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eachIntroducing and implementing an immunization information system in Indonesia province of Daerah Istimewa Yogyakarta: lessons for scale-up

Sulistyawati Sulistyawati, MPH, PhD[1*]
Trisno Agung Wibowo, MPH[2]
Rokhmayanti Rokhmayanti, MPH[1]
Andri Setyo Dwi Nugroho, MPH[2]
Tri Wahyuni Sukesi, MPH, PhD[1]
Siti Kurnia Widi Hastuti, MPH[1]
Surahma Asti Mulasari, MPH, PhD[1]
Marta Feletto, PhD[3]

[1] Faculty of Public Health, Universitas Ahmad Dahlan, Yogyakarta, Indonesia
[2] Daerah Istimewa Yogyakarta (DIY) Health Office, Yogyakarta, Indonesia
[3] Alliance for Health Policy and Systems Research, World Health Organization, Geneva, Switzerland

*Corresponding author: sulistyawati.suyanto@ikm.uad.ac.id.
Kampus 3 - Jl. Prof Dr Soepomo, Janturan, Umbulharjo, Yogyakarta, Indonesia.

Abstract

Background: Immunization is undeniable as a critical aspect of safe children from infections. To increase the coverage of immunization, valid and real-time data is needed. Accordingly, having a good report system is essential that rolled as defaulter tracking to prevent the children's immunization failure. DIY health office developed an individual electronic immunization registry and successfully implemented it for more than five years. It is the only individual-based record system in Indonesia that has survived for such a long time. To date, there is no systematic assessment of this system. Therefore, this research aimed to examine SIMUNDU's introduction and implementation process to draw lessons that could inform scalability and sustainability across the country.

Methods: An explanatory sequential mixed-method design was used in this study by involving 142 and 9 participants quantitative and qualitative study - respectively. Entry data clerk in all level of health facility was systematically selected to participate in the survey. While in the key informant interview, the informant was selected based on the survey result. The descriptive and thematic approach was employed to analyze the quantitative and qualitative data. Integration between the two approaches was accomplished in the interpretation of the result by comparison and contrast.

Results: Three core themes emerged from our analysis that describes the SIMUNDU success journey as an electronic immunization registry: system strengths, potential threats and opportunities.

Conclusions: The individual electronic immunization registry has been implemented well, and it may contribute to increase immunization coverage in DIY. Stakeholders should consider the sustainability of this system by providing related resources and consider scale-up nationally by looking at this promising program.

Keywords: immunization, electronic immunization registry, immunization information system, interoperability, implementation research

Background

Neonatal and childhood vaccination is an essential component of infectious disease prevention and an absolute human right (1),(2). Vaccination has been proven to reduce the burden of infectious disease globally (3). According to the WHO, in 2020 estimated 23 million children under one year of age did not receive their essential vaccinations. Of these, 60% live in just ten countries, one of which is Indonesia (4). Indonesia is the fourth most populous country globally. It is composed of thousands of islands organized into 34 provinces. Various geographical and cultural factors influence population inequalities to access to health services (5). In 2001, the Indonesian government's decentralization policy was enacted. This was an excellent strategy to foster development by engaging regional resources (6). However, this strategy was not without consequence. One major concern is the fragmentation of the Health Information System (HIS).

Indonesia's federal structure results in provinces and districts being relatively independent of the national Ministry of Health. This means that information systems at provincial and district levels are locally regulated (7). For instance, *Pemantauan Wilayah Setempat* (PWS) is a management tool used to monitor coverage of specific health services in an administrative boundary. It can be paper- or electronic-based, depending on the service and region. PWS-KIA is the monitoring system specific to maternal and child health (KIA), including immunization. Data recorded in the PWS-KIA are reported to the District or City Health Office, which reports to the Province Health Office, which transmits the data to the central level through simple emails if reporting is done in excel, or through various information systems including Komdat, SiTT, SIHA, PISPK, SIKDA Generik. In some provinces only, PWS-KIA data feeds into the DHIS2. Regional information systems have varying data quality, which reflects inequities in resources across regions. This adds to data integration challenges at the national level (7),(8) and affects strategic policymaking.

In the context of Indonesia's federal system, Daerah Istimewa Yogyakarta (DIY) Province has the authority to regulate and use its budget within its four districts (Sleman, Gunungkidul, Bantul, Kulonprogo) and Yogyakarta city. Regarding childhood vaccination, DIY is among the top ten performing provinces in the country, with 97.7 % complete basic immunization coverage in 2019 (9). Immunization services are provided by Primary Health Centres (*Puskesmas*), as well as private clinics, hospitals, and midwives' practices (typically referred to as *Unit Pelayanan Swasta* (UPS).

In 2014, the DIY Health Office introduced an electronic immunization registry named SIMUNDU (*Sistem Informasi Imunisasi Terpadu*/ Integrated Immunization Information System). An electronic immunization registry is a tool for recording individual children's immunization histories. An electronic registry serves essential functions at all levels of the health system. The service delivery level can facilitate individual follow-up of vaccination status and enable health workers to identify children due for vaccination and those who missed their vaccinations (defaulters). At the district and higher levels, it allows for monitoring vaccination coverage by the vaccine, dose, cohort, and other variables – and can support microplanning and vaccine management.

SIMUNDU was designed to link with the PWS-KIA for immunization and interoperability with the DHIS2. While it predominantly contains individual-level immunization records, SIMUNDU also serves as a source for aggregation and can synergize with the *Pemantauan Wilayah Setempat* (PWS) reporting system. For this reason, it can be considered an Immunization Information System (IIS). This means that data from City and District levels feed into Provincial and National levels *(Personal communication with DIY immunization program officer)*.

The original prototype was designed by the information and technology (IT) department of DIY Health Office to be operated offline. In DIY, three out of the four districts and the city introduced the system in 2015. The final district introduced it in 2017. At this stage, the point of data entry was the Puskesmas only. By 2018, UPS facilities were also equipped with SIMUNDU and could enter data into the system. In 2019, the prototype was further developed to operate online. The online version was rolled out in 2020 (Figure 1). As of May 2021, 79.4% of all Puskesmas and UPS facilities were complying. This average rate masks, however, the fact that while all PHCs adopt SIMUNDU, it is more challenging to enforce its use in UPC facilities (Suyani 2020, oral communication, 2020 May 11)

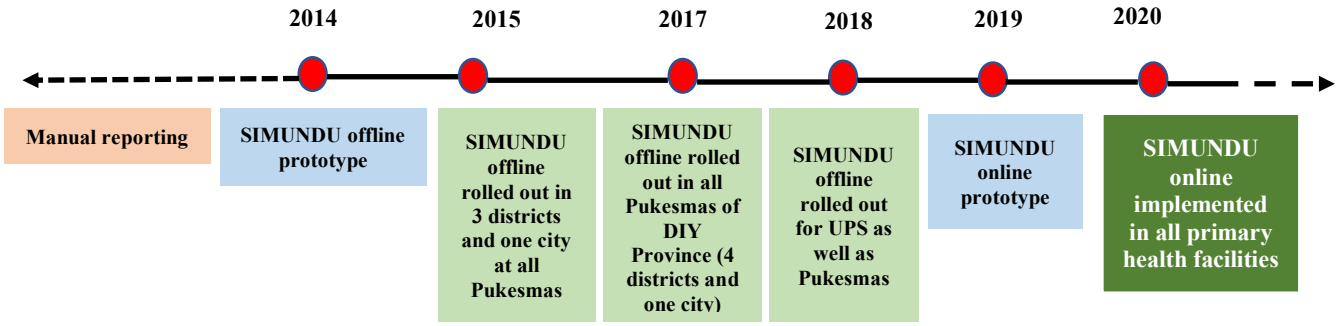

Figure 1. SIMUNDU's development and introduction

When a child receives a vaccination in a health facility, information on the child and the vaccination is entered in SIMUNDU as an individual child record. Each record includes an individual identifier, child's socio-demographic characteristics (e.g., name, gender, date of birth, name of parents, address), the antigen administered, and the date and place of vaccination. SIMUNDU has been recently updated to allow recording of vaccinations administered in schools (e.g., Human papillomavirus (HPV), Difteri Toxoid (DT), Tetanus Difteri (TD), and Measles-Rubella (MR)) – at this stage, only in aggregate form. Furthermore, SIMUNDU is being developed to record COVID-19 vaccinations in health facilities and those carried out in masse.

Monitoring is conducted every month to assess data completeness across health facilities, while an evaluation is conducted every year. These exercises have allowed the identification of several challenges related to implementing the system (e.g., workload, staff turnover, and rotation) and data quality (e.g., accuracy and timeliness). However, no systematic assessment of the system has been conducted to date.

SIMUNDU is the first immunization information system ever introduced in Indonesia. Other districts and provinces have shown interest in rolling it out, and the Ministry of Health has acknowledged the innovation. The objective of this work was to examine SIMUNDU's introduction and implementation process to draw lessons that could inform scalability and sustainability across the country.

Methods

From May to October 2020, we examined the experience of introducing and implementing an immunization information system in the DIY province using a sequential mixed-method design, where each step informed the next (10). First, we conducted a desk review of all relevant documentation available in the DIY health office – e.g., staff notes, meeting notes and monitoring notes – documenting SIMUNDU development and management processes. We also examined online documents, including health profiles and regulations on health reporting systems in Indonesia. This served as the initial source of data and provided an overview of who was involved and their role in developing and implementing SIMUNDU. This informed the survey design that we conducted as a second step. The survey was conducted with staff responsible for entering data in SIMUNDU across Puskesmas and UPS facilities and staff responsible for managing the system at the district and city level. Sampling and recruitment strategies are outlined in Table 1.

