A routine immunization decision support system framework for vaccine demand forecasting in the city health office

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ABSTRACT

"Immunization" has been documented as one of the most flourishing measures for community well-being ever devised. Management of "immunization" information will ensure that children and newborns receive immunization on schedule. However, managing this immunization information is done manually. Customary data processing method are time-intensive, lengthy, slow in progress and susceptible to inaccuracies during encoding, verification, and re-ordering. In this study, a web-based routine immunization decision support system (RIDSS) was conceptualized to address these challenges. The web-based system is an innovative tool designed to streamline vaccine demand forecasting within the city health office (CHO) of Panabo. This system uses time series analysis and machine learning models to output accurate predictions of future vaccination demand. Using historical data on the performance of routine immunization (RI), it allows identification and analysis of actionable signals to facilitate better-informed decisions with respect to vaccine procurement, distribution and allocation. The system is a substantial improvement of the current basic vaccine supply management, making it possible for Panabo CHO to have an organized program in administering immunization. Key stakeholders identified were presented with the prototype of system to assure effectiveness and utility. An act of major recognition to the system and its relevance in community health.

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1. INTRODUCTION

The World Health Organization (WHO) established the expanded program on immunization (EPI) in 1974 to combat illnesses that can be prevented by vaccines and ensure that children in all countries have access to life-saving vaccinations [1]-[3]. Immunization is regarded as one of the most successful public health strategies ever established, aiming to control and eradicate illnesses that are vaccine-preventable [4], [5]. Immunization for "infants/children/women" is done through the "reaching every district (RED)" strategy. The general objective is to decrease the mortality among kids in resistance to the foremost, not unordinary, vaccine-preventable illnesses. During infancy, parents gave their best and prioritized their infant's health. Mothers subject themselves to pre-birth to ensure their babies proper nutrients are supplemented. Hence, strengthening vaccine-preventable disease surveillance is vital for the eradication/elimination efforts and the most economical practices in child health care [6], [7]. Since adopting the program in 1978, immunization against common childhood diseases has been essential to the mother and child's well-being [5], [8]-[10], as well as protecting the health of families, and communities [11].

Outreach delivery along with health facility visits are the two most common immunization methods [12], [13]. Cold chains are time-critical, complicated, and dynamic, necessitating careful attention to preserve vaccination efficacy [6], [14]. Vaccine storage and transportation are critical operations in the cold chain, from the producer to the major vaccine stockpile and finally to the outreach sites, which are typically located in health centers. To ensure regular operations, it is critical to maintain an inventory on a regular basis to ensure continuous and timely delivery of vaccine supplies while also ensuring quality criteria are met [15]. Otherwise, insufficient inventory leads to shortages and disruptions [16]. Inventory management involves a component of "supply chain management" that plans, implements, and coordinates movement and storage of goods, and associated information between the place of origin and delivery to congregate consumer demands [5], [17]. The effort to promote routine immunization (RI) for children and infants in the Philippines is led by the "reaching every barangay (REB)" approach, which is a refinement of "WHO-UNICEF's RED" strategy. The goal is to increase RI enrolment and reduce dropout rates. The approach study facts for action, re-creation of outreach services, fortification of connections amid groups and administrations, strong management, and augmentation of supplies. Its significance is dependent on precision when considering the type of immunization, the presentation (vial size), the dosage, and the timing of vaccine delivery [18]. In Panabo City, Davao del Norte, the conduct of RI is done through barangay health centers (BHC). Scheduled child visits are mostly done anytime on the second week of each month. The BHCs are supplied and monitored through the city health office (CHO). Further, the CHO is responsible for managing the vaccine cold chain and administering immunization programs in all forty barangays. The CHO oversees the reception, distribution, and monitoring of several "expanded program on immunization (EPI)" vaccinations, such as Bacillus Calmette-Guérin (BCG), Hepatitis B, bivalent oral polio vaccine (bOPV), inactivated polio vaccine (IPV), Measles, Mumps, and Rubella vaccine (MMR), Pneumococcal Conjugate vaccine (PCV), and Pentavalent vaccines. As a result, there is a need to create and submit reports on these activities.

