristics ensured that Vaxi-eTrack was practical and sustainable for real-world deployment in local health settings.

Table 2. Non-functional Requirements

Category	Requirements	Definition
Performance	Fast Data Retrieval	The system responds to user queries within seconds, even with multiple records.

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		supported device.
Maintainability	Modular Design	System modules can be updated or improved without affecting the whole system.

User Design

Based on the functional and non-functional requirements, the researchers were able to develop the system design. During the User Design phase, the system architecture formulated is presented in Figure 3, in Figure 3 to 6, Use Case Diagrams, Figure 7, Activity Diagrams presents the sequential workflows of key processes, while Figure 8, System Flow Diagrams provides a detailed representation of how data moves through each module. Additionally, Figure 9, UML Diagram includes structural and behavioral models that define component relationships and data flow.

System Architecture Diagram

The Vaxi-eTrack system uses a modern full-stack architecture built on Next.js, combining React Server and Client Components for efficient application logic, routing, and rendering. User access across roles (Admin, Health Worker, Assistant, Parent) is secured through Firebase Auth, while data persistence is managed by Firestore, a scalable real-time NoSQL database with strict security rules. Appwrite supports specialized backend services such as file storage and report generation. System stability and performance are maintained through an Observability and Logging block, using tools like Sentry, Datadog, and Stackdriver to monitor errors, logs, and overall health in real time.

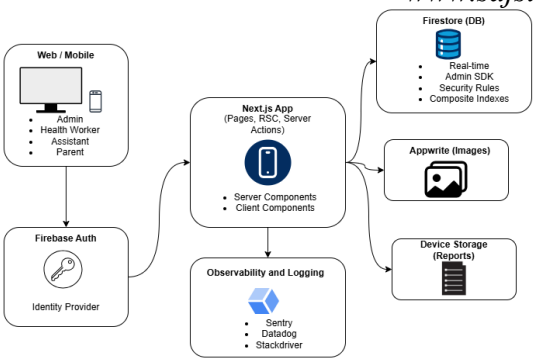

Figure 2. *System Architecture Diagram*

Use Case Diagram

Figure 3 shows the functionalities of the admin user, who has full control over the system. The admin can monitor child records, manage vaccine inventory, oversee user accounts, and handle vaccine request reports, all requiring database interactions for retrieving and updating information.

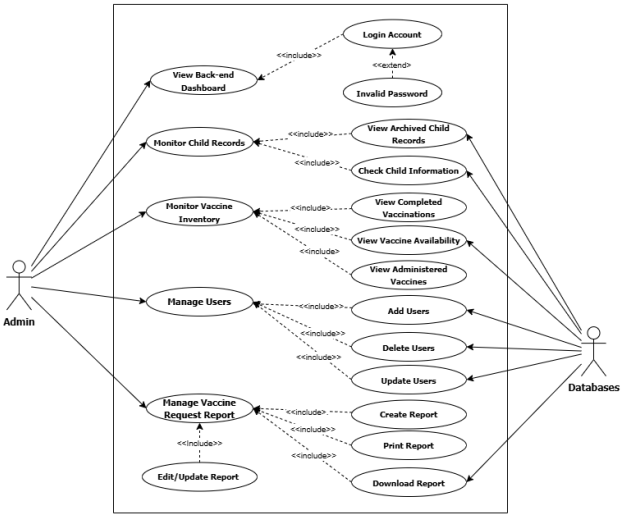

Figure 3. *Admin Use Case Diagram*

Figure 4, presents the Health Worker's functionalities, focused on managing child records. The Health Worker can access the back-end dashboard and add, update, or delete child records, ensuring accurate and up-to-date information in the database.

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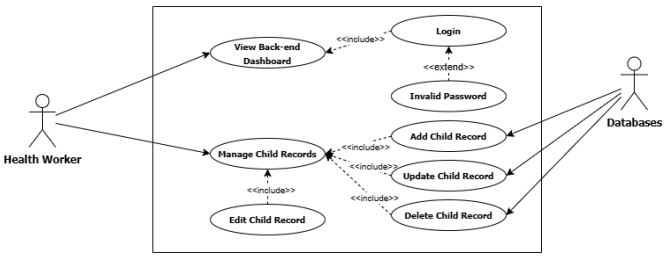

Figure 4. *Health Worker Use Case Diagram*

Figure 5 outlines the Assistant's role in managing vaccine inventory. The Assistant can access the dashboard, add or delete vaccines, update their availability, and view current inventory, all involving continuous interaction with the database.

