

SCVAX: A SOLUTION TO NATIONWIDE VACCINATION MANAGEMENT INFORMATION SYSTEM

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Abstract

SCVax is a robust application platform designed to manage vaccination programs efficiently. The problem at hand is the need for an effective vaccination management information system. This paper introduces SCVax, offering unique features in mapping, visualization, and data handling with QR code integration for data reliability and confidentiality. The focus is on designing, developing, and deploying SCVax to streamline vaccination programs. It utilizes technologies like QR codes, online web applications, location mapping, data visualization, and a mobile QR scanner app. Rapid application development enables swift data collection, analysis, and development. SCVax facilitates faster and accurate registration, minimizing manual form-filling at vaccination centres. It includes a scheduling feature for resident convenience, generates QR-coded vaccination cards, provides real-time verification, and creates vaccination certificates with passport features. Additionally, SCVax supports government reporting and aids contact tracing. Users positively rated its usability, functionality, security, and portability. SCVax addresses the problem of inefficient vaccination management by offering an accurate, efficient, and user-friendly solution. It streamlines the vaccination process, enhances public health initiatives, and enables local government units to handle data effectively for improved outcomes.

Keywords: Interactive maps, SCVax, Vaccination system, Visualization.

1. Introduction

The coronavirus known as COVID-19 is a widespread and life-threatening illness that has caused worldwide economic and health crises. The disease may cause mild to severe respiratory illness that may result in death. Due to alarming levels of spread COVID-19 was declared a global pandemic by the World Health Organization on March 12, 2020. The number of people infected, and the type of cases changes daily. Organizations that collect data and information about the disease including the WHO and the Centres for Disease Control and Prevention (CDC) played an important role in further learning and understanding the outbreak [1]. The Philippines is one of the countries greatly affected by the coronavirus. The diseases caused a lot of hardships for Filipinos. The government declared the entire country under a state of calamity initially for six months which was subsequently extended to date. Border control, lockdown, home quarantine, and limiting the movement of people outside their homes are also mandated by the government to prevent the spread of the coronavirus [2].

The local government of Surigao City (LGU) is one of the cities in the Philippines that actively support the implementation of health protocols and guidelines to prevent the spread of COVID-19. Local executive orders mandated border control, travel restrictions, limited movement of residents, and strict implementation of health and safety protocols. Residents are constantly reminded to wear masks, wash their hands, avoid crowded places, and observe one (1) meter of social distancing to avoid the spread of the virus [3]. During initial phase of its vaccination program, the local government of Surigao City through the City Health Office (CHO) requested the assistance of then Surigao State College of Technology (SSCT) now Surigao del Norte State University (SNSU) for the design and development of a vaccination management information system due to the challenges of manually implementing a mass vaccination program. With the request, a team of SNSU information technology faculty was assembled to handle the project to address the challenges of the ongoing manual vaccination program of the LGU and with the monitoring and tracing of the vaccinated residents which is a vital concern of the LGU.

The SCVax is a project aimed to create a vaccination information system capable of monitoring and tracing vaccinated and unvaccinated residents. It collects and secures data of residents who wanted to be vaccinated by accomplishing an online pre-registration form. The system is also used during the vaccination to capture relevant vaccination data. The application has features such as QR-code, location mapping, and data visualization to provide reliable and accurate data for monitoring and tracing residents in the locality [4]. It highlights the specific information by providing interactive charts, geo-mapping systems, and other comprehensive statistics data to improve decision-making and service delivery of the vaccination program of the LGU, especially on where vaccination campaigns should be more focused. SCVax also offers the generation of report requirements for government agencies such as the Department of Health (DOH) and the Department of Information and Communication Technology (DICT).

In line with the migration of the vaccination program from a manual to a digital platform, other vaccination paraphernalia has also been prepared such as the inclusion of the QR code in the vaccination cards and the design and development of an SCVax QR scanner mobile app. The system can also provide an LGU-issued

vaccination certificate with the same QR code that is available in the system upon the request of the user. A real-time online vaccination validation feature has been added to the QR code in every valid vaccination card and certificate to mitigate the use of fake vaccination cards and to provide travel authorities outside Surigao City with a “vaccination passport” feature.