Table 1. Survey sampling

Level of the data entry and reporting system	Total number of facilities/ offices	Study population	Sampling strategy	Recruitment	Sample size
Puskesmas/Primary Health Centre (PHC)	121	Immunization coordinator and data entry clerk	All facilities	Open invitation across all facilities	115
Hospital (Central, General, Maternity and Pediatric)	65	Immunization coordinator and data entry clerk	Randomly selected 2 facilities per district/city (2*5=10)	Open invitation across selected facilities	8
Clinic	73	Immunization coordinator and data entry clerk	Randomly selected 2 facilities per district/city (2*5=10)	Open invitation across selected facilities	7
Midwives' Practice	271	Immunization coordinator and data entry clerk	Randomly selected 2 facilities per district/city (2*5=10)	Open invitation across selected facilities	110
District/City Health Office	5	Immunization coordinator	Total sampling	Open invitation	6*
			Total		**146**

*As the immunization coordinator had recently changed, the former was also invited.

All immunization coordinators and data entry clerks from all primary health facilities and the District/City Health Office were invited to participate in this survey. For UPS facilities, we randomly selected two clinics, two midwives' practices, and two hospitals per district and city and invited all of their staff involved in SIMUNDU data entry and management.

We developed and pre-tested an online survey in Bahasa Indonesia to inquire about SIMUNDU implementation, processes, and outcomes (*Sup.1*). All participants provided consent to participate in the survey. All participants were invited to the DIY health office to fill out the survey on their laptops. Having all participants in a room allowed researchers to monitor potential gaps in responses in real-time and follow-up with individual participants on-site to fill any gaps. Data were then exported into and analyzed in Microsoft Excel.

Next, we conducted key informant interviews to explore the challenges of implementing the system both from a practice and managerial standpoint. Each interview was conducted by three researchers with a different role: main interviewer, observer, and field note taker. SS, RR, TWS, SKW, and SAM were involved in the interviews. All of them were female with a public health background and worked as lecturers and researchers at university. An interview guide was developed by the research group and was consulted with the expert prior used for the interview. The interview takes approximately 30 minutes.

Informants were purposefully selected among survey participants to follow up on the range of perspectives that had emerged from the survey. As informed by the desk review, others were chosen for their management functions. The informant and interviewer did not know each other prior to the interview. Informants were invited to Province Health Office for interview purposes due to COVID-19 pandemic reasons. Before the interview, the informant was informed about the study and asked to sign the informed consent. All invited informants agreed to participate. A total of nine key informants were interviewed in Bahasa Indonesia language. The face-to-face interviews were recorded with consent from the informants. After the interview, the interviewer summarized our field notes to the informant for correction.

Thematic analysis was conducted using Quirkos qualitative tool following Braun and Clarke's approaches (11). Researchers familiarized themselves with the data, searching for initial codes and allowing themes to emerge. SS was the main coder during the analysis. Then the result of the coding reviewed together among the research group continued with defining and naming the core themes, analyzed the data for each of the core themes, triangulated information from the desk review, the survey, and the interviews. Themes were generated from the data during the analysis.

Results

Findings from the study are presented across the three core themes that emerged from the analysis, notably system strengths, potential threats, and opportunities, drawing from the qualitative and quantitative data collected (Figure 2).

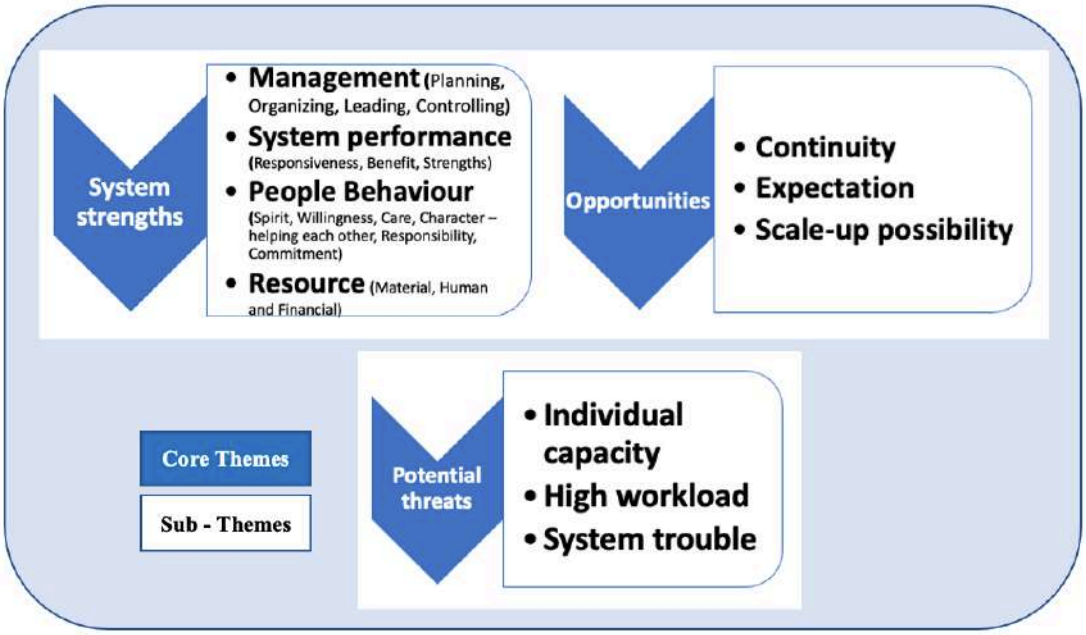

Figure 2. Strengths, potential threats, and opportunities for scale-up

System's Strengths

Factors contributing to the success of SIMUNDU include management, system performance, people's behavior, and resources.

Management

Management factors relate to SIMUNDU development and all levels of the management chain (**planning, organizing, leading, and controlling**). SIMUNDU arose due to concerns from the DIY health office immunization section around data quality, including inaccurate data, duplicate or missing data and lack of timely data, and the need to support follow-up and appropriate planning. SIMUNDU was designed to address these challenges and needs.

To our knowledge, [SIMUNDU development] started with a problem: estimates of the target population varied depending on the data source.

Yes, I think [SIMUNDU management team] started to tire of managing a large volume of data with dubious validity. They need to know the situation in each district.

Effective management of SIMUNDU from development to implementation has been highlighted as an essential determinant of its success. Here, we review its management across the critical functions of Planning, Organizing, Leading, and Controlling.

Careful Planning has been ensured at each stage of SIMUNDU development and implementation. These stages include an initial business plan, training on and socialization to SIMUNDU, and a staff replacement plan to respond to turnover or retirement of staff in charge of operating or entering data into SIMUNDU. The parties involved in planning included the head disease prevention and control department, IT personnel, and immunization program staff from the DIY health office.

Organizing - the organization of SIMUNDU is carried out at several levels. The top-level is at the level of the DIY health office, the second level is at the district/city health office, and the third level is the level of the health facilities (figure 2). A third party was also involved in developing the system interface.

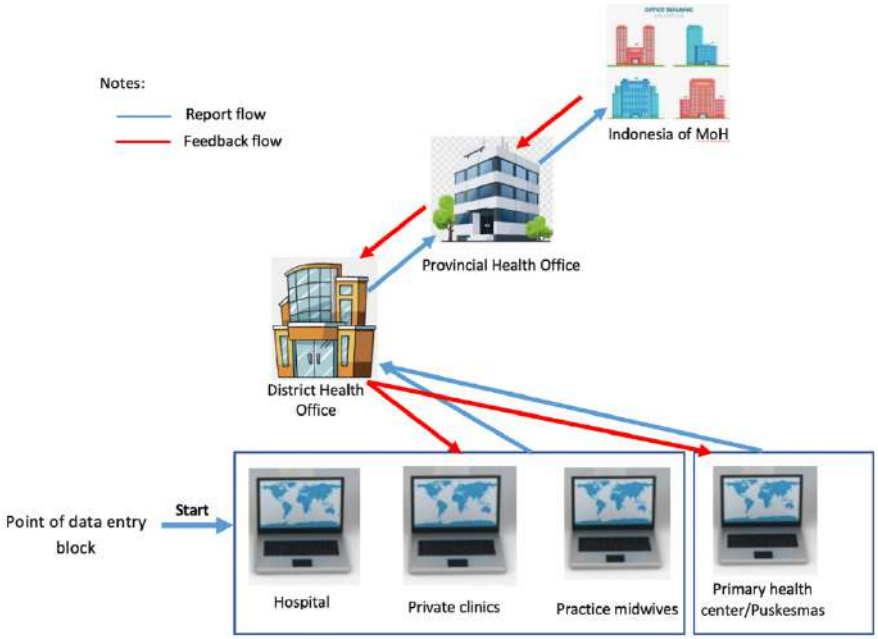

Figure 2. Visual organizing framework of SIMUNDU – DIY Province, Indonesia

At the beginning of SIMUNDU development, essential functions included database administrators, interface designers, and server administrators, and their interplay facilitated the smooth operation of the system. Training specific to SIMUNDU was integrated with other training, typically immunization-related training. This enabled to sharing of resources with other programs, thus ensuring viability. The training was delivered in the district/city health office: 70% of survey respondents indicated they had benefited. Training typically consisted of short training and included practice on the trainee's device and how to operate the system both in online and offline mode. Day-to-day operations were carried out autonomously by the staff, through adjusting their work

to protect time to enter the data. Some informants reported that staff members divided tasks effectively to ensure work was carried out effectively.

Leading - the success of SIMUNDU implementation is arguably related to strong leadership. Informants noted that managers played a key role in bridging the immunization program with the system design, closely monitoring the initial implementation process, and creating an enabling environment.

I try to combine supporting and managing the people involved and monitoring them. Currently, I monitor whether [SIMUNDU] can run optimally as our users are health facilities. I also monitor program development and the system's output.

[SIMUNDU] was born from program managers, primary health centers, Districts, and DIY health offices wanting to build systems together. We – DIY health office - give them motivation in every meeting.