In the BHC, immunization registries are essential to vaccine delivery and in assessing the progress and the basics of the success of the RI. The immunization is scheduled to be conducted every Wednesday of the month, in a 28-day cycle. The profiling of the infants/children are done manually, as shown in Annex A, Figures 1 and 2. It is observed that each barangay has devised its own registration forms, implying a lack of uniformity in the forms used. The child immunization record is in the form of a one-fourth vellum paper. Further, the files of brown envelopes containing the registration forms of children are stored in the cabinet. Thus, retrieving these forms during scheduled visits is time-consuming and cumbersome due to the increasing volume of paper records as the immunization program continues. The increasing file of papers poses fire hazards which may harm the safety of the health centers. The manual profiling of infants/children and the lack of uniform registration forms across barangays create inefficiencies in the immunization program. The increasing volume of paper records poses challenges in maintaining and accessing the necessary information.

The recording of vaccine (receiving and issuance) is done using the stock card (ledgers) in the health centers, and in the vaccine cold chain section of the city health, as presented in Annex B and Annex C respectively. These forms and ledgers could be misplaced or destroyed. The ledgers used for recording vaccine receiving and issuance could be misplaced or destroyed, leading to the potential loss of critical data. This traditional process is prone to data entry errors, which can lead to inaccuracies in the amount of vaccination vials ordered. These inaccuracies in vaccination order numbers can have an impact on stock levels and reorder scheduling, potentially disrupting immunizations.

Another reason that causes variance and interruptions in the immunization system is missing the opportunity due to obliviousness of parents or caregivers to vaccinate their children. Prior reminders are not offered as pointed out in the study [19]. Thus, a framework for portable innovations, such as reminder/recall [5], [20], offers an arrangement that mitigates a few of these challenges. Engaging people to have more control of their claim immunization data utilizing available resources, such as smartphones, moves forward the convenience and accuracy of the information. Emerging technologies and computerized frameworks such as decision-support tools [21] or web-based systems with mobile applications such as the routine immunizations decision support system (RIDSS) have allowed the Barangay Health Workers to accomplish their tasks from profiling to the filing phase more efficiently and in sending notifications to the child's parents and expectant mothers as prior reminders of their scheduled visits. Furthermore, this framework also aims to support the parents' children, pregnant mothers, and barangay health workers to have real-time access to the same information to make strides in persistent care, effective procurement planning, inventory management, and more preciseness in predicting vaccine demand. This is to guarantee the availability of vaccines in the proper quantity and condition, delivered to the right place at the right time [22], [23].

The RIDSS is supported through the following review of related literature according to its functionality:

– Pre-registration and notification

Over the years, the health sector has built an extensive network of medical facilities and community health workers to provide lifesaving interventions to the most vulnerable communities. The reach of immunization demonstrates the ability for health services to reach children in their initial months of life. The programs are particularly well-suited to assisting with birth registration initiatives. Scheduled immunization appointments are frequently children's first interactions with a government-supported system, and they provide an opportunity for crucial event notice and official registration. Immunization is typically offered broadly throughout the country through health-care facilities and community outreach programs [20], [24].

Information systems played critical roles in storing vaccination records, managing vaccines, managing cold chains, and verifying immunization status upon school admission. The number of children's records counted and uploaded to the portal determined the proportion of duplicate records, such as name, birth date, and place of birth. These data were used to identify the identical data, with the mother's name and phone number serving as supplementary information for de-duplication if needed. The application's information was uploaded to the web-based administration platform in real time or at regular intervals to ensure its completeness and accuracy [25]. Hence, registration and profiling are necessary for every immunization program. Moreover, pushing notifications to the child's parents and expectant mothers is essential as a reminder of their scheduled visits.

– Consistency of the monitoring of the consumption of vaccines in the health center.