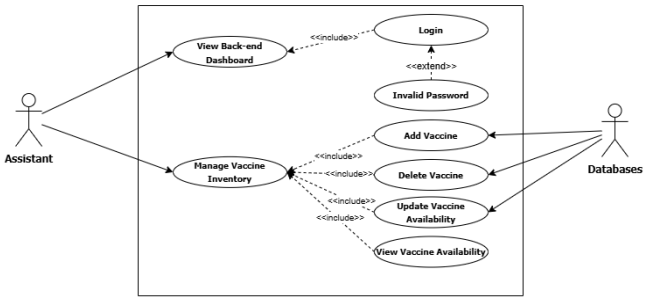

Figure 5. *Assistant Use Case Diagram*

Figure 6, illustrates the Parent user's functionalities, including viewing the dashboard, accessing their information, checking their child's details, receiving alerts, switching child IDs, and viewing location details. These actions primarily involve retrieving data to keep parents informed about their child's vaccination status.

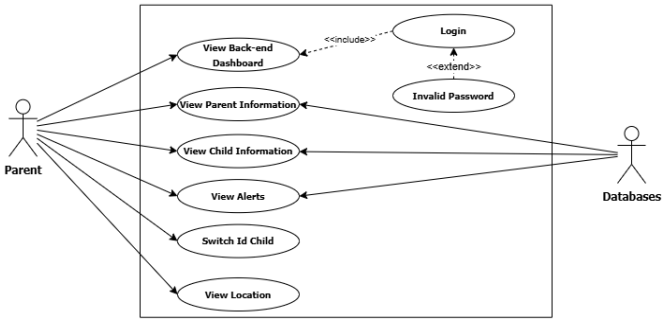

Fig. 6. *Parent Use Case Diagram*

Activity Diagrams

Figure 7 presents the activity flow of the Admin in the Vaxi-eTrack System. After successful login, the Admin accesses the back-end dashboard to monitor child records, manage vaccine inventory, oversee user accounts, and handle vaccine request reports. These operations rely on validated data retrieved and updated through Appwrite and Firestore.

Figure 7. *Admin/Midwife Activity Diagram*

Figure 8 outlines the Assistant's activity sequence. The Assistant enters the dashboard to manage vaccine inventory. The system displays current vaccine stocks from Firestore, and any validated updates are immediately reflected to ensure accurate and up-to-date inventory tracking.

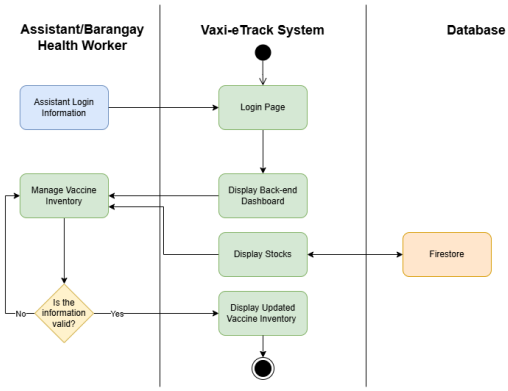

Figure 8. *Assistant/Barangay Health Worker Activity Diagram*

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Figure 9 depicts the Parent's interaction flow. Following login validation, the Parent accesses the parent portal to view child records, parent information, alerts, and health center location details. All displayed information is retrieved directly from Appwrite and Firestore, providing parents with reliable and timely data.