I see that [management] is very good at networking. Staff data entry in the field always said that these people are very kind.

The role of IT in developing SIMUNDU was also reported to be significant. They helped develop the system and supported correct data entry by assisting data entry operators who experienced technical issues or helping resolve inconsistencies in the data records. Acknowledgment of staff efforts was also an important lever to maintain motivation and buy-in.

In the early days of SIMUNDU's development, the system was challenging to operate, as it wasn't as stable as it is now. I praise the enthusiasm and dedication of the users).

Managing **quality assurance** was critical to avoid data duplication or missing entries. This process was not regulated by specific Standard Operating Procedures but was addressed during training and monitored monthly. In addition, the DIY health office provided negative incentives to health facilities that were not providing complete records and provided regular feedback from monitoring and evaluation exercises.

We found that 90%, 76%, and 100% of survey respondents in PHC, UPS, and DHO, respectively, reported their work had been monitored regarding SIMUNDU. More than half of the respondents in Puskesmas and UPS facilities were observed at least once in 2019. At the PHC level, more than 50% reported that staff from the district/city level conducted the monitoring, and >40% reported that the DIY health office staff conducted monitoring. Furthermore, almost 40% of respondents from UPS facilities were monitored by Puskesmas. Nearly 100% of survey respondents stated they received feedback from the monitoring, mainly from the District/City and DIY health offices. Forty percent of respondents from UPS facilities reported receiving feedback from Puskesmas. Immunization coordinators from the District/City health offices reported that the DIY health office provided them with feedback.

In a [evaluation] meeting, DIY health office or district health office showed the progress of our data entry – correct or not, proper or not

Another resource that influences the successful implementation of SIMUNDU is the size of the DIY province. This province is quite a small geographic area. Because it consists of five districts and one city, this province is relatively easy to monitor across all phases, from planning through monitoring and evaluation.

System performance

While SIMUNDU predominantly contains individual-level immunization records, it also serves as a source for aggregation and can synergize with other information systems. Notably, SIMUNDU can link to the DHIS2 and generate immunization-specific reports as per Ministry of Health requirements. These reports are sent to the upper levels directly if SIMUNDU is operated online or submitted via email if SIMUNDU is operated offline. This functionality had an essential role in ensuring the acceptability and adoption of the system.

Informants noted how transitioning from paper-based tools to an electronic system made data entry easier and reduced errors. It also facilitated the implementation of protocols for data storage and security. It facilitated follow-up and defaulter tracking. Finally, integration with the DHIS2 meant reduced workload for the staff.

We can do faster tracking of children who may have immunizations in different locations. For example, when the first dose of a vaccine is given in Bantul, then the second immunization in Yogyakarta can be connected and detected with the SIMUNDU system.

Using SIMUNDU makes it easier to detect what data and immunizations are missing since we enter data from the children's birth through the end of the immunization schedule. So, we will know where they missed any vaccine.

The benefit of using SIMUNDU is first: we know the situation of immunizations more accurately….so, we say that our predictions are real for planning for the future… So, our budget, staff, facilities can be more effective and efficient in providing services.

Colleagues from the mother and child health (KIA) program enter via the KIA "Sembada." So, this data will appear automatically in SIMUNDU because the two-system are connected.

SIMUNDU is user-friendly and can be flexibly operated offline or online, allowing the responsible staff to maintain data entry irrespective of connectivity. More than 80% of survey respondents indicated they use the online version of SIMUNDU, and less than 20% of them operate the system offline.

People behavior

The survey showed that staff commitment was critical for the successful implementation of SIMUNDU, as indicated by their willingness to work overtime and bring home the data to enter into the system.

I take it [the data] home too, for example, after immunization sessions– in my clinic, immunization runs four times per month, every week. So, when the session is finished, we can take it home, [and] do the entry at home while relaxing

Some determinants that facilitated the implementation of SIMUNDU were the societal culture of helping others and responsibility and commitment to the team. An enabling environment helped people view SIMUNDU as a shared responsibility and a collective endeavor. Informants also noted the high motivation of dedicated staff.

That's all; we cannot judge by money [people kindness, culture, and behavior]; it's essential to explain how good people are in Yogyakarta. I was in another place before, and I could not find people's kindness like in Yogyakarta - different characters.

The second thing is that we need human resources who are concerned and love with data; otherwise, even though we have a good system, it will amount to nothing without good human resources. But when people are concerned about data, good implementation will come more easily.

Other characteristics, such as the culture of helping others and responsibility and commitment to tasks, revealed from the interviews, were critical determinants in the successful implementation of SIMUNDU.

Resource: human, financial, and material resources

Infrastructure and equipment emerged as critical factors to introducing and sustaining SIMUNDU implementation. Some desktops were specifically allocated to the immunization program, and some had to be shared with other programs' staff. Other data entry officers reported using laptops or personal smartphones. The survey found that in Puskesmass, almost 40% of data entry clerks used their private laptops to enter data into SIMUNDU. In UPS facilities, nearly 41% reported using office-supplied PCs, and in the DHO, more than half of the respondents stated they used an office-supplied laptop. The majority of respondents reported their current device was sufficient to perform their work on SIMUNDU. Regarding internet access, more than 60% of PHC and UPS staff reported using the office internet connection to enter data into SIMUNDU. However, 75% of DHO respondents reported no internet source found during SIMUNDU monitoring.

Management of financial resources was also crucial. Key informant interviews revealed no special allocation of funds to SIMUNDU in the initial stages. Resources were leveraged by sharing activities such as monitoring visits or transportation with other

programs, thus allowing cost efficiencies. Integration with other programs proved critical to ensuring sustainability.

SIMUNDU's budget comes from the state budget called as Anggaran Pendapatan dan Belanja Negara (APBN). Every year the APBN allocates funding envelop for immunization to DIY and other provinces, where the budget is apportioned across the program [not explicitly written for SIMUNDU]

Human resources are critical to the operation of SIMUNDU. According to respondents, SIMUNDU data entry clerks must have patience, work carefully and not rush, be interested in data, be responsible, and have basic computer skills such as Ms word and Ms excel. Our survey showed that most data entry clerks in PHC and UPS facilities had a diploma level of education (>80%), while at the managerial level (DHO), 75% of respondents had a bachelor's degree, suggesting that they have good computer literacy. Our survey shows that less than 20% and 9% of respondents in PHC and UPS, respectively, had low computer literacy.

Various data entry clerks looked for strategies to resolve their obstacles to entering data to SIMUNDU. Among them, they increased their computer skills by taking private computer courses. In addition, some of them learned from other colleagues at their offices. To deal with the accumulation of data needing to be entered in SIMUNDU, staff sometimes took data home for entry purposes because there is insufficient time during work hours since they have several other duties. If data entry clerks faced SIMUNDU trouble, informants said they asked for help from those who might have more information, for example, the district person in charge.

If we found obstacles, we asked people in charge in PHC – asking for a solution or sharing by WhatsApp – or sometimes I asked the IT person in the DIY health office.

Potential threats

The potential constraints on implementing SIMUNDU are individual capacity, technical or IT issues, and high workload. To date, SIMUNDU can be said to have had successful implementation. But it does not mean there were no obstacles faced. However, the important thing is how these obstacles were dealt with.

Computer literacy of staff was identified as one of the main issues. Internet connectivity was another obstacle to implementation, as not a good network supported all health facilities equally. As shown by the survey, only about 60% of Puskesmas and UPS staff used office internet, while others had to rely on their home internet.

Another issue that emerged was related to incomplete and inconsistent records; for example, the child's date of birth or name spelling not matching across different entries, making it difficult to have a unique and consistent record for each child. During the development stage, the system interface had to be incrementally finetuned, and some system failures made it challenging to enter the data. Even though these were temporary

and were promptly resolved, these system failures were an issue for staff, who were already juggling a very tight schedule in the office, as they caused some delay. As shown by the survey, for more than 97% of respondents, entering data in SIMUNDU was not their only responsibility or function – they also had other tasks.

Opportunities

Informants said that SIMUNDU is a good system for immunization data. SIMUNDU has become necessary for program managers and policymakers because it facilitates monitoring coverage and informing planning and programming. Currently, SIMUNDU is stable, thus is easier to manage than when it was in the development phase. This means that the system is not as reliant on the core workforce that has been heavily involved since inception and will possibly accommodate changes in the workforce. The hopes expressed by data entry clerks are that SIMUNDU would be easier to operate, and system errors did not occur. In addition, informants revealed the need for refresher SIMUNDU training so that their understanding of SIMUNDU would not be lost.

In my opinion, SIMUNDU is the best program in DIY which is a collaboration between program managers and IT. It will continue to be implemented because it is a necessity. It has been stably used for more than five years, meaning this is needed.

If I have the tool, in this case, SIMUNDU, when it is stable, whoever will hold it, I am sure that anyone can operate it. It means that it doesn't matter if we have people shifting (jobs).

In the future, if SIMUNDU is still used, other reports are not necessary. Now we have two different reports: SIMUNDU and stock card of vaccine – each stand-alone and need a separate report.

Based on the informants' statements, SIMUNDU is likely to be developed on a broader scale. The DIY health office is open to any party learning and implementing SIMUNDU in their region. However, informants advised that SIMUNDU must have a strong commitment from the data entry staff and management sides. The leadership in DIY has shown willingness to assign staff to other provinces who have expressed interest in SIMUNDU for orientation to the system,

Discussion

Robust health information systems (HIS) are essential components of strong health systems (12). Having a timely Immunization Information System (IIS) that collects individual information and vaccine recipient's history to improve immunization services is essential to personalize vaccination information, communicate targeted information as a decision support system, and record vaccination hesitancy (13). Here, we provide evidence of how an immunization information system has been implemented in practice.