As vaccination initiatives grow, better and more efficient inventories use larger weights to provide precise estimates for item requests, distribute supplies more effectively, and optimize supply delivery. The primary purpose is to keep stocks at an optimal level, eliminate stockouts and excesses, and address the contentious dependent tasks evaluated by the availability of supplies [26]. Thus, effective management of inventory balances product availability while keeping inventory expenses under control. It provides increased and sustained vaccination finance, continuous vaccine supply, overcoming inequities in immunization and cold chain processes, workforce strengthening, and the integration of immunization information systems into all elements of the program [1], [27]-[29]. Timely access to reliable consumption data of vaccines provides new opportunities for the CHO to monitor and continuously improve their performance, reach, and efficiency [1], [19], [30] on the vaccine delivery of RI.

– Reports generations on the conduct of routine immunization for efficient planning, procurement, and re-order policy.

An important factor affecting information systems in RI is the demand and consumption of vaccines and supplies in health centers. The storage of these vaccines before consumption is essential to ensure their potency and to avoid wastage [28], [31], which may affect inventory and timely administration and delivery of vaccines [32], [33]. Reports on the scheduled child visits and vaccine consumed per visit are necessary for real-time inventory reports. The information gathered from these reports will be combined for analysis and used in predictive modelling and algorithms that employ machine learning to examine historical data and find indications of trends in vaccine demand. These strategies enable the system to accurately anticipate future vaccination requirements. As a result, it is critical to ensure the availability and accessibility for timely immunization administration to infants and children, as well as the regular operation and supply of vaccines. This would also ensure efficient planning and procurement, as well as ongoing improvement in the reordering strategy for vaccinations in health canters [34].

2. RESEARCH METHOD

The components of the immunization system at the BHC include service delivery, supply and logistics, communication, management, and monitoring. These elements are aligned with the broader building blocks of the health system, guiding the design and implementation of the RIDSS while addressing the comprehensive needs of the immunization program. Furthermore, it is tailored to enhance specific priorities, thereby strengthening the health system according to local contexts and requirements. Immunization registries are integral to this system, documenting all vaccinations administered at the BHC and improving coverage and uptake by providing accurate, real-time immunization histories. These resources ensure consistency and precision in evaluating immunization efforts and forecasting vaccine demand [35]. This comprehensive approach helps ensure that the system is effective in supporting RI decision-making.

The study followed a software development approach starting with stakeholder engagement to gather insights from health officials and community leaders. A needs assessment and technology review identified system requirements, leading to the system design phase informed by stakeholder input. In prototype and design technology, a functional prototype was developed for early testing and feedback. implementation and training will ensure effective system use by end-users and will be followed by monitoring and evaluation to assess performance. A re-order plan, sustainability, and scaling strategy will be created for long-term operation and expansion. Lastly, vaccine demand forecasting techniques and model evaluation metrics will enhance demand prediction through accuracy and precision metrics.

2.1. Establishing stakeholder engagement

The study began by engaging stakeholders who were involved during its conduct. Presentation of the framework and the prototype of the RIDSS to the identified stakeholders and their participation through special sessions is essential in the validation and deployment of the system [21]. The session included barangay healthcare workers from the barangay local government unit and the CHO, community members, and barangay officials. The consultation aims to understand the level of needs, concerns, and expectations by seeking input to better understand their perspectives and tailor the system accordingly. Updates on progress, milestones, and changes was communicated through various channels like emails and meetings to acknowledge and address any potential conflicts or challenges that may arise from different stakeholder perspectives. Feedback mechanisms and opportunities for stakeholders to engage in dialogue was provided. Stakeholders were engaged in the design, implementation, and evaluation of the RIDSS through focus group discussions and workshops to ensure the system meets the needs and expectations of all relevant parties.