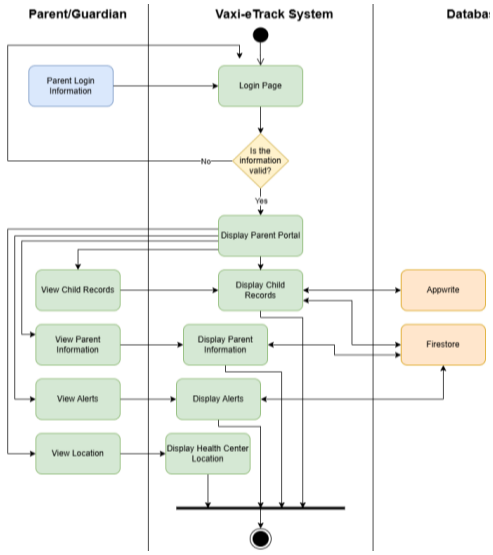

Figure 9. *Parent/Guardian Activity Diagram*

System Flow Diagrams

Figure 10 presents the administrative workflow of the Vaxi-eTrack System. The admin oversees all processes from access and authentication through inventory management, ensuring compliance and coordination. A unique responsibility of the admin is initiating automated report generation, which compiles data from vaccine requests and utilization logs to support strategic planning, resource allocation, and supply forecasting. Inventory management is maintained both through direct updates when new stocks arrive and through automated data reflection, which adjusts stock levels in real time whenever immunization records are updated.

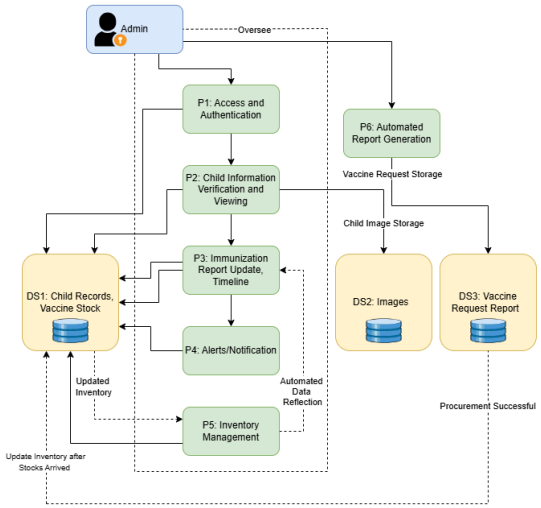

Figure 10. *Admin System Flow Diagram*

Figure 11 illustrates the clinical interaction and patient services module. Parents securely access the system through authentication, enabling child information verification and record viewing. Nurses use the same process for registration and pre-vaccination checks, supported by stored documentation. Immunization updates are recorded directly into the central data store, and completion of this process triggers alerts and notifications to parents, reinforcing engagement and compliance with vaccination schedules.

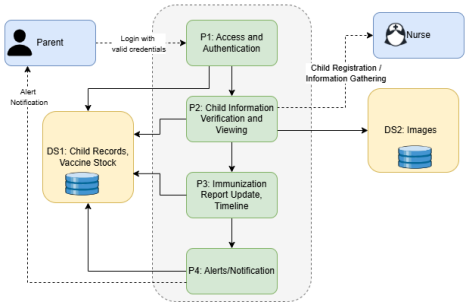

Figure 11. *Parent System Flow Diagram*

Figure 12 integrates both administrative and clinical workflows into a closed-loop system. Administrative oversight ensures accurate records, timely vaccine replenishment, and automated reporting, while clinical processes enable secure parent–nurse interactions, real-time immunization updates, and proactive notifications. Together, these functions

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optimize healthcare delivery, resource management, and patient engagement in community immunization programs.

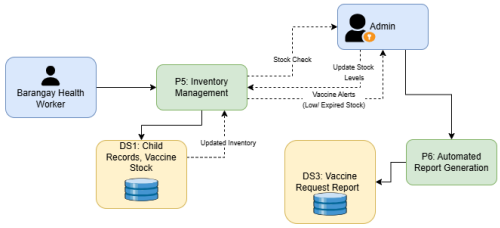

Figure 12. *Barangay Health Worker System Flow Diagram*

Unified Modelling Language Diagram

Figure 13 presents a UML class diagram that illustrates the core entities and their relationships within the Vaxi-eTrack system. It defines the primary classes; ManageUser, User, ChildRecord, Alert, and Vaccine, along with their attributes and operations. The diagram also highlights the associations among these classes, showing how the system's components interact and support its overall functionality.