Sistem Informasi Imunisasi Terpadu (SIMUNDU) or Integrated Immunization Information System in the DIY province enabled the creation of individual immunization records for children. SIMUNDU allows users and managers to collect, store and analyze data on utilization of immunization services, including following up individual children and creating cohort data. Currently, DIY is the only province in Indonesia – out thirty-four - that uses an IIS. This work has shed light on the strengths and underlying barriers of implementing an IIS in this context. The objective was to draw lessons that inform sustainable scale-up in other regions and possibly at the national level.

This study studied the potential factors that facilitate or pose a barrier to SIMUNDU implementation. We identified management, system performance, people's behavior, and resources as determinants for SIMUNDU's strength that influenced implementation outcomes: the acceptability, implementation cost, and adoption of this innovation (14). Individual capacity, system trouble, and high workload were barriers to implementation.

Despite several obstacles encountered during the implementation of SIMUNDU, we see that this innovation is well accepted by the stakeholders involved. The first stakeholder group is data entry clerks, who accept several aspects of SIMUNDU: data entry content, ease of input to the system (not complex), and comfort using SIMUNDU compared to the previous system. The second stakeholder group is managers; they accepted this system well and felt there was a benefit in this innovation, namely the output in cohort data to help them monitor and improve immunization coverages.

Having an excellent managerial process – meaning proper planning, monitoring, and evaluation - is one reason SIMUNDU has survived and been viable for the last 5 years. Managers use their power to encourage the beliefs and actions of other people (15). This requires a dedicated and robust process for the whole of the management process cycle. SIMUNDU was born from the need for credible data at the DIY health office to assist in carrying out its duties at the managerial and operator levels. At the managerial level, the disease prevention and control department and the IT department collaborated to create a system readily accepted by users. Immunization and IT programmers played a central role from the beginning of the design throughout the implementation process with appropriate coordination and communication. Their ability to do so was facilitated by the full support of their respective superiors.

SIMUNDU is cost-effective in several ways. During the introductory period of SIMUNDU implementation, immunization programmers, IT officers, and other staff assisted in disseminating SIMUNDU to all existing districts. This was done side by side with other programs, making it cost and time-efficient for managers and staff. As mentioned, organizing activities is certainly not easy, but it can be carried out well, even sustainably, by sharing resources. Additionally, SIMUNDU maintenance does not require high costs because the DIY Health Office developed and maintained the system. Thus, the IT department can develop improvement processes and tailor them to user needs

without additional cost. In addition, the location of affordable services (health facilities) is also part of cost-effectiveness.

A good program without good leadership could fail in its implementation, and even if it was initially successful, it might not be sustainable (16). In the context of SIMUNDU, support from leadership and the involvement of good people at managerial levels may have facilitated the program's adoption. The level of SIMUNDU uptake was good because all health facilities providing immunization services have successfully used this system, and it has been running well. The adoption of SIMUNDU was facilitated by the strong networks of the main person in charge of SIMUNDU. Communication, care, and attention to staff concerns positively affected staff performance. They feel well supported and are treated kindly – this means that they carry out their work joyfully. Several informants brought up this theme who stated that the person who played an essential role in SIMUNDU was the immunization program manager.

The monitoring and evaluation mechanisms of SIMUNDU were also important. Preferred monitoring and evaluation activities include monthly reports and direct discussion with staff during site monitoring visits. The immunization program manager suggested this approach to maintain data quality and system sustainability. These chosen mechanisms allow program managers to know the real conditions in the field and the obstacles faced to inform decisions about the follow-up actions that must be taken. This supports the ongoing development and learning of SIMUNDU as a tool for data collection, analysis, and visualization tool, provides benefits for managers to carry out monitoring and evaluation. The same point was stated by previous research in India about the innovation of health management information systems for primary health care agrees that this can provide essential benefits (17).

Human resources are determinants of the success of health information system implementation (18). The people's behavior affects how the system works, develops, and survives (19),(20). In the case of SIMUNDU, implementation was facilitated by the caring character, networks, and meticulous attitude towards data of both the program manager and IT team. From the staff's point of view, the local culture of helping each other and doing their job correctly and responsibly is translated into staff that carries out their duties with enthusiasm and high commitment. Although facilities, funding and volume of human resources are limited, the people involved are highly motivated and supportive. Socio-cultural values, attitudes and beliefs held by staff have contributed to the successful implementation of SIMUNDU.

Despite the clear strengths of SIMUNDU, there are potential obstacles to its sustainability in the future. These obstacles can be divided into human variables and technical variables. From the human variables side, unequal individual capacities at the operator level can cause obstructions during data entry in the field. Another potential future obstacle is the staff's high workload because generally, they have to do other tasks besides SIMUNDU data entry. From the interview results, the data entry clerks have tried finding strategies

to overcome this additional workload burden, such as doing data entry at home and overtime at the office. But from the health system perspective, if this is not anticipated and a strategy to address it is implemented, it may become unsustainable to expect staff to continue to do overtime. This will potentially interfere with the data's quality and overall harm SIMUNDUsustainability.

From this study, we know that SIMUNDU is a promising immunization reporting system. Although obstacles exist, the benefits and strengths outweigh them. In-depth interviews revealed the potential for scale-up of this program to other areas. Our findings show that to maintain the continuity of SIMUNDU, some actions should be taken, such as providing regular training to the data entry clerks, as the system is constantly being updated. In addition, there is a need to layering the management structure to anticipate staff rotation or retiring. Lastly, appropriate motivation, incentive, and support for data entry clerks need to be ensured.

Conclusions

SIMUNDU was developed in 2014 by the DIY health office. It was introduced in 2015 across the province and has been successfully implemented. However, there was no systematic evaluation of the data collected to date's accuracy, completeness, and timeliness. The benefit of SIMUNDU can be seen from the outputs generated, such as the cohort data that allows the immunization staff to track and observe each child's immunization progress, which may contribute to the increase in immunization coverage in this region.

Despite resource constraints, it was still possible to run SIMUNDU. Initially, there was no special allocation funding for SIMUNDU, so the program ran side-by-side with other health programs in the DIY health office. This mechanism allowed cost-efficiency. There were three prominent persons in charge of developing SIMUNDU: 1) IT person responsible for system creation and maintenance, 2) the immunization program manager responsible for the strategic development of SIMUNDU, and 3) data entry clerks who are accountable for careful data entry into SIMUNDU. When seen from a facility perspective, SIMUNDU does not require expensive equipment – all that is needed is a computer or phone and internet access. The fair managerial process influenced the success of SIMUNDU to date from the DIY province. This required appropriate planning, organizing, leading, and controlling.

Three recommendations stemmed from this study, addressed to the DIY health office, the national government, and researchers. First, to guarantee continuity and sustainability and reduce the system's dependency on the particular person or party, SIMUNDU management and maintenance should be related to others with the competency and interest in a good reporting system. Furthermore, existing human resources should be strengthened in preparation for scaling up SIMUNDU in other regions or at a national level; this is necessary to avoid vacant positions when DIY province staff are seconded

to requests for mentoring from other areas. Second, the bottom-up approach to developing and implementing SIMUNDU has shown that the system is feasible and viable. The approach to scaling up SIMUNDU should be stepwise, considering each region's specific characteristics and problems. Therefore, it is vital to develop a readiness map and a timeline for the roll-out of SIMUNDU in a particular region. Third, further research is needed on the impact of SIMUNDU on immunization coverage, for instance, through a before and after comparative study with a 2–3-year time window in a low-performing region.

Declarations

Ethics approval and consent to participate

This study was approved by the Ethical Review Board of Universitas Ahmad Dahlan, Yogyakarta, Indonesia (ethical approval code: 012005021). Before data collection began, consent to participate was obtained from research subjects (both survey and key informant interviews).

Adherence to national and international regulations

Not applicable

Consent for publication

Before data collection begins, an approval that data is taken for publication purposes is obtained from research subjects (both surveys and key informant interviews).

Availability of data and materials

The datasets generated and/or analyzed for this study can be requested to the corresponding author.

Competing interests

The authors declare that they have no competing interests

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Authors' contributions

SS, TAW, RR, ASDN and MF designed the study. SS, TWS, SKW, SAM collected the data. SS and RR conducted data analysis. SS developed the paper with inputs and comments from MF on each draft. All authors agree with the manuscript's results and conclusions.

Acknowledgments

We are grateful to Mr. Suyani Hartono and Mrs. Ani Roswiani for assisting with the data collection. We also thank all immunization coordinators, managers, and data entry staff who participated in the survey and interviews. Finally, we thank Geetanjali Lamba for the editorial support.

Authors' information:

The authors alone are responsible for the views expressed in this article. They do not necessarily represent the views, decisions, or policies of the institutions affiliated with them.

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Revisi 1

Date:	15 Feb 2022
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From:	"BMC Health Services Research Editorial Office" Eloisa.HadeNolasco@springernature.com
Subject:	Your submission to BMC Health Services Research - BHSR-D-21-00992R1

BHSR-D-21-00992R1
Introducing and implementing an immunization information system in Indonesia province of Daerah Istimewa Yogyakarta: lessons for scale-up
Sulistyawati Sulistyawati; Trisno Agung Wibowo; Rokhmayanti Rokhmayanti; Andri Setyo Dwi Nugroho; Tri Wahyuni Sukesi; Siti Kurnia Widi Hastuti; Surahma Asti Mulasari; Marta Feletto
BMC Health Services Research

Dear Dr Sulistyawati,

Your manuscript 'Introducing and implementing an immunization information system in Indonesia province of Daerah Istimewa Yogyakarta: lessons for scale-up' (BHSR-D-21-00992R1) has been assessed by our reviewers. They have raised a number of points which we believe would improve the manuscript and may allow a revised version to be published in BMC Health Services Research.