1.1. Mapping

Mapping software applications are useful tools to explore and discover new horizons of innovation and they are also considered interactive data repositories. They are remarkably used in the field of geoscience, agriculture, mining, business transactions, or even a simple destination location in our routines and needs.

A mapping and locator system application helps efficiently in planning and allocating resources for vaccinations [5]. It allows authorities to identify areas or regions with higher vaccination needs, enabling them to allocate the necessary vaccines, healthcare personnel, and equipment accordingly. With a mapping and locator system, authorities can identify specific populations or demographics that require targeted vaccination campaigns [6]. This can include vulnerable groups, high-risk individuals, or areas with low vaccination rates [7]. By focusing efforts on these specific groups, the system helps ensure that vaccination efforts are effective and reach those who need it the most.

Google Maps is one of the most popular applications being used. It provides locations of the cities, marginal borders, geographic, and satellite images [8]. It also offers a feature of a street viewpoint that allows users to overview houses and stores and gives directions for trips. It may not have real-time updates of infrequent conditions, such as road construction and damages due to weather, streets blocked by some events, and fairs [9]. Some isolated areas and locations are not included in google maps [10]. In term of search function, the google map users can search for specific vaccination sites or facilities using keywords like "COVID-19 vaccination centers" or "flu shot clinics" within Google Maps [11]. It provides a list of relevant results along with their addresses contact information, and user reviews.

Software applications such as ArcGIS Pro are similar to Google Maps but have an advantage in terms of their characteristics and elements. It produces 2D and 3D customizable maps and can analyse data through patterns in such a way it can be considered Artificial Intelligence (AI) [12]. Its library facilitates features to provide maps with different views like satellite or street and the option to load geodatabases with different layers. The geodatabase holds indispensable information, and this application has library maps that deal with features that are capable of customizing maps and executing altered procedures and transactions [13]. ArcGIS Pro provides powerful spatial analysis tools that enable users to analyze vaccination coverage, identify areas with low vaccination rates, and assess population density and demographics [14]. This aid in targeting resources and intercession effectively to ensure equitable vaccine distribution.

A digital surface model (DSM) has a high definition of aerial photograph modelled and can generate solar-radiation maps that can be considered as one of the significant programs to analyse locations for valuation energy possibilities for definite regions [15]. DSMs provide detailed information about the topography and elevation of a region [16]. This data can be utilized for terrain analysis, such as

identifying slopes, ridges, valleys, or other land features. Understanding the terrain is crucial for various purposes, including urban planning, infrastructure development, and environmental assessments. DSMs provide the foundation for creating accurate 3D models of landscapes and urban areas [17]. These models are valuable in urban design, architectural visualization, and simulation of various scenarios.

The SCVax application provides some features of Google Maps and ArcGIS that uses contextual tools for visualizing and analysing the collected data from the system. It has scientific analytical tools to combine multiple data sources to make maps as viewed in the system from the collected data. It includes responsive windows commands with information from the system and triangulation tools to zoom in and zooms out a certain image in the location map.

1.2. Visualization

Data visualization is one of the most comprehensive data analyses and interpretations offering to the user the most convenient, easy, and readable graphics information out of the data raw collected [18]. It is widely used in healthcare operations for transforming data into a graphical representation and tools for business professionals for consumer behavior analysis. It is a monitoring key indicator to easily spot emerging trends in varied and large data sets.

In health care sectors, data visualization gives a great result by summarizing hidden data. Geo-spatial analysis combines geographic data with healthcare data to identify patterns, spatial relationships, and disparities [19]. By mapping health data onto geographic locations, healthcare professionals can identify areas with higher disease prevalence, analyse access to healthcare services, and target interventions more effectively [20]. It can analyse and process information through exploratory data analysis to produce meaningful data and information [21]. It also gives a process called mining-based control flow to determine and extract the underlying connections between events of the processes with correlation from the gathered data [22].

Real-Time Fire Prediction System provides a real-time prediction using data visualization of wildfire risk at specific locations based on a machine learning model. It also provides interactive map features that show the historical wildfire events with environmental information [15]. Integrating real-time data streaming capabilities into data visualization allows healthcare providers to monitor and respond to emerging health situations promptly [23]. This is particularly valuable during outbreaks or public health emergencies when up-to-date information is critical for effective decision-making. Data visualization can be coupled with alerting systems to notify healthcare providers of critical events or anomalies in real-time [24]. This enables timely interventions and enhances patient safety by flagging abnormal trends or deviations from expected outcomes.