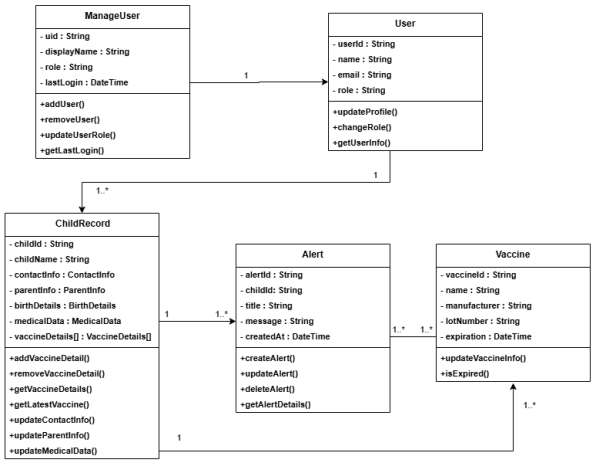

Figure 13. *Vaxi-eTrack Unified Modelling Language Diagram*

Iteration

The review process was conducted in two phases to identify and correct design issues across key modules such as the Admin Dashboard, Parent Dashboard, Immunization Report, User Management, and Vaccine Request Generation. During the first iteration, feedback highlighted the need for better organization and data clarity. The Parent Dashboard and Immunization Report were noted as disorganized and missing crucial details like vaccination dates, while the Vaccine Request Generation module was considered confusing due to poor report structure. Although some prototypes, such as the Login and Add New Vaccine Stock screens, were deemed acceptable, the overall recommendation emphasized clearer layouts and proper data listing.

The second iteration reflected significant improvements. Reviewers observed visible enhancements, praising updates to the Login Page and Admin Dashboard for presenting properly listed and necessary information. The design was described as more appealing and consistent, with strong encouragement to continue refining toward final completion.

Overall, the iterative cycle validated the design modifications, confirming notable progress in both user interface and user experience across critical system functions.

Construction

The construction phase of the Vaxi-eTrack system involved the actual development and building of the platform including the various technologies used and translating the requirements identified during the planning phase into a functional software system. During this phase, both functional and non-functional requirements were addressed to ensure that the system operates correctly, efficiently, and securely.

Technical Background

The Vaxi-eTrack system was developed using a carefully selected set of modern tools and technologies, each contributing to its robustness, scalability, and usability. Next.js served as the full-stack framework, enabling efficient frontend and backend development, while Tailwind CSS and shading UI ensured a clean, consistent, and responsive interface. For data visualization, Recharts provided interactive charts to monitor vaccination trends and inventory. The system

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was enhanced with Next-PWA, allowing offline access and mobile installability, which is vital for clinics with limited connectivity. Core data management relied on Firestore, a real-time NoSQL database, complemented by Appwrite for file storage and report generation. Deployment and collaboration were streamlined through Vercel and GitHub, offering automated CI/CD and version control. Finally, Html5-qrcode integrated QR code scanning directly into workflows, improving accuracy and efficiency in vaccine data entry. Together, these technologies supported fast development, reliable performance, and a user-friendly experience across all system modules.

Vaxi-eTrack System

Sample screenshots of the Vaxi-eTrack dashboards, illustrating the admin interface alongside other user views, Health Worker, Assistant, and Parent. These images highlight the role-specific features and layout designed to support immunization tracking, inventory management, and patient engagement and performance.

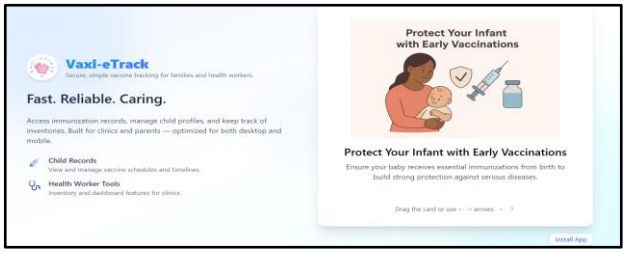

Figure 14. *Landing Page of Vaxi-eTrack*

Figure 15, from this dashboard, the admin can monitor low stock, upcoming expirations, expired vaccines, and the overall vaccination status of children. It also displays monthly and yearly statistics, supporting the admin's role in managing records, monitoring inventory levels, and generating system reports.

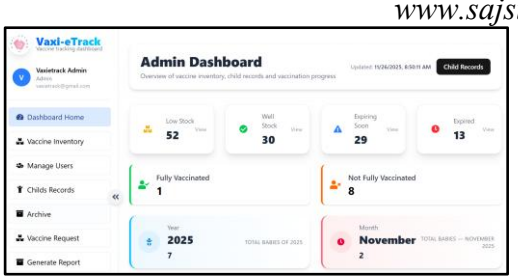

Figure 15. *Admin Portal*

Figure 16 shows the Health Worker Dashboard displays vaccination statistics, a child list with profile details.

