The Seybold Report
ISSN 1533-9211
DOI 10.5281/zenodo.6641053

DEVELOPMENT AND EVALUATION OF THE COVID-19 VACCINATION MANAGEMENT SYSTEM FOR THE LOCAL GOVERNMENT UNITS

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ABSTRACT

The main purpose of this study was to provide an efficient, convenient and a systematic processing of COVID-19 vaccination among residents being catered by the Rural Health Unit of the Municipality of Estancia, Iloilo. As such, this paper aimed to design and developed a web-based immunization information system with SMS support that would meet user requirements, determined the extent of usability in terms usefulness, satisfaction, ease-of-use of system prototype as perceived by the residents and health personnel, and determined the degree of quality of the proposed system based on ISO/IEC 25010:2011 Systems and Software Quality Requirements and Evaluation Quality Model as perceived by expert evaluators. A total of forty-seven (47) respondents participated in the study. Developmental and descriptive research designs were employed in this study to systematically develop the system product and to describe the observation of the respondents based on the set objectives. Likewise, the Rapid Application Development Model was used in the development of the system prototype. The mean statistics were employed to describe the extent of usability and degree of quality of the system prototype. Findings showed that the levels of usability, as perceived by both residents and health personnel, was described as very good. On the other hands, the degree of quality of the system prototype was viewed by the expert evaluators as good.

Keywords:COVID-19, vaccination, local government units, decision-support system, SMS notification, USE questionnaire.

INTRODUCTION

At the end of 2019, a novel virus identified as the Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) causing severe acute respiratory syndrome was discovered from Wuhan, China [1] and was subsequently named as "COVID-19" which was declared the pandemic status [2]. It quickly spread like wildfire. On 30th January 2020, the Philippines confirmed its first case of novel coronavirus [3].

In its efforts to address the impacts of the COVID-19 pandemic, the government created the Inter-Agency Task Force for the Management of Emerging and Infectious Diseases (IATF) by virtue of Resolution No. 01, Series of 2020 dated 28 January, 2020 [4]. The Task Force initiated several measures in order to mitigate the prevent and/or minimize the spread of the virus in the country. One of the earliest issuances of the IATF was to issue travel restrictions.

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The government also declared a nation-wide "Enhanced Community Quarantine" to strictly imposed home quarantine in all households [5].

Minimum health protocols were also endorsed by the Department of Health to minimize the spread of the virus. These include the wearing of face mask and face shield, sanitizing hands, practice one-meter physical distancing and limit physical interaction [6].

Ultimately, the whole world was led to the development of the COVID-19 vaccine. The COVID-19 vaccination is offering a way to transition out of the pandemic. In the Philippines, the COVID-19 vaccines that are granted with Emergence Use Authorization (EUA) by the Philippine Food and Drug Administration (FDA) because they are considered safe and effective based on the available evidence [7].

The use of information technology improved the manner by which vaccination programs are implemented in various countries. For instance, in Viet Nam, a Digital Immunization Registry System was developed to allow for near real-time access to immunization records and for the easy generation of reports at the community health centers and district levels. By using the said system, reporting of immunization details became more accurate and in near real-time. It electronically calculates and provide reports to personnel of community health centers through a web-based application that is accessible on desktop computers and on smartphones. The system then sends text message (SMS) reminders to parents about monthly child immunization days, and tracks the vaccines they receive. The results of their motoring suggested that there was an improvement in the timely delivery of appropriate services, and facilitated program monitoring more efficiently [8].

In [9], they developed a vaccination system in Pakistan. The Immunization Information Systems (IIS) is smartphone-based vaccinator monitoring app that they deployed to store digital records of every child to efficiently improve the vaccination programs as it has shown mixed but promising results in terms of success.

In Tanzania, [10] successfully conducted a study on the effectiveness of a web-based Vaccine Information Management System (VIMS) in. After one year of piloting, most users of the VIMS positively viewed the new system being effective due to its easy-to use functions while minimizing tasks related to multiple data collection and reporting functions.

In [11], they studied on the effectiveness of a smartphone app on improving immunization of children in rural Sichuan Province, China. The aim of their study was to assess the effectiveness of an EPI smartphone application (EPI app) on improving vaccination coverage. In the intervention group, village doctors used the EPI app and reminder text messages while village doctors in the control group are asked to use their usual procedures including text messages. They also reported saving time by looking up information of caregivers and contacting caregivers for overdue vaccinations quicker.