2.2. Conducting needs assessment and technology review

After the establishment of stakeholder engagement, the next phase was to conduct a needs assessment and technology review. An interview was held with the head of the BHW in two (2) barangays of Panabo city, one (1) from the Poblacion area and the other one (1) from the urban area. The head of the BHW of each barangay discussed and explained the processes and the conduct of the RI and presented the forms used for the registration and scheduled visit transactions and immunization report booklet. The concept was also discussed by the CHO head and the vaccine cold chain in charge.

This process evaluated the current technology landscape, identifies gaps and inefficiencies, and determines future technology requirements. The first step was to gather information from stakeholders to better understand their current workflows, pain points, and expectations from technology. The assessment also considered the organization’s strategic goals and how technology can support these objectives. Thereafter, the assessment reviewed the current technology infrastructure, including hardware, software, and network systems. This involves identifying areas where the existing technology is impeding productivity or efficiency. The assessment also considered the potential for technology to improve workflows, enhance customer service, and increase healthcare worker productivity. The findings from the needs assessment and technology review were utilized to guide technology investment decisions, ensuring that the selected technology aligns with the organization’s goals and objectives. Key factors such as cost, implementation time, and maintenance requirements were thoroughly assessed to guarantee that the chosen solution is both strategic and effective.

2.3. Designing the system

Once the needs assessment and technology review were done, the system design phase commenced. A series of discussions, interviews, and observations of the manual processes were carried out to identify needs, propose strategies for initiating the system’s development, enhance efficiency, and minimize paperwork and time spent, especially in documenting scheduled child visits. A framework was created to guide the development of the system.

In this phase, the system development life cycle model was utilized. The method includes analysis, design, implementation, and maintenance. Each project phase involved business modelling, analysis and design, implementation, testing, and deployment. Considering the role of the RIDSS in assisting immunization programs and providers, it facilitates vaccine ordering and inventory management, offers clinical decision support for evaluation and forecasting, provides reminder and recall capabilities for patient follow-up, consolidates immunization histories, verifies proof of immunity, and estimates vaccination coverage for specific geographic areas and population groups. Figure 1 depicts a conceptual framework for defining and clarifying the software system’s boundaries. It identifies data flows between the design and external entities.

Further, the RIDSS was built on evidence-based public health informatics. The system leverages advanced data analytics, and decision support techniques to provide accurate and timely vaccine demand forecasts and immunization recommendations. The underlying scientific basis includes the following as describe in the subsections below.