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Technical Comments:

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reviewers are not named (unless they opt in to include their name).

Reviewer reports:
Reviewer 1: Overall Comments:
This article makes and important contribution by highlighting the transition and use of digital data systems in tracking childhood immunization in Indonesia. The authors provided a strong description of the system's rollout, enabling factors, challenges, and opportunities. The article could be strengthened by providing additional information from the survey to support the quotes presented. Also, the article would benefit from having short (1 paragraph) limitations and recommendations sections. (The last paragraph of the conclusion is well done and could be expanded for a recommendation section)
Abstract:
Line 31 "To increase the coverage of immunization, valid and real-time data is needed.
Accordingly, having a good report system is essential that rolled as defaulter tracking to
prevent the children's immunization failure" Please reword this sentence, as it is difficult to understand the meaning of the word "rolled".
Line 40: Reword to : An explanatory sequential mixed-method design was used in this study which collected quantitative data from 142 participants and quantitative data from 9 participants.

Background:

Pg 2 Line 22: Add "the" before provincial
Pg 2 Line 44: Changes to "with 97.7% of children completing basic immunization coverage in 2019"

Methods:
Overall: Note the procedures that were used for transcription and translation of qualitative data (if not conducted in and analyzed in the same language). For quantitative data collection, was the survey
* Pg 5 Line 12: The text states "All participants were invited to the DIY health office
* to fill out the survey on their laptops. Having all participants in a room allowed
* researchers to monitor potential gaps in responses in real-time and follow-up with
* individual participants on-site to fill any gaps." It is important to note the potential for bias that this method introduces into the data collection - monitoring the answering of questions and asking participants to fill in gaps left. This can be noted in the discussion section or in limitations.
* Pg 5 line 25: Was the interview guide semi-structured? Did the researchers ask probing questions (not on the interview guide) depending on the answers?
* Add a few sentences/paragraph on limitations of the study
Results:
Overall: The data and information presented appears to rely heavily on the 9 qualitative interviews. The section refers very little the answers from the survey. If possible, add more of the survey data into the results section, and attribute the information to the survey. Additionally, ensure that data is presented fully instead of rounding off the point estimates and writing "more than or less than 50%. Instead, state the true % - example 52.3%.
Change the highlights/red text so it is consistent for each sub section of the results.
* Pg 9 line 52 (and elsewhere where survey data is presented)" Present the quantitative results fully - instead of saying "More than 80% of survey respondents", give the actual statistic (for example 81.2%).
* Pg 11 line 42-44: reword: A number of obstacles were encountered and addressed during implementation.
* Pg 11 line 53: replace ";" with "." After the first sentence. Then change sentence two to read: "An example of this inconsistency of child's date of birth or name spelling among different entries, making it difficult to consistently record immunization information.

Discussion:
Overall, gives a good overview of the results and opportunities, however, it can be difficult to follow at points.
* Pg 15 lin 45: Reword: "The fair managerial process influenced the success of SIMUNDU to date from the DIY province." What does "the fair managerial process mean? Please reword or explain this better

* Pg 16 line 1-2: "Second, the bottom-up approach to developing and implementing SIMUNDU has shown that the system is feasible and viable." Can this be reworded? It is difficult to understand as written.

* Pg 16 line 8-9: How would the information from a study like this be useful? Please state it the paper. Third, further research is needed on the impact of SIMUNDU on immunization coverage, for instance, through a before and after comparative study with a 2-3-year time window in a low-performing
region.

Reviewer 2: General Comments:
Immunization information systems are an important infrastructure. Authors describe the implementation and evaluation of a system in Indonesia for children. However, methods are very unclear. Perhaps the manuscript could be restructured to describe the implementation first, because it is very unclear if the information was obtained from the methods or not? Seems some of the implementation data was obtained from documents review. Then use the survey and key informant information as an evaluation of the system?

Title: Recommend changing to "Implementation of an immunization information system in Indonesia province of Daerah Istimewa Yogyakarta:lessons for scale-up
Abstract:
Background - change safe to save
Authors use abbreviations in the abstract that should be defined such as DIY, SIMUNDU
Background:
Page 2, paragraph 2. Please provide a definition of the DHIS2 since it is used later
Page 2, paragraph 3. Authors describe primary health centres as puskesmas or PHC in other areas of the manuscript. Please be consistent in terminology and if going to use PHC please define it here.

Page 3, paragraph 2. This paragraph uses both puskesmas and PHCs
Page 3, paragraph 3. Please use English diphtheria
Page 3, paragraph 3, - please explain how the school information is being loaded into SIMUNDU in aggregate
Methods:
Page 4, paragraph 2. Last sentence. Please explain the difference between staff responsible and immunization coordinator are they the same. The table uses immunization coordinator. Also here use puskesmas versus PHC. Are you also using private clinics and hospitals as in the table.
Table 1. Seems a small sample for the clinic and hospital versuse PHC and UPS - is there a reason?
Page 5, paragraph 1. Again are the immunization coordinators the staff responsible and would all facilities have an immunization coordinator.
Page 5, paragraph 1, last sentence. Authors state all staff involved with data entry and management. Authors need to be more clear who completed surveys - seems the samples are not consistent across all practices does that mean that private clinics for example had much fewer staff involved with SIMUNDU than UPS for example?
Page 5, paragraph 2. Please describe the survey in more depth - how was it developed, how many questions, what types of questions? Any demographic data of the respondents? Usually, a key informants interview would be done first to then inform the survey. So methods are slightly different approach. How was the survey data used to drive the key informant interviews.
Results:
Authors do not present any of the survey data from 146 respondents? Only key themes and not sure where the key themes are from - the survey or the key informant interviews. Were the themes already developed when the survey was developed?
Author reporting of the results seem to mix the introduction and the use of SIMUNDU. Perhaps authors could describe the implementation as part of the background and introduction and then use the survey data and key informants as the results of the system. But it is not clear because authors do not provide enough information to evaluate the survey and the key informant interviews.
Page 6, paragraph 2. This provides a lot of information about why the system was implemented. Did this come from the survey or the desk review?
Throughout the authors mentioned the survey showed? But how? What were the questions how many respondents, etc.
Page 9, paragraph 3. The authors provide some survey data - this is helpful. Need to see this in all sections to really understand.
Page 11. Also has some survey data presented by the authors but it is difficult to interpret with not all sections containing survey data.

Discussion
Page 13, paragraph 1. Authors provide a nice summary here, but are these questions that were included in the survey.

Conclusion
Authors should include recommendations and be identified as lessons for scale-up in the discussion instead of conclusion. Conclusion contains background information, that should be deleted. The conclusion should offer a succinct concl

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Declarations
- Ethics approval and consent to participate
- Consent to publish

- Availability of data and materials
- Competing interests
- Funding
- Authors' Contributions
- Acknowledgements
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Reviewer 1

Dear Reviewer 1, thank you very much for your advance comments and inputs to this manuscript; we appreciate it. Our response to all your comments and input is presented in the table below.

Reviewer 1: Overall Comments: This article makes and important contribution by highlighting the transition and use of digital data systems in tracking childhood immunization in Indonesia. The authors provided a strong description of the system's rollout, enabling factors, challenges, and opportunities. The article could be strengthened by providing additional information from the survey to support the quotes presented. Also, the article would benefit from having short (1 paragraph) limitations and recommendations sections. (The last paragraph of the conclusion is well done and could be expanded for a recommendation section)	Study limitation has been added on Page 16. The recommendation has been completed together with the conclusion.
Abstract: Line 31 "To increase the coverage of immunization, valid and real-time data is needed. Accordingly, having a good report system is essential that rolled as defaulter tracking to prevent the children's immunization failure" Please reword this sentence, as it is difficult to understand the meaning of the word "rolled".	We change rolled to function. The change can be found in Abstract – Page 1 *"To increase the coverage of immunization, valid and real-time data is needed. Accordingly, having a good report system is essential that functions as defaulter tracking to prevent the children's immunization failure"*
Line 40: Reword to: An explanatory sequential mixed-method design was used in this study which collected quantitative data from 142 participants and quantitative data from 9 participants.	Thank you for your input; the correction can be found in the methods section – Page 1
Background: Pg 2 Line 22: Add "the" before provincial	Thank you for your correction. The change can be found on page 2
Pg 2 Line 44: Changes to "with 97.7% of children completing basic immunization coverage in 2019"	Thank you for your correction. The change can be found on page 2
Methods: Overall: Note the procedures that were used for transcription and translation of qualitative data (if not conducted in and analyzed in the same language). For quantitative data collection, was the survey	The information about the translation process has been added in the method section – Page 5.
* Pg 5 Line 12: The text states "All participants were invited to the DIY health office * to fill out the survey on their laptops. Having all participants in a room allowed * researchers to monitor potential gaps in responses in real-time and follow-up with *individual participants on-site to fill any gaps."	Study limitation has been added on Page 16