In Ethiopia, [12] stated that two of the bigger challenges among healthcare workers in the implementation of the vaccination program in Ethiopia are the non-attendance of the recipients and the delay for vaccination schedules. Thus, they developed a text-messaging

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ISSN 1533-9211
DOI 10.5281/zenodo.6641053

reminder system employing an iterative development process comprising of requirement analysis, design, development, testing and refinement phases. Their automated reminder system was developed anchored upon the specific requirements of the prospect users. The text message reminder system has two key components: first, a web-based application for client registration and automatic reminder scheduling; and second, an SMS component that will automatically send SMS text messaging.

In Malaysia, majority of health centers are still using a paper-based vaccination system in the processing of vaccination record of young children. Also, reminders to parents about vaccination schedules are done manually, which unfortunately causes workload on nurses. Moreover, it is not a cost-effective procedure. This being a setback on the healthcare system, they proposed for the development of a system called Virtual Health Connect. It is a SMS-based vaccination reminder and management system. The purpose of their study was to help improve the vaccination implementation by advocating to use technology among health centers and to the parents as well. This was due to the fact that health centers' intention to use the proposed system was further influenced because of its perceived usefulness than their attitude to use [13].

A web-based management information system can be one of the easiest ways to organize a system in a workplace. [14] developed the VCS or Vaccination Control System. This management information system was intended for the vaccination process control for the Brazilian public health system. Among the process it performed, the VCS include the management of in the administration of vaccines, patients' personal records, mass immunization campaigns, access control to the recorded information, record of immunizations and history of immunizations per individual, and many statistical reports. All information in the VCS can be made available on the Web in the form of reports about cities, regions, states, or nationwide. Another benefit provided by VCS is the reduction of the vaccine lost, which results in the public resource savings. It is also possible to perform comparisons between vaccinations that were applied on geographically near health care facilities and to send the excess of vaccines to the places where the demand yet exists.

Most highly urbanized cities in the Philippines have initiated to develop their own COVID-19 online vaccination registration systems. Several local government units in Metro Manila have launched their online portals where their constituents can perform pre-registration procedures [15]. However, at present, there are still several institutions in the Philippines that are using manual-type of operations such as the Rural Health Unit (RHU) of the Municipality of Solano, Nueva Vizcaya. Thus, [16] developed an efficient record management system with a decision support system in order to meet the challenges of the unit. Her developed system was able to map the disease-occurrence whereby it is able to assist rural health physicians and other health professionals in the unit giving them the advanced information critical to their decision-making tasks particularly in diagnosis, treatment and recommendations. Ultimately, her developed system gained a "very great extent" qualitative rating.

It is therefore imperative to make the vaccination initiatives as aggressive as possible. With that, many big Local Government Units (LGUs) took the extra step in order that these targets

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DOI 10.5281/zenodo.6641053

will be realized in the soonest time. One solution that they integrate is to employ technology to reach more of their constituents. However, despite the efforts coming from the government and the Department of Health, many small towns all over the Philippines still uses pen and paper in gathering data for vaccination. In order to address this gap, the researcher was motivated into developing the COVID-19 Vaccination Management System for the Local Government Units.

MATERIALS AND METHODS

System Development Model

In the development of the software solution, we employed the Rapid Application Development (RAD) model as the software development life cycle for the software development activities. The RAD model is based on prototyping and iterative development with no specific planning involved. The process of writing the software itself involves the planning required for developing the product. It focuses on gathering customer requirements through workshops or focus groups, early testing of the prototypes by the customer using iterative concept, reuse of the existing prototypes, continuous integration and rapid delivery. It further uses minimal planning in favor of rapid prototyping. A prototype is a working model that is functionally equivalent to a component of the product [17].

The RAD model is consist of four phases namely requirements planning phase, user design phase, rapid construction phase and cutover phase. At each phase, the researcher performs specific activities leading to the phase's deliverable. Since the RAD model heavily relies on the involvement of the users, the deliverables are presented to them to further refine the final product. We used the RAD model for the requirements gathering and planning, user design, construction and implementation of the system product.

Logical Architecture Design

The model, which is an n-tier architecture which is also called multi-tier architecture because the software is engineered to have the processing, data management, and presentation functions physically and logically separated [18]. There are three layers included in the design. These are the presentation tier, the logic tier and the data tier.