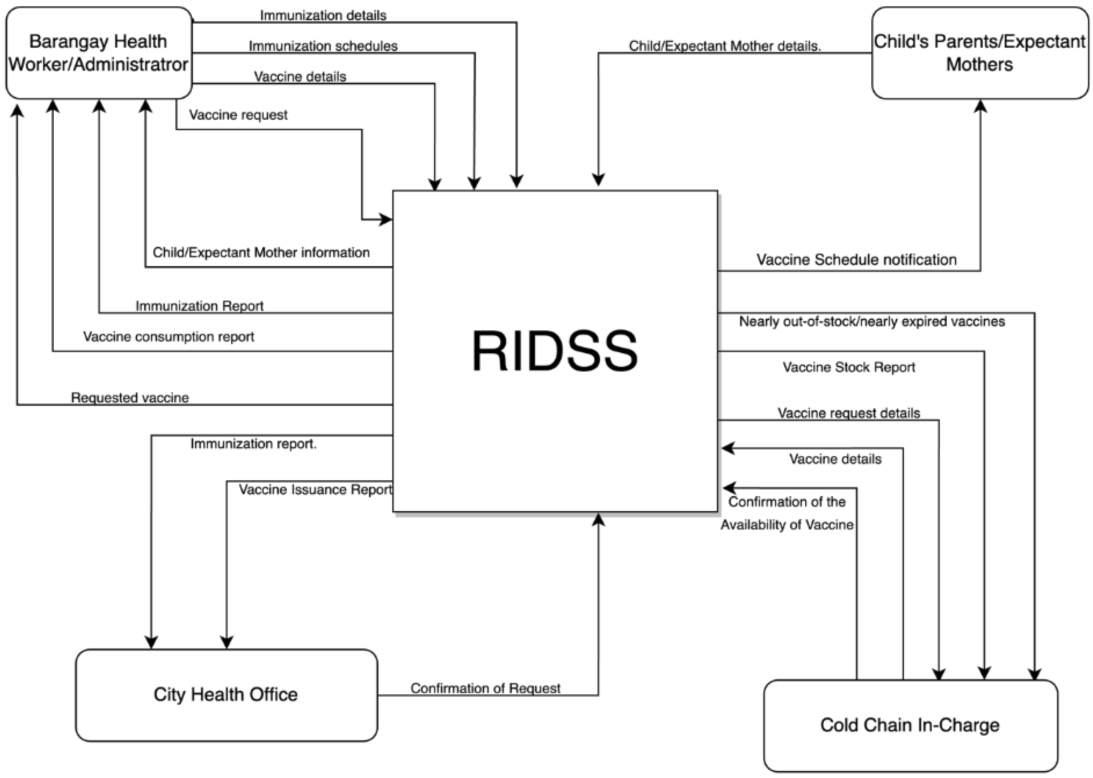

Figure 1. Conceptual framework

2.3.1. Input

The RIDSS recorded vaccine data such as vaccine types, stock levels of vials per vaccine type, expiration dates, and batch numbers. It records children's and expectant mothers' profiles through the registration function.

- Data integration: integrating data from various sources, such as immunization registries, demographic databases, and immunization records, allowed the RIDSS to generate comprehensive and reliable forecasts that account for local, provincial, and regional variations in vaccine demand.
- Notifications and reminders: the system provided short message service notifications for scheduled immunization visits and reminders to the parents of the child and expectant mothers. This helps improve immunization coverage and timeliness, eliminating missed opportunities that ultimately contribute to reducing vaccine-preventable diseases and improving health outcomes.
- Immunization recommendations: the RIDSS provided specific immunization recommendations based on the date of birth, vaccination history, and national immunization guidelines. This ensures that children receive the appropriate vaccines at the right time, minimizing missed opportunities for vaccination.

2.3.2. Process

The RIDSS processed the data collected from the immunization reports submitted by the BHC, integrated it for analysis, and utilized it in predictive modelling for vaccine demand.

- Data preparation: in the preparation stage, historical data stored in the RIDSS database was divided using the 80:20 rule, where 80% was allocated for training and 20% for testing purposes.
- Forecasting: The RIDSS employed a time series forecasting model to predict future vaccine requirements with a high degree of accuracy.

2.3.3. Output

The RIDSS generates several key reports to enhance decision-making:

- Summary of vaccine demand: this includes the (i) inventory report which shows the vaccines consumed per type, providing valuable insights into usage patterns, (ii) distribution report which generates a distribution report to track the allocation and delivery of vaccines, and (iii) immunization report which includes the details of the immunization and vaccination activities, enabling data-driven analysis.
- Vaccine demand per type: the system also generates a report on the demand for each type of vaccine, supporting informed procurement and distribution decisions.

These centralized reports, enabled by the RIDSS, provided a comprehensive platform for data visualization, analysis, and reporting. This empowers policymakers, program managers, and healthcare workers to make well- informed decisions on vaccine procurement, distribution, and delivery. Moreover, it is grounded in the principles of evidence-based vaccines, public health informatics, and data-driven decision-making. By utilizing advanced technologies and integrating data from various sources, these systems seek to enhance the efficiency and effectiveness of RI programs. This, in turn, contributes to the reduction of vaccine-preventable diseases and aids in optimizing immunization initiatives, aligning with global health objectives. The theoretical framework illustrating the input-process-output model of the RIDSS is presented in Figure 2.