It is important to note the potential for bias that this method introduces into the data collection - monitoring the answering of questions and asking participants to fill in gaps left. This can be noted in the discussion section or in limitations.	
* Pg 5 line 25: Was the interview guide semi-structured? Did the researchers ask probing questions (not on the interview guide) depending on the answers?	Yes, we used a semi-structured interview that allowed the interviewer to probe questions. This information has been added to Page 5.
* Add a few sentences/paragraphs on limitations of the study	Study limitation has been added on Page 16
Results: Overall: The data and information presented appears to rely heavily on the 9 qualitative interviews. The section refers very little the answers from the survey.	We are presenting the Quantitative result in the Table that we put on the Supplementary file due to the length of pages. Then Qualitative study presents in Figure 2. In the narrative, we put together the result among the two studies with a sequence - theme from qualitative - put quotations - survey result (percentage)
If possible, add more of the survey data into the results section, and attribute the information to the survey.	Information about respondent and informant have been added on Page 6-7. For the survey result, we put it in the supplement. While the narration of the percentage presented together in each theme emerged
Additionally, ensure that data is presented fully instead of rounding off the point estimates and writing "more than or less than 50%. Instead, state the true % - example 52.3%.	All percentages have been changed to the true %
Change the highlights/red text so it is consistent for each sub section of the results.	All read highlight has been changed to make it consistent all sections
* Pg 9 line 52 (and elsewhere where survey data is presented)" Present the quantitative results fully - instead of saying "More than 80% of survey respondents", give the actual statistic (for example 81.2%).	All percentages have been changed to the true %
* Pg 11 line 42-44: reword: A number of obstacles were encountered and addressed during implementation.	The suggestion has been made on page 11
* Pg 11 line 53: replace ";" with "." After the first sentence. Then change sentence two to read: "An example of this inconsistency of child's date of birth or name spelling among different entries, making it difficult to consistently record immunization information.	The second sentence has been changed according to the reviewer's suggestion (Page 11)
Discussion: Overall, gives a good overview of the results and opportunities, however, it can be difficult to follow at points. * Pg 15 lin 45: Reword: "The fair managerial process influenced the success of SIMUNDU to date from the DIY province." What does "the	The fair managerial process means that the manager of SIMUNDU implements planning, monitoring and evaluation, and feedback correctly. Reword has been made on Page 17.

fair managerial process mean? Please reword or explain this better	
* Pg 16 line 1-2: "Second, the bottom-up approach to developing and implementing SIMUNDU has shown that the system is feasible and viable." Can this be reworded? It is difficult to understand as written.	This sentence is reworded to "Second, the bottom-up approach during SIMUNDU development and implementation positively impacts this system and makes it is feasible and viable to use" Page 17
* Pg 16 line 8-9: How would the information from a study like this be useful? Please state it the paper. Third, further research is needed on the impact of SIMUNDU on immunization coverage, for instance, through a before and after comparative study with a 2-3-year time window in a low-performing region.	Dear Marta, I don't get this point. Please help!

Reviewer 2

Dear Reviewer 2, thank you very much for your advance comments and inputs to this manuscript; we appreciate it. Our response to all your comments and input is presented in the table below.

General Comments: Immunization information systems are an important infrastructure. Authors describe the implementation and evaluation of a system in Indonesia for children. However, methods are very unclear. Perhaps the manuscript could be restructured to describe the implementation first, because it is very unclear if the information was obtained from the methods or not? Seems some of the implementation data was obtained from documents review. Then use the survey and key informant information as an evaluation of the system?	 Desk review aimed at growing evidence of the history of SIMUNDU development from the beginning until recent implementation based on the available document. This desk review was conducted in collaboration with the DIY Health Office as the document provider. In general, we presented the result of the desk review in Figure 1, which is the history of SIMUNDU development and introduction. While quantitative was used to capture the implementation process, it was digging information gathered from the quantitative study in the qualitative.
Title: Recommend changing to "Implementation of an immunization information system in Indonesia province of Daerah Istimewa Yogyakarta: lessons for scale-up	The title has been modified on page 1
Abstract: Background - change safe to save	Safe already changed to save – Page 1
Authors use abbreviations in the abstract that should be defined such as DIY, SIMUNDU	DIY dan SIMUNDU have been spelling out
Background: Page 2, paragraph 2. Please provide a definition of the DHIS2 since it is used later	DHIS2 has been spelled out on Page 2 DHIS2 means The District Health Information System 2
Page 2, paragraph 3. Authors describe primary health centers as puskesmas or PHC in other areas of the manuscript.	Puskesmas has been changed to PHC across the pages
Please be consistent in terminology and if going to use PHC please define it here.	Puskesmas has been changed to PHC across the pages
Page 3, paragraph 2. This paragraph uses both puskesmas and PHCs	Puskesmas has been changed to PHC across the pages
Page 3, paragraph 3. Please use English diphtheria	Difteri has been changed to Diphtheria

Page 3, paragraph 3, - please explain how the school information is being loaded into SIMUNDU in aggregate	The information has been added on page 3. The aggregate is related to the number of students in a particular school.
Methods: Page 4, paragraph 2. Last sentence. Please explain the difference between staff responsible and immunization coordinator are they the same. The table uses immunization coordinator. Also here use puskesmas versus PHC. Are you also using private clinics and hospitals as in the table.	Let me explain as follow: Staff responsible for interfering with the data in PHC and UPS means staff who face the raw data that has to be input to SIMUNDU. While staff in district/city is a manager in that area who supervises the staff in PHC and UPS. The sentences have already been modified to make them clearer. Yes, UPS consists of some health facilities such as private clinics and hospitals.
Table 1. Seems a small sample for the clinic and hospital versuse PHC and UPS - is there a reason?	Based on the information that has been collected before we executed the survey and considering that the characteristics of each group are almost the same, together with the provincial health office, we agreed to take 2 units per district randomly.
Page 5, paragraph 1. Again are the immunization coordinators the staff responsible and would all facilities have an immunization coordinator.	The modification has been made on Page 4. Immunization coordinator only in district/city, while data entry clerk in all health facility invited
Page 5, paragraph 1, last sentence. Authors state all staff involved with data entry and management. Authors need to be clearer who completed surveys - seems the samples are not consistent across all practices does that mean that private clinics for example had much fewer staff involved with SIMUNDU than UPS for example?	Immunization coordinator only in district/city, while data entry clerk in all health facility invited. Private clinics are part of UPS. So overall, we divided the sample into 3 groups: PHC, UPS (hospital, clinic, midwives practice)
Page 5, paragraph 2. Please describe the survey in more depth - how was it developed, how many questions, what types of questions? Any demographic data of the respondents? Usually, a key informant's interview would be done first to then inform the survey. So, methods are slightly different approach. How was the survey data used to drive the key informant interviews.	Detailed information about the survey has been added on Page 5, paragraph 1. Then how was information from the quantitative study used in qualitative study was completed on Page 5, Paragraph 2. Since we used to explain why a particular case like this or like that, we should know first the existing situation in the field, it is why in this research we used explanatory sequential mixed-method design, where quantitative data were completed first then the finding was used to inform the qualitative phase – referred to *Fetters MD, Curry LA, Creswell JW. Achieving integration in mixed methods designs - Principles and practices. Health Serv Res. 2013;48(6 PART2):2134–56.* I have added more information about the approach in the methods section, Page 4, paragraph 1.
Results: Authors do not present any of the survey data from 146 respondents? Only key themes and not sure where the key themes are from - the	Dear reviewer, We have added table 2 and table 3 for the informant's characteristics on Page 6-7.

survey or the key informant interviews. Were the themes already developed when the survey was developed?	Regarding the survey result, we will add it as a supplementary file because it has many pages. This supplementary will replace the questionnaire that we attached before. The theme had developed during the qualitative study analysis that we apply deductive analysis related to the managerial process (input – process and output)
Author reporting of the results seem to mix the introduction and the use of SIMUNDU. Perhaps authors could describe the implementation as part of the background and introduction and then use the survey data and key informants as the results of the system. But it is not clear because authors do not provide enough information to evaluate the survey and the key informant interviews.	Dear reviewer, Our research aim was to draw lessons learned about SIMUNDU to a scale-up possibility since it is the first system developed in Indonesia. We thought that we should explain the system from development, introduction, implementation and how it was monitored.
Page 6, paragraph 2. This provides a lot of information about why the system was implemented. Did this come from the survey or the desk review?	We present surveys and key informant interviews (KII). In the result section, we put together information from KII and survey to compare what we found in the 2 approaches.
Throughout the authors mentioned the survey showed? But how? What were the questions, how many respondents, etc.	Thank you for your question. The information about respondent and informant characteristics has been added on Page 6-7. The survey result will add as supplementary due to the page length.
Page 9, paragraph 3. The authors provide some survey data - this is helpful. Need to see this in all sections to understand.	Yes, we add the survey result as Sup. 1
Page 11. Also has some survey data presented by the authors but it is difficult to interpret with not all sections containing survey data.	We add the survey result as Sup. 1
Discussion Page 13, paragraph 1. Authors provide a nice summary here, but are these questions that were included in the survey.	Page 13, Par. 1: Sistem Informasi Imunisasi Terpadu (SIMUNDU) or Integrated Immunization Information System in the DIY province enabled the creation of individual immunization records for children. SIMUNDU allows users and managers to collect, store and analyze data on utilization of immunization services, including following up individual children and creating cohort data. Currently, DIY is the only province in Indonesia – out thirty-four - that uses an IIS. This work has shed light on the strengths and underlying barriers of implementing an IIS in this context. The objective was to draw lessons that inform sustainable scale-up in other regions and possibly at the national level. In this part, we declared our background and again stated our research aim to remind the reader.
Conclusion Authors should include recommendations and be identified as lessons for scale-up in the discussion instead of conclusion. Conclusion contains background information, that should be deleted. The conclusion should offer a succinct concl	Dear reviewer, The first paragraph containing the background has been deleted. We have put 3 recommendations in the second paragraph of the conclusion.

Implementation of an immunization information system in Indonesia province of Daerah Istimewa Yogyakarta: lessons for scale-up

Sulistyawati Sulistyawati, MPH, PhD[1*]
Trisno Agung Wibowo, MPH[2]
Rokhmayanti Rokhmayanti, MPH[1]
Andri Setyo Dwi Nugroho, MPH[2]
Tri Wahyuni Sukesi, MPH, PhD[1]
Siti Kurnia Widi Hastuti, MPH[1]
Surahma Asti Mulasari, MPH, PhD[1]
Marta Feletto, PhD[3]

[1] Faculty of Public Health, Universitas Ahmad Dahlan, Yogyakarta, Indonesia
[2] Daerah Istimewa Yogyakarta (DIY) Health Office, Yogyakarta, Indonesia
[3] Alliance for Health Policy and Systems Research, World Health Organization, Geneva, Switzerland

*Corresponding author: sulistyawati.suyanto@ikm.uad.ac.id.
Kampus 3 - Jl. Prof Dr Soepomo, Janturan, Umbulharjo, Yogyakarta, Indonesia.