The presentation tier implements the functionality required to allow users to interact with the proposed system. There are two user interfaces: web-based interface intended for the use of the system administrator, RHU personnel and the residents while the SMS-based interface is intended for the residents. In this system, the web-based interface can be opened using any browser while the SMS-based interface can be accessed using any GSM-capable cell phones. The logic tiers implements the core functionality of the system, and encapsulate the relevant business logic. Under this tier are the various modules and sub-modules that will perform the actual functions of the proposed system. This is implemented in the server computer. The data tier implements the processes involving the management of records used by the proposed system. Structured queries are forwarded to this layer where data are created, read, updated and deleted. This is also where the physical database is located. The Structured

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ISSN 1533-9211
DOI 10.5281/zenodo.6641053

Query Language and the MySQL database server are used in the implementation of this tier. Figure 1 shows the logical architecture design of the proposed system.

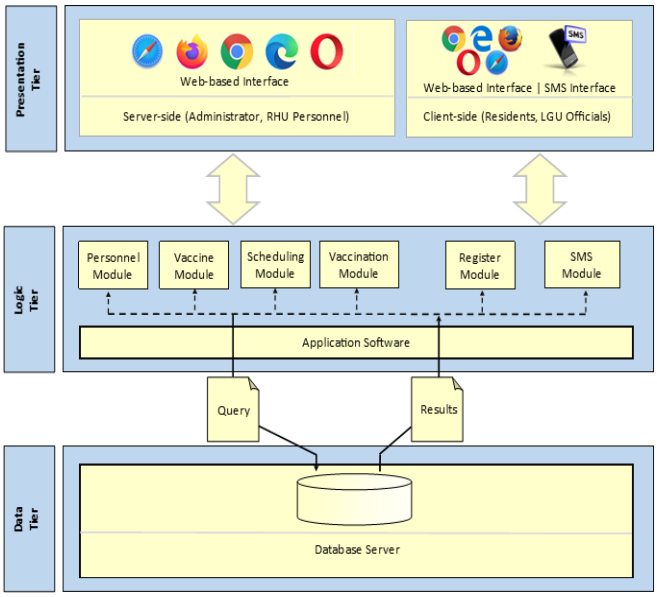

Figure 1. Shows the Architectural Model for the Proposed System.

Construction of the System Prototype

In the construction of the system prototype, we used standard development tools. For the web-based components, we developed the system product using the HTML, CSS, Javascript, PHP and MySQL. Thus, to achieve this, we have also downloaded and installed XAMPP Version 3.2.2.

For the SMS module, we use the Microsoft Visual Studio 2010. For efficient user interface design, we applied web-based techniques to design the graphical user interfaces of the system prototype with emphasis on the harmonization of fonts, color, sizes, styles as well as whitespaces.

The proposed system has two main graphical interfaces. First is the client-side interface which is accessible thru a live URL. The second is the administrator-side interface which can be accessed using the web host's address. Initially, the residents will need to register their personal details. Specific questions are asked from them, particularly if they have existing medical conditions that are critical information as to the type of vaccines that will be given to them. Another important piece of information that will be solicited from the registrants is their mobile phone numbers since it will become the main line between them and the proposed system. Once they have successfully registered, all they have to do is to wait for the schedule date through SMS notification.

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DOI 10.5281/zenodo.6641053

On the server side, the designated administrator will need to login to access the system's core interfaces. After a successful sign in, the user will be brought to the main user interface which is the Dashboard. The Dashboard page is divided into two panes: the left-side page includes the menus that the user can manipulate and the right pane which display the information based on the menu selected in the left pane. Depending on the user type, the number of menus differ as there are certain modules that are only limited for access to certain type of users. Figure 2 shows the Dashboard of the proposed system.