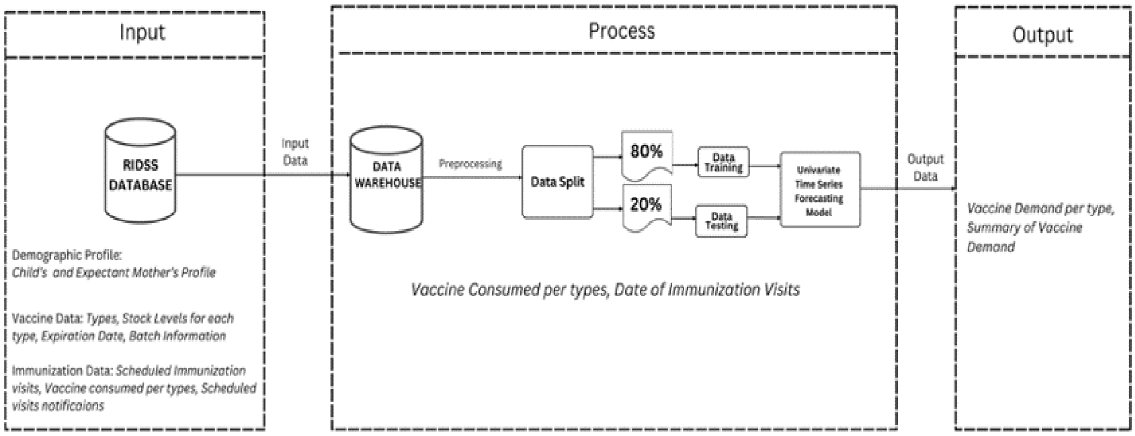

Figure 2. Theoretical framework

2.4. Prototype and design technology

After the completion of the system design phase, the prototype and design technology also started. The system was designed as web-based and with a mobile application. The prototype of the system was created using the Figma Collaborative Design Tool. The system used the brave search engine, PhP MyAdmin as a database administration framework, visual studio code as a database administration framework, XAMPP Control Panel v3.2.4, and Adobe Illustrator in making outlines, charts, diagrams, logos, and delineations.

2.5. Implementation and training

The system will be implemented in the identified BHC in Panabo city and the CHO respectively. There will be a series of call-for-coordination meetings with stakeholders to develop a detailed implementation plan with timelines, responsibilities, and communication/training schedules. During the deployment of the system, user training will be conducted first for the authorized personnel responsible in the BHC, so they become acquainted with the system workflows and functionalities. The involvement of parents of the child and expectant mothers is also necessary, especially in the registration and profiling process. Provision of technical support and troubleshooting will be available during the initial implementation phase. Additionally, monitoring of system usage and user feedback will be conducted to identify areas for improvement.

2.6. Monitoring and evaluation

The results framework with key performance indicators, such as immunization coverage, vaccine wastage, and user satisfaction, will be established. The collection of data on RIDSS usage will be analyzed, with regular review of monitoring data, and adjustment of the system or implementation as needed. Conduct periodic evaluations to assess the long-term sustainability and scalability of the system. Evaluation of findings will be shared through coordination meetings with stakeholders and be able to use these findings to inform future improvements. By following this plan, the BHC and CHO can effectively integrate a RIDSS into their immunization program, leading to improved immunization outcomes and enhanced decision-making capabilities for healthcare workers.

2.7. Re-order plan, sustainability, and scaling

The results obtained from the forecasting process will guide the re-order plan of the vaccine demand. The time series data collected will be used, analyzed, and reviewed to understand demand trends. To assess the long-term sustainability and scalability of the system, periodic evaluations will be conducted, including its ability to forecast vaccine demand accurately. By following these activities, the RIDSS can effectively forecast vaccine demand, optimize vaccine inventory management, and enhance decision-making capabilities to ensure adequate vaccine supply and coverage.