Abstract

Background: Immunization is undeniable as a critical aspect of saving children from infections. To increase the coverage of immunization, valid and real-time data is needed. Accordingly, having a good report system is essential that functions as defaulter tracking to prevent the children's immunization failure. Daerah Istimewa Yogyakarta (DIY) health office developed an individual electronic immunization registry and successfully implemented it for more than five years. It is the only individual-based record system in Indonesia that has survived for such a long time. To date, there is no systematic assessment of this system. Therefore, this research aimed to examine Sistem Informasi Imunisasi Terpadu (SIMUNDU) introduction and implementation process to draw lessons that could inform scalability and sustainability across the country.

Methods: This study used an explanatory sequential mixed-method design, which collected quantitative data from 142 participants and qualitative data from 9 participants. Entry data clerk in all level of health facility was systematically selected to participate in the survey. While in the key informant interview, the informant was selected based on the survey result. The descriptive and thematic approach was employed to analyze the quantitative and qualitative data. Integration between the two approaches was accomplished in the interpretation of the result by comparison and contrast.

Results: Three core themes emerged from our analysis that describes the SIMUNDU success journey as an electronic immunization registry: system strengths, potential threats, and opportunities.

Conclusions: The individual electronic immunization registry has been implemented well, and it may contribute to increasing immunization coverage in DIY. Stakeholders should consider the sustainability of this system by providing related resources and consider scale-up nationally by looking at this promising program.

Keywords: immunization, electronic immunization registry, immunization information system, interoperability, implementation research

Background

Neonatal and childhood vaccination is an essential component of infectious disease prevention and an absolute human right (1),(2). Vaccination has been proven to reduce the burden of infectious disease globally (3). According to the WHO, in 2020 estimated 23 million children under one year of age did not receive their essential vaccinations. Of these, 60% live in just ten countries, one of which is Indonesia (4). Indonesia is the fourth most populous country globally. It is composed of thousands of islands organized into 34 provinces. Various geographical and cultural factors influence population inequalities to access to health services (5). In 2001, the Indonesian government's decentralization policy was enacted. This was an excellent strategy to foster development by engaging regional resources (6). However, this strategy was not without consequence. One primary concern is the fragmentation of the Health Information System (HIS).

Indonesia's federal structure results in provinces and districts being relatively independent of the national Ministry of Health. This means that information systems at the provincial and district levels are locally regulated (7). For instance, *Pemantauan Wilayah Setempat* (PWS) is a management tool used to monitor coverage of specific health services in an administrative boundary. Depending on the service and region, it can be paper- or electronic-based. PWS-KIA is the monitoring system specific to maternal and child health (KIA), including immunization. PWS-KIA data are reported to the District or City Health Office, go to Province Health Office, and finally report to the main level. Generally, the data is in excel; it will report via emails or various information systems, including Komdat, SiTT, SIHA, PISPK, SIKDA Generik. PWS-KIA data feeds into the District Health Information System 2 (DHIS2) in some provinces. Regional information systems have varying data quality, reflecting inequities in regions' resources. This adds to data integration challenges at the national level (7),(8) and affects strategic policymaking.

In the context of Indonesia’s federal system, Daerah Istimewa Yogyakarta (DIY) Province has the authority to regulate and use its budget within its four districts (Sleman, Gunungkidul, Bantul, Kulonprogo) and Yogyakarta city. Regarding childhood vaccination, DIY is among the top ten performing provinces in the country, with 97.7 % of children completing basic immunization coverage in 2019 (9). Immunization services are provided by Primary Health Centres (PHC), as well as private clinics, hospitals, and midwives' practices (typically referred to as *Unit Pelayanan Swasta* (UPS).

An electronic immunization registry is a tool for recording individual children’s immunization histories. In 2014, the DIY Health Office introduced an electronic immunization registry named SIMUNDU (*Sistem Informasi Imunisasi Terpadu*/ Integrated Immunization Information System). An electronic registry serves essential functions at all levels of the health system. At the district and higher levels, it allows for monitoring vaccination coverage by the vaccine, dose, cohort, and other variables – and can support microplanning and vaccine management. The service delivery level can facilitate individual follow-up of vaccination status and enable health workers to identify children due for vaccination and those who missed their vaccinations (defaulters).

SIMUNDU was designed to link with the PWS-KIA for immunization and interoperability with the DHIS2. While it predominantly contains individual-level immunization records, SIMUNDU also serves as a source for aggregation and can synergize with the *Pemantauan Wilayah Setempat* (PWS) reporting system. For this reason, it can be considered an Immunization Information System (IIS). This means that data from City and District levels feed into Provincial and National levels *(Personal communication with DIY immunization program officer)*.

The original prototype was designed by the information and technology (IT) department of DIY Health Office to be operated offline. In DIY, three out of the four districts and the city introduced the system in 2015. The final district introduced it in 2017. At this stage, the point of data entry was the PHC only. By 2018, UPS facilities were also equipped with SIMUNDU and could enter data into the system. In 2019, the prototype was further developed to operate online. The online version was rolled out in 2020 (Figure 1). As of May 2021, 79.4% of all PHC and UPS facilities complied. However, this average rate masks that while all PHCs adopt SIMUNDU, it is more challenging to enforce its use in UPC facilities (Suyani 2020, oral communication, 2020 May 11).

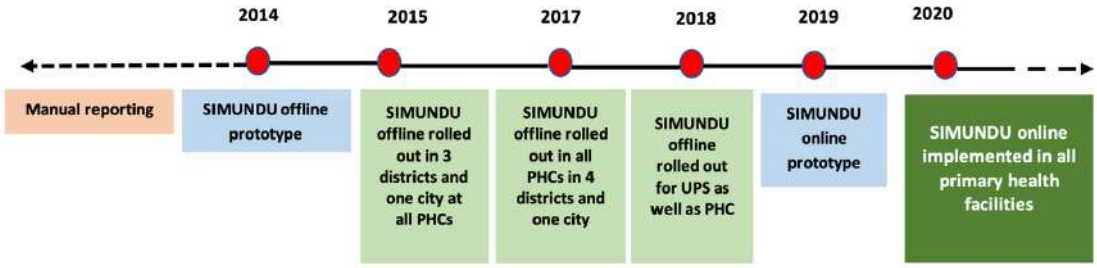

Figure 1. SIMUNDU's development and introduction

When a child receives a vaccination in a health facility, information on the child and the vaccination is entered in SIMUNDU as an individual child record. Each record includes a personal identifier, the child's socio-demographic characteristics (e.g., name, gender, date of birth, name of parents, address), the antigen administered, and the date and place of vaccination. SIMUNDU has been recently updated to allow recording of vaccinations administered in schools (e.g., Human papillomavirus (HPV), Diphtheria Toxoid (DT), Tetanus-Diphtheria (TD), and Measles-Rubella (MR)). Furthermore, SIMUNDU is being developed to record COVID-19 vaccinations in health facilities and those carried out in masse. At this stage, SIMUNDU only facilitates the reporting in aggregate based on the number of students in the school.

Monitoring is conducted every month to assess data completeness across health facilities, while an evaluation is conducted every year. These exercises have allowed the identification of several challenges related to implementing the system (e.g., workload, staff turnover, and rotation) and data quality (e.g., accuracy and timeliness). However, no systematic assessment of the system has been conducted to date.

SIMUNDU is the first immunization information system ever introduced in Indonesia. Other districts and provinces have shown interest in rolling it out, and the Ministry of Health has acknowledged the innovation. The objective of this work was to examine SIMUNDU's introduction and implementation process to draw lessons that could inform scalability and sustainability across the country.

Methods

From May to October 2020, we examined the experience of introducing and implementing an immunization information system in the DIY province using an explanatory sequential mixed-method design, where quantitative data were completed first then the finding was used to inform the qualitative phase (10). Before the survey started, we conducted a desk review of all relevant documentation available in the DIY health office – e.g., staff notes, meeting notes and monitoring notes – documenting SIMUNDU development and management processes. We also examined online documents, including health profiles and regulations on health reporting systems in Indonesia. This served as the initial data source and provided an overview of who was involved and their role in developing and implementing SIMUNDU. This informed the survey design that we conducted as a second step. The survey was conducted with staff responsible for entering data in SIMUNDU across PHC and UPS facilities and immunization coordinator at the district and city level. Sampling and recruitment strategies are outlined in Table 1.

Table 1. Survey sampling

Level of the data entry and reporting system	Total number of facilities/ offices	Study population	Sampling strategy	Recruitment	Sample size
Puskesmas/Primary Health Centre (PHC)	121	Immunization coordinator and data entry clerk	All facilities	Open invitation across all facilities	113
UPS - Hospital (Central, General, Maternity and Pediatric)	65	Immunization coordinator and data entry clerk	Randomly selected 2 facilities per district/city (2*5=10)	Open invitation across selected facilities	8
UPS - Clinic	73	Immunization coordinator and data entry clerk	Randomly selected 2 facilities per district/city (2*5=10)	Open invitation across selected facilities	7
UPS - Midwives' Practice	271	Immunization coordinator and data entry clerk	Randomly selected 2 facilities per district/city (2*5=10)	Open invitation across selected facilities	10
District/City Health Office	5	Immunization coordinator	Total sampling	Open invitation	4*
			Total		**142**

*When the immunization coordinator had recently changed, the former was also invited.