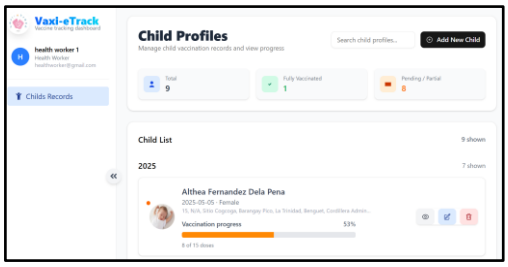

Figure 16. *Health Worker Portal*

Figure 17 displays the Assistant Dashboard, where staff manage vaccine inventory by updating stock entries, batch numbers, and expiration dates. displays the Vaccine Stock Management Widgets, highlighting key inventory metrics including 7 vaccine types, available lots, administered lots, expiring soon, and well stock.

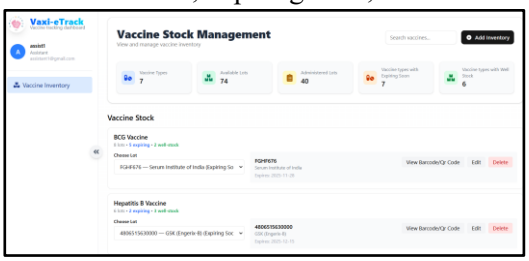

Figure 17. *Assistant Portal*

Figure 18, displays the Parent Dashboard Interface, highlighting a child's vaccine progress, schedule, and quick links to health centers for easy tracking.

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Figure 18. *Parent Portal*

Figure 19, displays the Alerts & Reminders interface, specifically showcasing Vaccination Reminders per child, detailing the schedule for each vaccine based on the child's age in month.

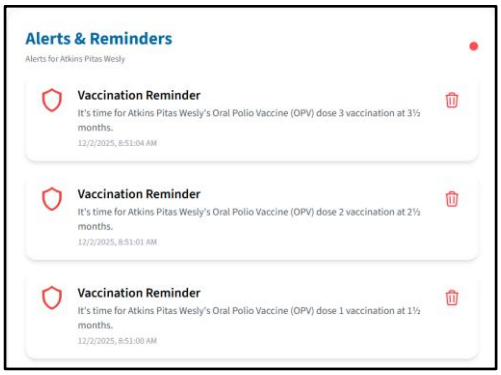

Figure 19. *Alerts & Reminders in the Parent's Portal*

Figure 20, displays the Vaccine Expiration Status Panel for the BCG Vaccine, showing a drop-down list that organizes specific lots by manufacturer and status, including Expired, Expiring Soon, and Well Stock, to manage stock alerts and prevent wastage.

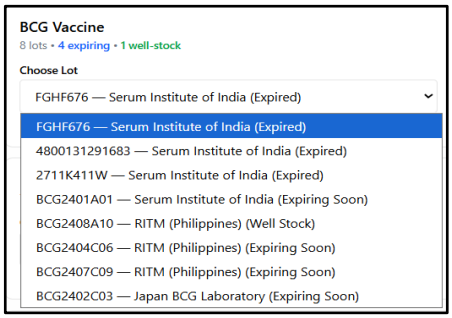

Figure 20. *Stock Alerts*

Figure 21, Immunization Reports Form, displays the Real-Time Data Entry for Immunization Reports, showing a summary of administered doses, lot numbers, dates, and reactions, with a Progress bar indicating overall doses administered.

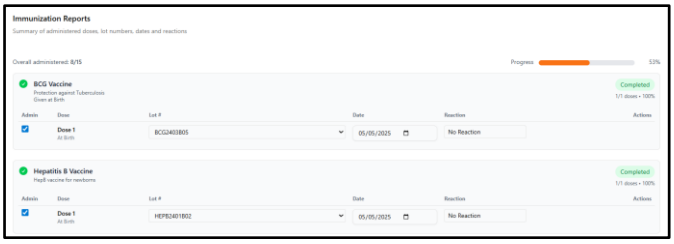

Figure 22. *Real-Time Data Entry for Immunization Report.*

Figure 23, System Performance: Fast Data Retrieval Times, displays a network performance log that documents the speed and efficiency of data retrieval for a web application. This log provides clear evidence that the system is engineered for high performance and fast data retrieval, successfully fetching and rendering page resources in a fraction of a second.