Additionally, for long-term sustainability and scalability, the following strategies should be developed: first, establish collaboration and partnership among various stakeholders including governments, donors, and industry partners, to ensure a collective approach to vaccine demand forecasting and supply planning. This collaboration can facilitate the sharing of data, expertise, and resources, enhancing the accuracy and effectiveness of forecasting models. Second, establish sustainable funding models that support the development and implementation of vaccine demand forecasting and supply planning systems. This can include public-private partnerships, grants, and other forms of financial support. Funding models should be designed to ensure the long-term viability and scalability of these systems. Third, implement robust data collection and analysis systems to provide accurate and timely information on vaccine demand and supply. This data can be used to inform strategic decisions and optimize vaccine distribution, ensuring that vaccines reach those who need them most. Fourth, provide training and capacity-building programs for healthcare workers, and other stakeholders involved in vaccine distribution. This can enhance their understanding of vaccine demand forecasting and supply planning, enabling them to make informed decisions and effectively manage vaccine distribution. Fifth, establish a system for monitoring and evaluating the effectiveness of vaccine demand forecasting and supply planning strategies. This can help identify areas for improvement and ensure that strategies are adapted to changing circumstances. Sixth, engage with stakeholders, including healthcare workers, policymakers, and the public, to ensure that vaccine demand forecasting and supply planning strategies are responsive to their needs and concerns. This can involve public education campaigns and community outreach programs. Seventh, continuously fund research and development initiatives focused on improving vaccine demand forecasting and supply planning. This can involve the development of new technologies, the refinement of existing models, and the exploration of innovative solutions to challenges in vaccine distribution. Eight, develop strategies that can adapt to changing circumstances, such as shifts in vaccine demand or supply chain disruptions. This can involve the development of contingency plans and the establishment of emergency response systems. By incorporating these elements into vaccine demand forecasting and supply planning strategies, agencies can develop sustainable and effective systems that ensure the long-term availability of vaccines and support global health goals.

2.8. Vaccine demand forecasting techniques and model evaluation metrics

Forecasting vaccine demand is a strategic technique that can assist organizations in making informed decisions, planning effectively, managing inventories efficiently, optimizing resources, and enhancing customer satisfaction across various sectors. To accurately predict vaccine demand, it is essential to analyze historical time series data, employ statistical modelling techniques, and leverage machine learning algorithms. This study aims to create and compare different machine learning models for vaccine demand prediction models, alongside the goal of identifying the most effective approach.

By comparing the accuracy and reliability of these forecasting methods, the study seeks to determine the best-performing approach for predicting vaccine demand. The findings from this research can be utilized to enhance decision-making processes and optimize vaccine supply chain management. To assess the performance of the vaccine demand forecasting models, two key metrics will be employed, such as mean absolute error (MAE). This metric quantifies the average size of the errors in the same units as the original data, providing an overall indication of the model's accuracy. The MAE is calculated as the average of the absolute differences between the actual values yt and the predicted values y^t, divided by the number of observations n. Another metric is mean absolute percentage error (MAPE). MAPE calculates the average of the absolute percentage errors, contribution to a relative model effectiveness measure that is independent on the magnitude of the data. It can be determined by taking the average of the absolute differences between the actual values yt and the predicted values y^t, divided by the actual values yt, and then multiplying by 100. By evaluating the forecasting models using these metrics, the study aims to identify the most accurate and reliable approach for predicting vaccine demand, ultimately contributing to improved decision-making and optimized vaccine supply chain management.

3. RESULTS AND DISCUSSION

The coordination meeting with key stakeholders encompassed a comprehensive discussion of the system's framework and the unveiling of the prototype. The prototype was presented to two Barangay Health Workers in Brgy. JP Laurel, two parents, one nurse assigned in Brgy. New Malitbog, respectively. Moreover, a coordination meeting also took place at the CHO which was attended by the immunization cold chain assigned personnel of the CHO located at Brgy. JP Laurel, Panabo city. After the meeting, the stakeholders evaluated the prototype using the software usability matrix. The result of the evaluation yielded a positive outcome with consent indicating a favorable reception towards the proposed system and a readiness to adopt and implement it within the community. Deliberations revealed a shared understanding among participants regarding the system's potential benefits and value for the community. The summary of the system usability is presented in Table 1.