Using data visualization tools are commonly used to meet certain requirements as a solution for consuming data and information [25]. Amazon Web Services (AWS) is one example of this application software wherein they use EMR notebooks, Kibana, and Amazon QuickSight to visualize data that might be supplementary for readers' business intelligence requirements [26].

The SCVax system has its own data visualization that could interpret massive data collected into a comprehensive graphical representation that could be easily understood by the user. It generates detailed reports from the system. It also provides an interactive

visualization chart with statistical data to help the local government of Surigao City in decision-making to improve the service delivery of the vaccination program.

Nowadays QR (Quick Response) code is common everywhere it is considered a part of our everyday life activities especially accompanied by smartphones. It is a big help for every industry because they are touchless and hygienic. A timely favourable application in the midst of a pandemic. The contactless nature of QR code scanning streamlines the verification process, reducing the need for manual document checks and minimizing physical interaction [27]. Moreover, QR codes can be encrypted and digitally signed, making them secure and tamper-proof. The data within the QR code can be encrypted, ensuring privacy and data integrity, with access restricted to authorized personnel [28].

The integration of the Google Apps Script application to process QR code features provides a real-time scanner and verifiable data and information. Using the QR code attendance system is a great help to store and secure information in the database. The QR code can match data, and form a huge data repository, it will also automatically record the time-in and time-out of a certain individual in a certain establishment [29]. In this case, it can be considered a reliable time-recording process.

QR code has maneuverer to share library practices like e-resource management, library orientation, linking to electronic resources from within the library, information about library space, the library catalogue, etc., through smartphones which specify the technological pros and cons of QR Code [30]. The QR code technology is very likely to be accessible, easy to handle, and easy to attract and display information to the user [31].

The SCVax system application has QR code functions that allow the user to pre-register using online forms provided by the system. In line with the function of the system, the QR code will be used for identification, monitoring and tracing. This QR code can be utilized in other health-related activities such as scanning of user's QR code if said individuals are fully vaccinated before entering any establishment and using the QR code to record visits to the City Health Office, District Health Centres, and Barangay Health Stations and scanning the QR code upon entering the evacuation centres during disasters for quick evacuation center statistics complete with health-related profiles.

1.3. QR code

Nowadays QR (Quick Response) code is common everywhere it is considered a part of our everyday life activities especially accompanied by smartphones. It is a big help for every industry because they are touchless and hygienic. A timely favourable application in the midst of a pandemic. QR code is usually used in E-commerce transactions such as transferring money and payments, shopping online, downloading apps, and many more [32].

The integration of the Google Apps Script application to process QR code features provides a real-time scanner and verifiable data and information [33]. Using the QR code attendance system is a great help to store and secure information in the database [34]. The QR code can match data, and form a huge data repository, it will also automatically record the time-in and time-out of a certain individual in a certain establishment [29]. In this case, it can be considered a reliable time-recording process.

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2.Methods

Rapid application development methodology was used in the design and development of SCVax. Swift data collection and analysis were done to quickly initiate design and development. Functional prototypes were built for immediate use. Debugging, testing and maintenance were made based on usage and user feedback.

2.1.Data collection

Data gathering is one of the important aspects in the design and development of the system to achieve a more comprehensive and efficient system project. The SCVax project uses various kinds of data in determining the requirements of the vaccination program of Surigao City. The researchers conducted interviews with the persons administering the program and how they want the system to work to properly facilitate the program. Relevant guidelines, processes, procedures, and reports were gathered to determine the use cases and classes required for the system. It was also decided during this phase that SCVax should have an online pre-registration module where an online application form will be filled up by the residents of Surigao City as categorized into priority groups of the population for the COVID-19 vaccination prescribed by the guidelines of DOH (see: <https://doh.gov.ph/node/28118>).

2.2. Design, development, and deployment

The CodeIgniter framework was used in the design and development of SCVax. This is a powerful PHP framework with built-in protection against CSRF and XSS attacks. It is compatible with a Model-View-Controller (MVC) design pattern and

an industry-standard web development framework for scalable projects. The system was deployed in a local data server with a 200 MBPS dedicated internet connection and backup battery to avoid power interruption.