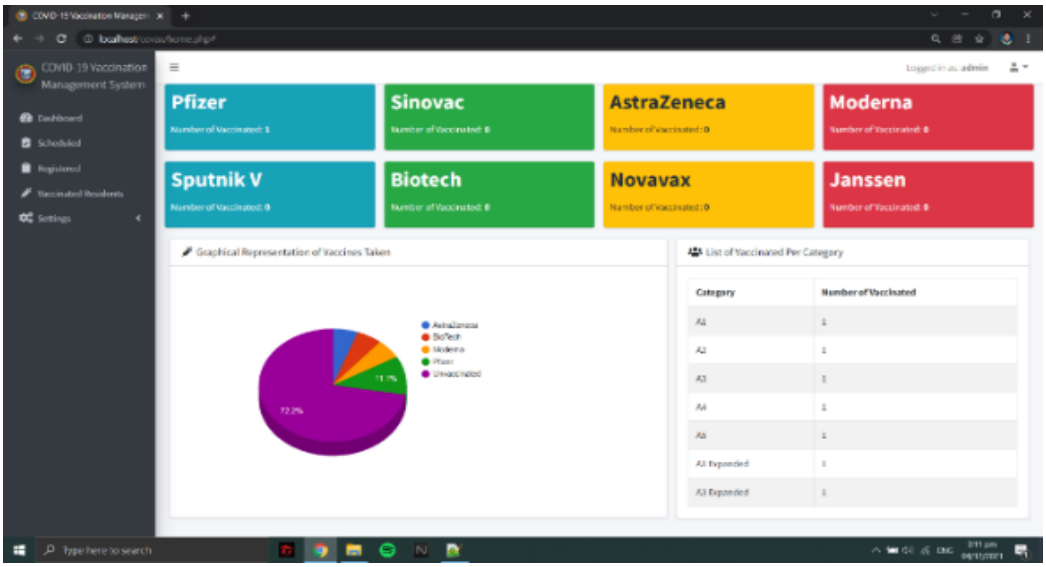

Figure 2. Shows the Dashboard Page of the Proposed System

At the core of this system is the Vaccination Schedule module. It should be noted that the information of the residents presented in the table do not have schedule for vaccination yet. Therefore, clicking the SMS button will launch a pop-up window where the user can create a vaccination schedule for registered resident. In the pop-up box, the name of the resident automatically appears as well as the registered contact mobile phone number. The system also creates a one-time password that would validate that the identity of the resident. The user of the system simply selects the brand of the vaccine as well as the proposed schedule date of vaccination. Once the "Submit" button is clicked, the developed system will generate a corresponding record for an SMS notification. Figure 3 shows the screenshot Vaccination pop-up window.

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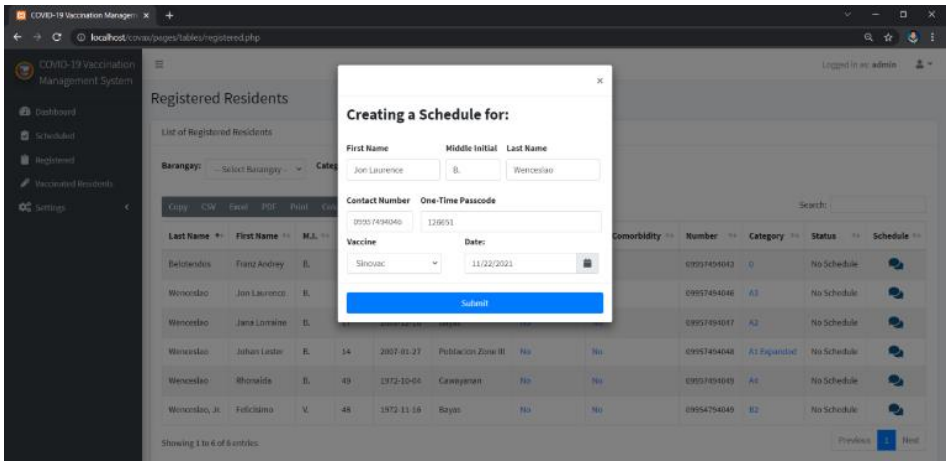

Figure 3. Shows the Create a Vaccination pop-up window of the Proposed System.

Another key module of the developed system is the SMS Manager. As the name suggest, this module is in-charge for automating all processes related to SMS. The SMS Manager is created using Microsoft Visual Studio 2019. It employs the AT commands that are essential in manipulating GSM-enabled modems. In this system, the GSM-enabled modem is the Globe™ Tattoo dongle attached in a USB port of the server computer.

Once the SMS Manager is started, it works in the background for a period of eight (8) hours per day with an interval of 15 seconds per run. It means that every 15 seconds, it performs a repetitive process of checking whether there is a record in the SMS table. If there is a record, it shall automatically retrieve the records and create an SMS message to the registered number. It will then wait for the OTP as the response of the resident to validate his or her identity and subsequently confirm the schedule date of vaccination. Figure 4 shows the screen captures.