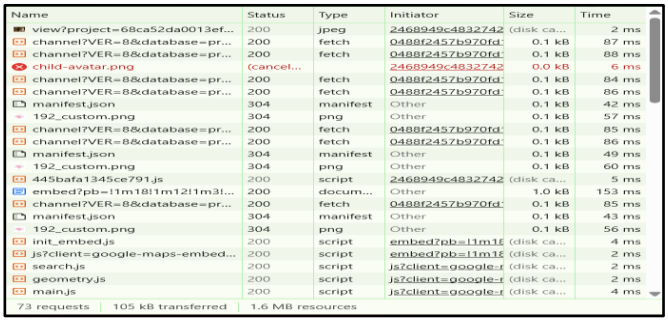

Figure 23. *Fast Data Retrieval*

Figure 24, displays Login Page and Figure No. 30, shows the sign-in interface, where both act as the critical access point enforcing Data Confidentiality for the entire system. The form requires user authentication via Email and Password (or through a secure Google sign-in option), ensuring that only authorized individuals can access the sensitive immunization data and reports.

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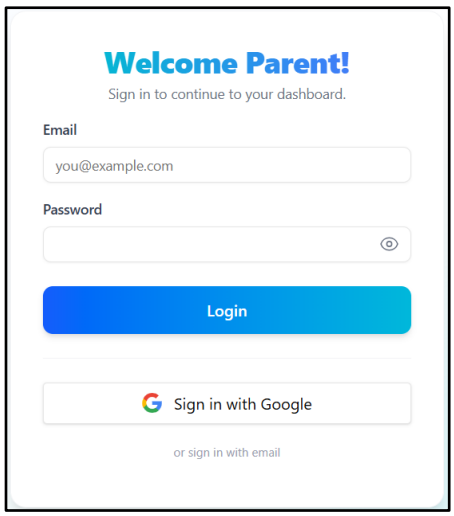

Figure 24. *Login Biometrics*

Figure 25, downloaded Vaxi-eTrack PWA on an Android Device highlights the system's Multi-Platform Accessibility and Compatibility by showcasing the Vaxi-eTrack icon installed as a Progressive Web Application (PWA) on an Android mobile device.

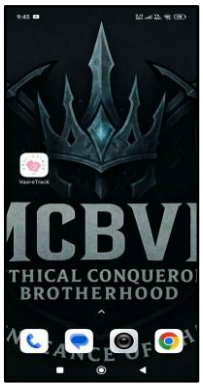

Figure 25. *Downloaded Vaxi-eTrack PWA on an Android Device*

Cutover

The cutover phase marked the transition of Vaxi-eTrack from development to full implementation. This phase encompassed the testing activities.

Unit Testing

Unit testing was carried out to validate the core functions of the Vaxi-eTrack System, focusing on Child Records Registration, Vaccine Inventory, Vaccine Request Generation, and User Management. The Child Records module performed reliably, handling correct inputs, detecting errors, and managing uncommon cases, with accuracy ratings of 4 to 5. Minor issues such as slight slowdowns during multiple registrations and initial uncertainty in filling certain fields were noted, but no critical errors occurred. The Vaccine Inventory module demonstrated strong stability, correctly processing inputs, displaying error messages, and passing boundary tests, also earning ratings of 4 to 5 with no bugs reported. The Vaccine Request Generation module consistently produced accurate requests based on inventory data, prevented invalid submissions, and provided clear validation prompts. Ratings remained 4 to 5, with only minor suggestions for clearer field labels. Finally, the User Management module supported user creation, role assignment, and account updates effectively, with users finding the interface intuitive. Accuracy ratings ranged from 4 to 5, and no bugs or errors were detected, confirming the module's robustness and readiness for deployment.