2.3. Debugging, testing and maintenance

Due to the immediate need for the vaccination system, the programmers debugged and tested the system synchronously with the users from the local office of the Department of Health. The maintenance of the system was also supported by the server, network, database, and web administrators of the institution to ensure that there will be no interruptions during the vaccination.

3. Results and Discussions

The SCVax was deployed and used during the roll-out of vaccines in Surigao City, Philippines, starting May 1, 2021. To date, the system is constantly updated based on the DOH protocols in the rolling out of vaccines. The SCVax had minimized the manual filling up of forms at the vaccination centres which speed-up the vaccination process. The resident will simply fill up the online forms with their information and generate the QR-coded SCVax ID which is needed during the vaccination. A scheduling feature was also added to manage and schedule when the residents will have to go to the vaccination site.

3.1. Online registration, printable forms, and generation of QR-coded SCVax ID

The vaccination starts with the patient registration online using the link <https://covid19.ssct.edu.ph/scvax> and the generation of printable QR-coded SCVax ID as shown in Figs. 1 and 2. This removes the manual filling up of forms at the vaccination site and can easily manage and schedule the applicants for their vaccination. The total number of applicants as of Sept. 1, 2021, is at 115, 587.

The system is capable of generating printable filled-up forms which are needed during the vaccination. The filled-up form must be printed based on the SCVax ID and signed by the patient and the doctor before the administration of the vaccine to the patient as shown in Fig. 3.

Fig. 1. Online registration form.



Fig. 2. QR-coded SCVax ID.



Fig. 3. Printable forms.

3.2. QR-coded vaccination card with online verification

After the vaccination, the patient will be provided with a QR-coded Vaccination Card with Online Verification feature as shown in Fig. 4. The QR-code is a link to the online verification page showing the vaccination details of the resident. This is to avoid counterfeit or forged vaccination cards. A sample validation page is shown in Fig. 5.

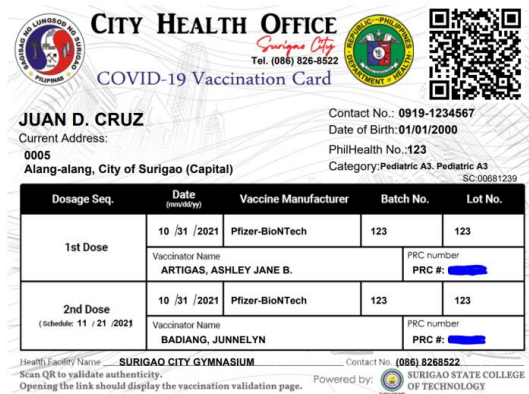


Fig. 4. QR-coded vaccination card.

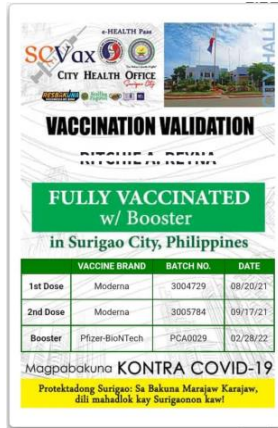


Fig. 5. SCVax vaccination validation page.

Upon request, the platform can also generate QR-coded Vaccination Certificate as shown in Fig. 6 which will be signed and sealed by the local health office that can serve as “vaccination passport” for travelling local residents.



Fig. 6. SCVax QR-coded vaccination certificate.

3.3. Interactive mapping

SCVax was packed with a permission level interactive mapping for administrators which can help in managing the vaccination. The administrators can view based on vax application, master listed applicants, the first dose, fully vaccinated, and by priority groups such as health care workers, senior citizens, adults with comorbidities, and essential frontline workers as shown in Fig. 7. The map was divided by municipality or city, and each is divided by barangays. Every designated official can only access data at their level and with permission.

The municipality, City, or Barangay selection can display reports regarding the population, person registered, Masterlisted, the first dose, and second dose. With the help of the heat maps, administrators can identify areas wherein vaccination campaigns should be focused.