Further, throughout the presentation, stakeholders actively engaged with the content, showcasing a strong grasp of the system's concept and functionalities. Notably, there was a widespread acknowledgment of the system's significance for community health, particularly in the realms of child and maternal health. This recognition sparked enthusiasm and support among participants. The prototypes were well-received, garnering positive feedback on their user interface, accessibility, user-friendliness, and security, as shown in Table 2. While stakeholders praised these aspects, they also provided constructive input, raised specific concerns, and offered suggestions concerning data privacy and security. This feedback emphasized the need for robust safeguards and highlighted a collaborative approach to system development.

As shown on Table 2, we found that the development of the study showed an impact on software usability. Interpreting the results, the proficiency, interactivity, accuracy, and security criteria were satisfied. Acknowledging the positive feedback, stakeholders recognized potential challenges during the implementation phase, particularly focusing on the necessity for adequate training and support for end-users. Addressing these considerations was deemed crucial for a successful deployment. The subsequent steps involved refining the system design to integrate valuable suggestions and address raised concerns. Additionally, a pilot implementation phase was planned to evaluate real-world feasibility and gather further insights. This iterative process aimed to drive enhancements that would ensure the system's effectiveness and seamless integration into community healthcare practices.

Table 1. Results of software usability evaluation

Items	Description	Agree	Disagree
	Proficiency		
1	The system is easy to navigate.	5	0
2	The system's functions are comprehensive.	5	0
3	The system has adequate search facilities.	5	0
4	The is always up and is accessible.	N/A	N/A
5	The system has valid inputs and outputs.	5	0
	Interactive		
6	The system has many interactive features.	5	0
7	The system is simple to use.	4	1
8	The system is useful.	5	0
9	The system is complete.	5	0
10	The system is clear.	5	0
	Accuracy		
11	The content is accurate.	5	0
12	The system's details about its functions are easy to find.	5	0
13	The system's fonts are formal and proper.	5	0
14	The system looks attractive.	5	0
15	The user interface of the system is understandable.	5	0
	Security		
16	The system does not show any malicious or suspicious functionalities.	5	0
17	The system functionalities are very well integrated.	5	0
18	The system is secured for carrying out processes.	5	0
19	The system is safe to use.	5	0
20	I feel comfortable using the system.	N/A	N/A

Table 2. Summary of the rating of the software usability evaluation

Software usability evaluation summary		
1	Proficiency	100%
2	Interactivity	96%
3	Accuracy	100%
4	Security	100%

4. CONCLUSION

The outcomes of the user level training, and system validation revealed a substantial level of support and enthusiasm among stakeholders. The results indicate that the web-based routine information decision support system framework is highly responsive. Its functionalities are well-integrated, facilitating processes that aid conventional data processing methods, which are often labor-intensive and susceptible to mistakes during vaccine encoding, verification, and reordering. Thus, the system's framework was found to be easy to navigate, comprehensive, and interactive. Its functionalities are well-integrated, facilitating processes that aid labor-intensive, slow and error-prone data processing methods during vaccine encoding, verification, and reordering. Moreover, the framework has already been accepted by the Philippine Council for Health Research and Development (PCHRD) in its recently concluded call for proposals for funding this coming fiscal year (FY) 2026 for further development and implementation.

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AUTHOR CONTRIBUTIONS STATEMENT

Name of Author	C	M	So	Va	Fo	I	R	D	O	E	Vi	Su	P	Fu
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Jovito P. Bolacoy Jr.			✓	✓	✓	✓		✓		✓	✓		✓	
Jovanne Alejandrino			✓	✓		✓		✓		✓	✓	✓	✓	
Mark Ronald S. Manseguiao					✓	✓	✓			✓	✓	✓	✓	✓

C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMENT

The authors declare that they have no financial, personal, or professional conflicts of interest related to this manuscript.

DATA AVAILABILITY

Data are available from the corresponding author upon request.

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