Usability Testing

Usability testing of the Vaxi-eTrack System was conducted using questionnaires based on the ISO 9241-11 framework and the System Usability Scale (SUS), measuring effectiveness, efficiency, and user satisfaction. Pilot sessions with healthcare workers and parents confirmed that core tasks, such as recording vaccine lots, updating child records, and generating reports, were completed successfully. Parents accessing the system via mobile devices initially faced issues with scaling, alignment, and loading speed, underscoring the importance of mobile optimization. Despite these challenges, overall feedback was highly positive, with most ratings between 4 (Agree) and 5 (Strongly Agree). Parents valued the vaccination reminders, while healthcare workers appreciated the role of -based dashboards and streamlined workflows that reduced manual record-keeping.

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Table 3. System Usability Scale (SUS) for Vaxi-eTrack System

SUS Item	Question	P 1	P2	P3	P4	P5	P6	P7
1	I think I would like to use this system frequently.	4	5	3	4	5	3	5
2	I found the system unnecessarily complex.	2	1	3	2	2	3	1
3	I thought the system was easy to use.	4	5	3	5	4	2	5
4	I think I would need the support of a technical person.	2	1	3	2	2	4	1
5	I found the various functions well integrated.	4	5	3	4	4	3	5
6	I thought there was too much inconsistency.	2	1	3	2	2	3	1
7	I would imagine most people would learn to use this system quickly.	4	5	3	5	4	3	5
8	I found the system very awkward to use.	2	1	3	2	2	3	1
9	I felt very confident using the system.	4	5	3	5	4	3	5
10	I needed to learn many things before getting started.	2	1	3	2	2	4	1
	TOTAL SCORES	75	100	50	82.5	77.5	42.5	100

SUS scores ranged from 42.5 to 100, reflecting varied user experiences. High scores indicated strong confidence and ease of use, while lower scores pointed to complexity and the need for additional guidance. The scoring method followed standard SUS computation, converting responses into a 0–100 scale, with higher values representing better usability.

Figure 26. Radar chart of usability testing results, highlighting strong system performance across seven dimensions. The chart shows high ratings in Security, Maintainability, and Compatibility, alongside solid scores in Reliability, Scalability, and overall usability, reflecting the system's maturity and readiness for deployment. With a mean usability score of 4.14 across seven dimensions. Security emerged as the highest-rated factor (4.52), demonstrating user trust in data protection. Maintainability (4.24) and Compatibility (4.21) also scored well, confirming resilience and adaptability across devices. Reliability & Availability (4.00) and Scalability (4.14) further validated operational stability and readiness for broad deployment. Overall, the findings show that Vaxi-eTrack is a secure, reliable, and user-friendly platform, with opportunities for improvement in mobile accessibility and interface simplification.

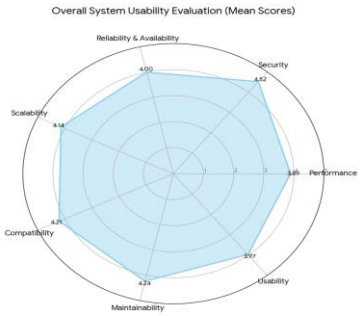

Figure 26. *Vaxi-eTrack System Attribute Stats (Radar Chart)*

User Acceptance Testing

After the successful completion of both Unit Testing and Usability Testing, the researchers proceeded to conduct User Acceptance Testing (UAT) as the final assessment before deployment. This phase involved the

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end users, including parents and healthcare personnel, to evaluate whether the Vaxi-eTrack system met their expectations and complied with the core functionalities required for effective vaccination. Feedback from this testing confirmed that the system was user-friendly, reliable, and fully functional, satisfying the needs of its intended users.

Table 4. User Acceptance Testing for the Health Personnel Raw Data

Number	Acceptance requirement	Critical		Test Result	
		Yes	No	Accept	Reject
1	Administered vaccines correctly appear in the inventory after being recorded.	✓		✓	
2	All inputs (child data, vitals, notes) save properly without disappearing.	✓		✓	
3	Images and uploaded documents preview correctly in the system.	✓		✓	
4	The child record management system is easy to navigate.	✓		✓	
5	Scheduling the next vaccination date works properly.	✓		✓	
6	Vaccine inventory loads quickly and displays accurate stock information.	✓		✓	
7	Notifications for upcoming vaccinations or low stock are timely and accurate.	✓		✓	
8	Health personnel can record vaccinations without errors or delays.	✓		✓	
9	The system allows fast searching and locating of child records.	✓		✓	
10	All features function clearly without requiring additional clarification.	✓		✓	