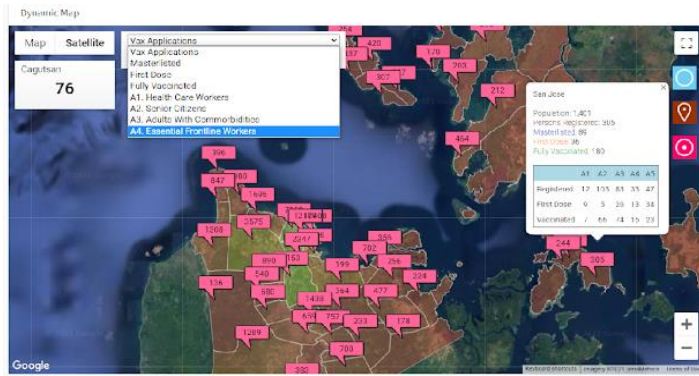


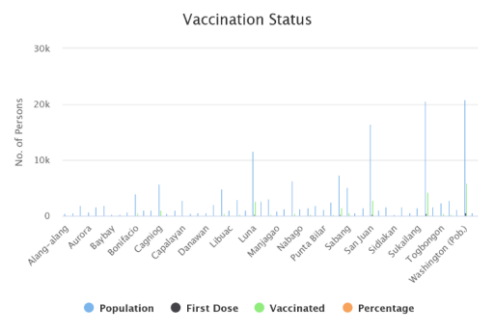
Fig. 7. SCVax interactive map.

3.4. Data visualization

The SCVax is capable of generating interactive barangay level charts by vaccination status, areas vs priority groups, vaccination rate, doses vs priority group, vaccination brands vs dose, and a table for vax details as shown in Fig. 8. This information can supplement the decision-making of the officials. These charts can either be viewed in full screen, printed, and downloaded in an image format (png, jpeg, pdf, and SVG vector), CSV, and XLS format.

3.5. Real-time scanning of vaccination status

A mobile application was developed that could scan the SCVax QR-coded vaccination cards and detect the vaccination status of the person and was registered at Google Play Store as shown in Fig. 9. This mobile app can be used by private and public establishments to implement vaccination mandates. With this application, the local government units can implement regulations easily where the person must be vaccinated before they could go to work, travel, or join event gatherings. The good thing regarding vaccination mandates is that they can promote herd immunity and mitigate the spread of the COVID-19 virus. Upon entry in establishments, the vaccination status of residents bringing the SCVax ID can be determined by in real-time using the SCVax scanner app. Figure 10 shows a sample display of vaccination status in the app.



(a)

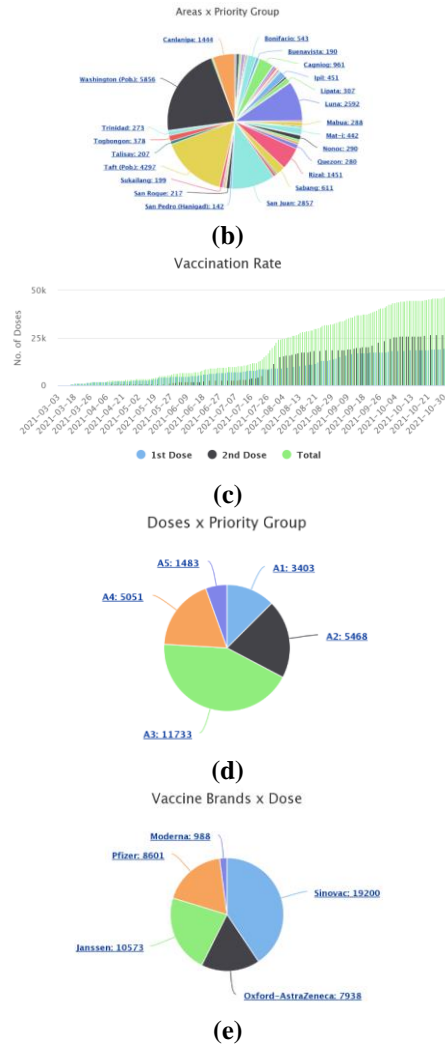


Fig. 8. Auto-generated charts, (a) vaccination status, (b) areas vs. priority group (c) vaccination rate, (d) doses vs priority group, and (e) vaccination brands vs. dose.