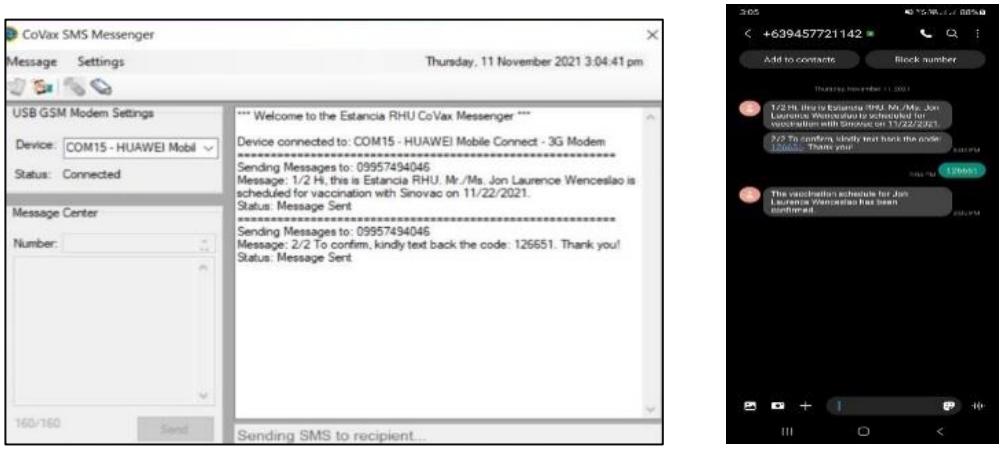

Figure 4. Shows the SMS Manager with SMS Messages

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ISSN 1533-9211
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Respondents of the Study

The respondents of the study were conveniently selected among the consumers of the COVID-19 Vaccination Management System for the Local Government Units. There was a total of 47 respondents of this study. They were categorized as residents, with 38 respondents, and 2 respondents for RHU Personnel who evaluated the usability characteristic of the system product. Seven (7) respondents that were considered as expert evaluators evaluated the performance of the system product. They were considered experts because they are practitioners in the field of software development.

Data Gathering Procedures

This study employed the two (2) types of survey questionnaires intended to capture the perception of the evaluators. Both were standard metrics for evaluation of software products. The first survey instrument was the USE Questionnaire developed by Lund [19]. The USE stands for usefulness, satisfaction and ease of use. This instrument was administered with the respondents representing the residents and those representing the RHU personnel.

The second evaluation instrument employed in this study was adopted from the ISO/IEC 25010 Software Quality Model Characteristics. This metric was used to gather the perception of the experts in the field of software engineering as respondents representing the system administrator. The metric evaluated the system prototype based on functional suitability, performance efficiency, compatibility, usability, reliability, security, maintainability and portability [20] using a 5-point Likert Scale where 1 is “very poor” and 5 is “excellent”. The Mean and Standard Deviation were employed to determine whether the developed system passed the evaluation criteria. The results of the computation were interpreted as “Very Good” (M=4.21-5.00), “Good” (M=3.41-4.20), “Average” (M=2.61-3.40), “Fair” M=2.61-3.40) and “Poor” (M=1.00-1.80).

Results and Discussion

Summary of Evaluation Result on the Extent of Usability of the System Prototype using the Usefulness, Satisfaction, and Ease of Use

The results indicated the perception of the respondents when it comes to usefulness, ease of use, ease of learning and satisfaction, the overall perception was that the system prototype was very good with the grand mean of 4.67 which is interpreted as Very Good. Specifically, the usefulness of the proposed system was perceived by the evaluators to be very good with a mean of 4.76. The proposed system allows the users to be more control of the activities relating to registration as well as scheduling of vaccination. They unanimously agreed that they were able to save time and their expectations were meet. For the ease of use, the mean score was at 4.67 which is also described as very good. Since the proposed system was very user friendly due to its simple design interface, the users are able to use it with ease. They said that using the proposed system was effortless. The ease of learning was similarly evaluated as very good with a mean of 4.58 since the evaluators said that they were able to easily remember the processes and quickly learned it. The same verbal description for user

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DOI 10.5281/zenodo.6641053

satisfaction of the proposed system with a mean of 4.68. They said that it was fun to use the proposed system because it works the way they wanted it to work. Table 1 shows the data.