Deployment Plan

The Vaxi-eTrack system is designed with continuous optimization to ensure high performance, using database indexing, caching, load balancing, and cloud scaling to handle growing records and users. Security is prioritized through multi-factor authentication, end-to-end encryption, audits, and role-based access control. Usability is enhanced via accessibility features, multilingual support, tooltips, and customizable dashboards, guided by ongoing feedback and testing. Reliability and availability are supported by redundant cloud infrastructure, automated failover, daily backups, and disaster recovery planning. Scalability is achieved through dynamic cloud expansion, modular database structures, and APIs for integration with national health systems, with future modules planned for broader immunization coverage. Compatibility is maintained through cross-platform testing and updates, with potential native mobile apps for improved performance. Maintainability is ensured by modular architecture, automated testing, documentation, and regular refactoring. Finally, a transition plan includes technical guidance, knowledge transfer, and early post-deployment support from researchers to ensure smooth adoption and long-term usability.

The deployment plan for the Vaxi-eTrack system includes several key components. The User Manual serves as a comprehensive guide for health workers and administrators, offering step-by-step instructions on account registration, login, child profile management, immunization data recording, vaccine inventory monitoring, appointment scheduling, and report generation. It is designed with clear instructions, labeled screenshots, and simple language to ensure

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usability even for users with limited technical background.

The Installation Manual provides detailed steps for setting up the system on both mobile devices and desktop computers through its Progressive Web Application (PWA) integration. It explains how to install the system from a web browser and add it to the home screen or desktop for easy access. The manual also specifies the minimum hardware and software requirements needed to ensure proper system performance.

The Network Plan outlines the system's connectivity requirements and data flow, ensuring smooth communication between modules and users. The Long-Term Plan addresses future maintenance, updates, and scalability considerations, supporting the system's sustainability and adaptability over time.

Network Plan

The researchers developed a network plan and cloud hosting requirements to ensure that Vaxi-eTrack performs optimally and provides a seamless user experience. The plan is designed around the system's deployment infrastructure and existing network capabilities. Vaxi-eTrack is hosted on Vercel, which manages the web application deployment and provides fast, scalable delivery. Firebase serves as the primary database, ensuring reliable storage and retrieval of immunization and user data. Appwrite is used to manage and store system images efficiently, supporting secure file handling. GitHub functions as the version control platform, handling system updates and source code management, which allows for coordinated development and deployment processes. These hosting and network configurations collectively support system stability, accessibility, and scalability. The table below summarizes the cloud hosting and network requirements for each service.

CONCLUSION AND RECOMMENDATION

Conclusion

The development and implementation of Vaxi-eTrack successfully demonstrated the effectiveness of a digital vaccination tracking system for community health settings. The system met the functional requirements outlined during the planning and design phases, providing modules for vaccine inventory management, vaccine lot expiration tracking, child vaccination records, and role-based access. Through pilot testing and deployment in Barangay Pico, the platform proved to be reliable, user-friendly, and accessible, particularly after enhancements to support mobile access via a Progressive Web Application.

The testing and deployment phases confirmed that Vaxi-eTrack improved operational efficiency, reduced manual record-keeping errors, and allowed both healthcare workers and parents to monitor vaccination schedules accurately. Feedback from users highlighted the system's practicality and positive impact on workflow, demonstrating that digital solutions can enhance immunization management at the community level. Overall, the project achieved its objectives of increasing accuracy, accessibility, and efficiency in vaccination monitoring, while also providing a scalable platform for potential future expansion to other communities.

Recommendations

Based on the development, testing, and pilot deployment of Vaxi-eTrack, several recommendations are proposed to enhance its effectiveness and support broader implementation. The system should be expanded to additional barangays and health centers to maximize its impact on community immunization tracking. Notification features can be enhanced through SMS or push alerts to improve parental awareness of upcoming vaccinations. To address connectivity challenges, offline functionality should be developed, ensuring uninterrupted access to records. Advanced reporting and analytics capabilities are recommended to enable healthcare authorities to monitor immunization trends, identify coverage gaps, and make data-driven decisions. Continuous user training and support for healthcare staff and parents will help maintain proper system use and facilitate adaptation to new features. Finally, periodic

system evaluations and updates based on user feedback and emerging requirements are essential to sustain relevance, efficiency, and overall system performance.

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