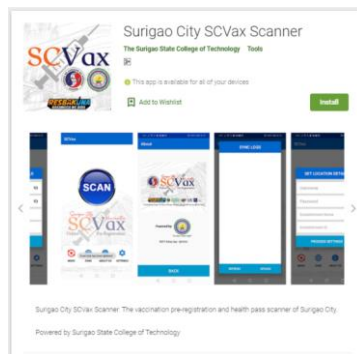


Fig. 9. SCVax mobile app real-time scanner.

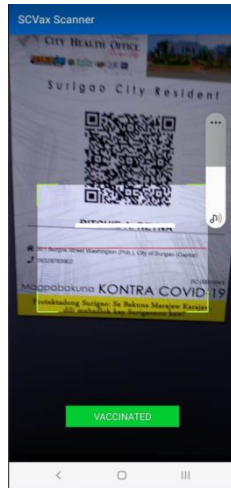


Fig. 10. Vaccination status as shown in the App.

3.6. Auto-generated reports

Another good point in this system is that it could generate government-mandated reportorial requirements in relation to the COVID-19 vaccination program. The reports can be downloaded in CSV format as shown in Fig. 11.

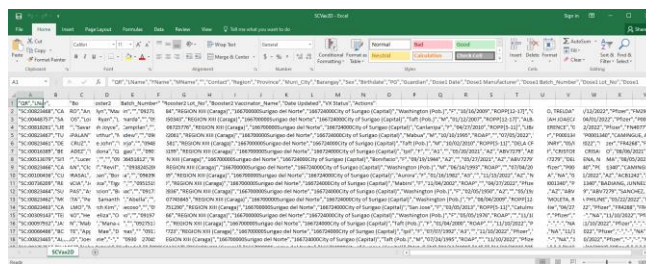


Fig. 11. SCVax auto-generated reports.

3.7. System evaluation

A researcher-made questionnaire based on applicable software characteristics was used in system evaluation. It was done by taking the responses from respondents who used the system. The system was rated favourably by users in functionality (4.57), usability (4.48), security (4.43), and portability (4.44). Furthermore, Table 1 shows the grand mean of 4.48 from the mean of every characteristic evaluated. The grand mean has a verbal description of Strongly Agree.

Table 1. Summary of evaluation result.

| Parameter | Mean | Verbal Description |
|---------------|------|--------------------|
| Functionality | 4.57 | Strongly Agree |
| Usability | 4.48 | Strongly Agree |
| Security | 4.43 | Strongly Agree |
| Portability | 4.44 | Strongly Agree |
| Grand mean | 4.48 | Strongly Agree |

4. Conclusion

The City Health Office acted as the main implementing unit of the vaccination platform SCVax. The platform was able to increase the efficiency of the vaccination program of the office and improved its services primarily in the following areas:

- Faster and more accurate registration of eligible vaccine recipients in the vaccination platform and minimized the manual filling up of forms at the vaccination centres which speed-up the vaccination process. A scheduling feature was also added to manage and schedule when the residents will have to go to the vaccination site
- Effective handling and monitoring of the vaccination program with the use of dynamic maps and interactive charts to summarize and visualize data to support decision making.
- Easily generate government-mandated reportorial requirements in relation to the COVID-19 vaccination program
- Utilization of vaccination platform in creating heat maps to identify areas wherein vaccination campaigns should be focused to
- Support ongoing contact tracing efforts as vaccination QR code is used simultaneously for contact tracing
- The sustained utilization of the system likely provided users convenience and satisfied their requirement for the vaccination program with users “strongly agreeing” to the usability of the system in- the evaluation.

Acknowledgment

This study was conducted at and supported by Surigao City Health Office in partnership with Surigao del Norte State University (SNSU). Special thanks to SNSU for funding the design, development, deployment, and ongoing maintenance of the project until the end of the pandemic.

- This project will not be pushed through without the support of the following:
 - Hon. Ernesto “Estong” U. Matugas Jr., Surigao City Mayor
 - Dr. Gregorio Z. Gamboa, Jr., SNSU President
 - Rowelto Enhaynes Dumale Jr., LDRRMO Officer
 - Mark Glenn Ortega, Surigao City CHO IT Officer

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