Table 1. Shows the Summary of Evaluation Result on the Extent of Usability of the System Prototype using the Usefulness, Satisfaction, and Ease of Use

Characteristics	Mean	SD	Verbal Interpretation
Usefulness	4.76	.433	Very Good
Satisfaction	4.68	.441	Very Good
Ease of Use	4.67	.436	Very Good
Ease of Learning	4.58	.443	Very Good
Total	4.67	.437	Very Good

Summary of Evaluation on the Degree of Quality of the System Prototype ISO/EIC 25010 Software Quality Model as Perceived by the Expert Evaluators

The proposed system was evaluated by a pool of expert evaluators in the field of software engineering. The functional suitability of the system prototype was computed at 4.29 which were interpreted as very good. The result indicated that the proposed systems was able to meet the functional requirements of the end-users. The respondents believed that the information generated by the proposed system was with high degree of precision. For the performance efficiency, the computed mean of the system prototype was 4.23 which is interpreted as very good. The respondents collectively agreed that the proposed system was able to perform its required tasks and functions using available resources with no system lags. It performed very well given the various computing equipment that they used during the evaluation.

For the compatibility, the developed system yielded a mean of 3.86 corresponding to a verbal interpretation of good. The respondents also believed that the proposed system can efficiently function while sharing the common resources with other systems. In terms of usability of the developed system, the respondents rated it with a computed mean of 4.21, which was interpreted as very good. They viewed the system to be easy to learn, highly accessible, with good aesthetic design and can be operated easily. The computed mean for the developed system's reliability was at 3.71, which was interpreted as good. The proposed system was perceived to be mature with a high degree of recoverability even after interruptions and failure.

The security characteristic of the developed system yielded a mean of 4.29, which was interpreted as very good. The system prototype is equipped with a security facility that would only allow authorized used to access the data. System logs are also present to record all activities happening in the system which can promote accountability and non-repudiation. For

ISSN 1533-9211

DOI 10.5281/zenodo.6641053

the maintainability characteristic, the developed system was rated at 4.07, which was interpreted as good. This result indicates that the various modules in the developed system can be used in building other systems and it can be effectively and efficiently modified without introducing defects or cause degradation to other systems. Finally, in terms of portability, the system prototype yielded a computed mean of 4.14, which was interpreted as good. The respondents believed that it can be used to replace other systems with similar purpose and can effectively work of different hardware or other environments. Table 2 shows the results.

Table 2. Shows the Summary of Evaluation on the Degree of Quality of the System Prototype ISO/EIC 25010 Software Quality Model as Perceived by the Expert Evaluators

Criteria	Mean	SD	Verbal Interpretation
Functional Suitability	4.29	.729	Very Good
Performance Efficiency	4.24	.441	Very Good
Compatibility	3.86	.651	Good
Usability	4.21	.572	Very Good
Reliability	3.71	.870	Good
Security	4.29	.467	Very Good
Maintainability	4.07	.450	Good
Portability	4.14	.569	Good
Total	4.10	.690	Good

CONCLUSIONS

This study was rated by the respondents using two industry accepted metrics in evaluating software products. The over-all perception of the respondents was very good which manifested their degree of agreement to the features of the proposed system. They acknowledged that the it can be able to help manage in the vaccination scheduling of the residents of Estancia LGU for their COVID-19 jabs. The proposed system incorporates processes such as web-based registration, scheduling of vaccination thru SMS notification, and its subsequent confirmation using the OTP.

Furthermore, results of the evaluation suggested that the proposed system as to the extent of its usability was perceived by both the resident-respondents and the personnel-respondents as very good. They believed that the proposed system could make their work become effective and therefore they are likely become more productive.

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Similarly, when it come to the ease of use, they collectively agreed that the proposed system is simple to use and user-friendly. They were able to learn the operations of the proposed system quickly and were able to quickly learn to use it. Overall, the respondents were fully satisfied with the proposed system.

Moreover, the expert evaluators also shared a similar perception depicting a good level of the software quality. The functionalities of the developed system were on-point as the results generated were able to meet the specific user requirements. The developed system is also high performing and can operate within the common resources of today's standards. In terms of the security features of the developed system, the expert evaluators regarded it to have met the confidentiality, integrity and availability. The overall perception of the proposed system as perceived by the expert evaluators was described as good.

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