All immunization coordinators in each district/city and data entry clerks from all primary health facilities (PHC) participated in this survey. We randomly selected two clinics, two midwives' practices, and two hospitals per district/city for UPS facilities.

We developed and pre-tested an online survey in Bahasa Indonesia to inquire about SIMUNDU implementation, processes, and outcomes in each different level (PHC, UPS and DHO/CHO. The total question for PHC and UPS were 48 and 46 – respectively, that

divided into 2 significant parts: 1) respondent identity and 2) SIMUNDU reporting and managerial. Questions are presented in "Yes, No" or "scale" questions. In some questions, respondent allows putting their reason for choosing a particular answer.

All participants provided consent to participate in the survey. All participants were invited to the DIY health office to fill out the survey on their laptops. Having all participants in a room allowed researchers to monitor potential gaps in responses in real-time and follow-up with individual participants on-site to fill any gaps. Data were then exported and analyzed in Microsoft Excel descriptively. A significant percentage for each question was noticed for informing the qualitative phase.

Next, we conducted key informant interviews to explore the challenges of implementing the system from practice and managerial standpoint. The interview takes approximately 30 minutes that runs in Bahasa Indonesia. Each interview was conducted by three researchers with a different role: main interviewer, observer, and field note taker. SS, RR, TWS, SKW, and SAM were involved in the interviews. All of them were female with a public health background worked as lecturers and researchers at university. The research group developed a semi-structured interview guide and consulted with the expert prior to the interview.

Informants were purposefully selected among survey participants to follow up on the range of perspectives that had emerged from the survey. As informed by the desk review, others were chosen for their management functions. The informant and interviewer did not know each other prior to the interview. Informants were invited to Province Health Office for interview purposes due to COVID-19 pandemic reasons. Before the interview, the informant was informed about the study and asked to sign the informed consent. All invited informants agreed to participate. A total of nine key informants were interviewed in Bahasa Indonesia language. The face-to-face interviews were recorded with consent from the informants. After the interview, the interviewer summarized our field notes to the informant for correction. Transcription was done in Indonesian by our research assistant.

Thematic analysis was conducted using Quirkos qualitative tool following Braun and Clarke's approaches (11). Researchers familiarized themselves with the data, searching for initial codes and allowing themes to emerge. SS was the main coder during the analysis. Then the result of the coding reviewed together among the research group continued with defining and naming the core themes, analyzed the data for each of the core themes, triangulated information from the desk review, the survey, and the interviews. Themes were generated from the data during the analysis. The entire coding was performed in Indonesian, and from the subcategory level, the data were translated to English.

Results

Characteristic participant

a. Quantitative study

In total, 142 respondents participated in this study spread across five districts or cities in the DIY province. Most respondents came from Gunungkidul District, PHC, UPS, and DHO, 24.8%, 24%, and 25%, respectively. For all research units, the majority are women. At the UPS and DHO/CHO levels, most respondents aged 41-45 years, i.e., 28.3% and 75%, respectively, while at the UPS level, the majority aged 25-30 years (56.0%). For education level, PHC and UPS are dominated by Diploma 3 graduates, namely 86.7% and 80%, respectively, while in DHO/CHO, it is predominantly undergraduate graduates (75%) (Table 2)

Table 2. Characteristic respondent in three groups of respondents

Characteristic	**PHC (n= 113) n (%)**	**UPS (n=25) n (%)**	**DHO/CHO (n= 4) n (%)**
District/City			
Bantul	23 (20.4)	5 (20.0)	1 (25.0)
Gunungkidul	28 (24.8)	6 (24.0)	1 (25.0)
Yogyakarta	17 (15.0)	4 (16.0)	0 (0.0)
Kulonprogo	21 (18.6)	4 (16.0)	1 (25.0)
Sleman	24 (21.2)	6 (24.0)	1 (25.0)
Sex			
Male	3 (2.7)	0 (0.0)	2 (50.0)
Female	110 (97.3)	25 (100)	2 (50.0)
Age			
< 25	0 (0.0)	5 (20.0)	0 (0.0)
25-30	3 (2.7)	14 (56.0)	0 (0.0)
31-35	30 (26,5)	3 (12.0)	0 (0.0)
36-40	19 (16.8)	1 (4.0)	0 (0.0)
41-45	32 (28.3)	0 (0.0)	3 (75.0)
46-50	18 (15.9)	0 (0.0)	1 (25.0)
>50	11 (9.7)	2 (8.0)	0 (0.0)
Education			
Master	0 (0.0)	1 (4.0)	1 (25.0)
Bachelor	5 (4.4)	1 (4.0)	3 (75.0)
Diploma 4	9 (8.0)	2 (8.0)	0 (0.0)
Diploma 3	98 (86.7)	20 (80.0)	0 (0.0)
Senior high school	1 (0.9)	1 (4.0)	0 (0.0)

b. Qualitative study

Nine informants were recruited to provide the required information to explore deeper into the quantitative study results. They hold roles as managers and staff at DHO/CHO, PHC, and UPS. Among the nine informants, 2 were men, and 7 were women. Three informants graduated from masters, one bachelor's, and five diploma graduates (Table 3).

Table 3. Informants' characteristics for the qualitative study

Sex	Age (years)	Education	Position	Subject group	Informant's code
Female	56	Magister	Head of disease prevention and control department at PHO level	Managerial	M 01
Male	57	Magister	The former of disease prevention and control section at PHO level	Managerial	M 02
Male	54	Bachelor	Immunization programmer at PHO level	Managerial	M 03
Female	47	Magister	IT Person	Managerial	M 04
Female	34	Diploma	Data entry at the PHC level	Staff	S 01
Female	25	Diploma	Data entry at UPS level	Staff	S 02
Female	31	Diploma	Data entry at UPS level	Staff	S 03
Female	42	Diploma	Data entry at the PHC level	Staff	S 04
Female	24	Diploma	Data entry at the PHC level	Staff	S 05

c. Finding

Findings from the study are presented across the three core themes that emerged from the qualitative analysis, notably system strengths, potential threats, and opportunities shown in Figure 2. We present the qualitative and quantitative results together to increase the reliability and validity of the finding. The detailed quantitative study is presented in Table Supplement 1.

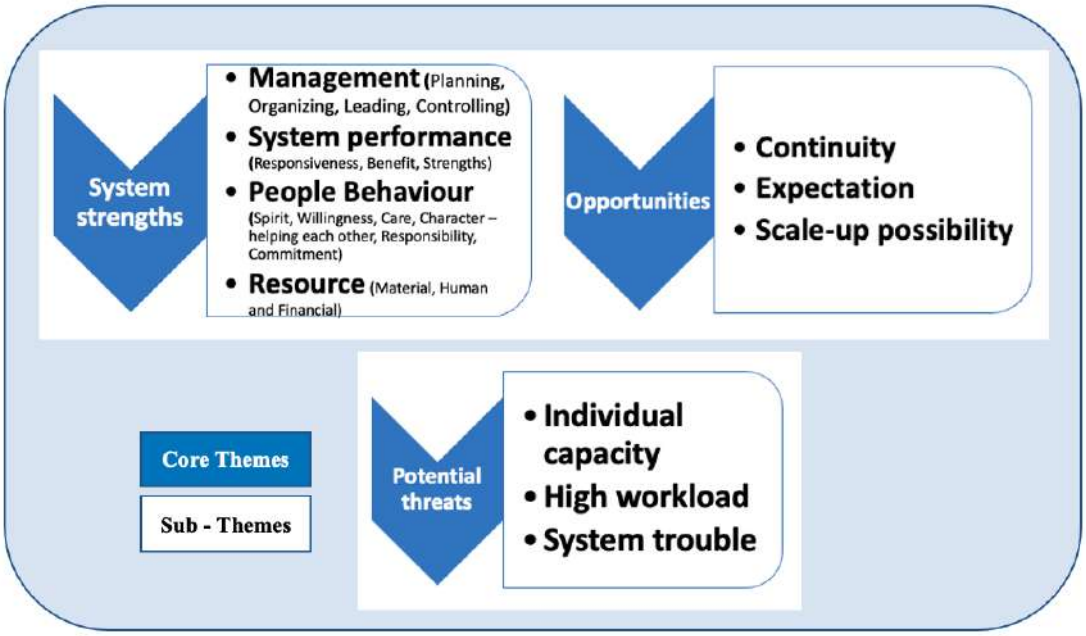

Figure 2. Strengths, potential threats, and opportunities for scale-up

System's Strengths

Factors contributing to the success of SIMUNDU include management, system performance, people's behavior, and resources.

Management

SIMUNDU arose due to concerns from the DIY health office immunization section around data quality, including inaccurate data, duplicate or missing data and lack of timely data, and the need to support follow-up and appropriate planning. SIMUNDU was designed to address these challenges and needs. Management factors relate to SIMUNDU development and all levels of the management chain (planning, organizing, leading, and controlling).

To our knowledge, [SIMUNDU development] started with a problem: estimates of the target population varied depending on the data source.

Yes, I think [SIMUNDU management team] started to tire of managing a large volume of data with dubious validity. They need to know the situation in each district.

Effective management of SIMUNDU from development to implementation has been highlighted as an essential determinant of its success. Here, we review its management across the critical functions of Planning, Organizing, Leading, and Controlling.

Careful Planning has been ensured at each stage of SIMUNDU development and implementation. These stages include an initial business plan, training on and socialization to SIMUNDU, and a staff replacement plan to respond to turnover or retirement of staff in charge of operating or entering data into SIMUNDU. The parties involved in planning included the head disease prevention and control department, IT personnel, and immunization program staff from the DIY health office.

Organizing - the organization of SIMUNDU is carried out at several levels. The top level is at the level of the DIY health office, the second level is at the district/city health office, and the third level is the level of the health facilities (Figure 2). A third party was also involved in developing the system interface.

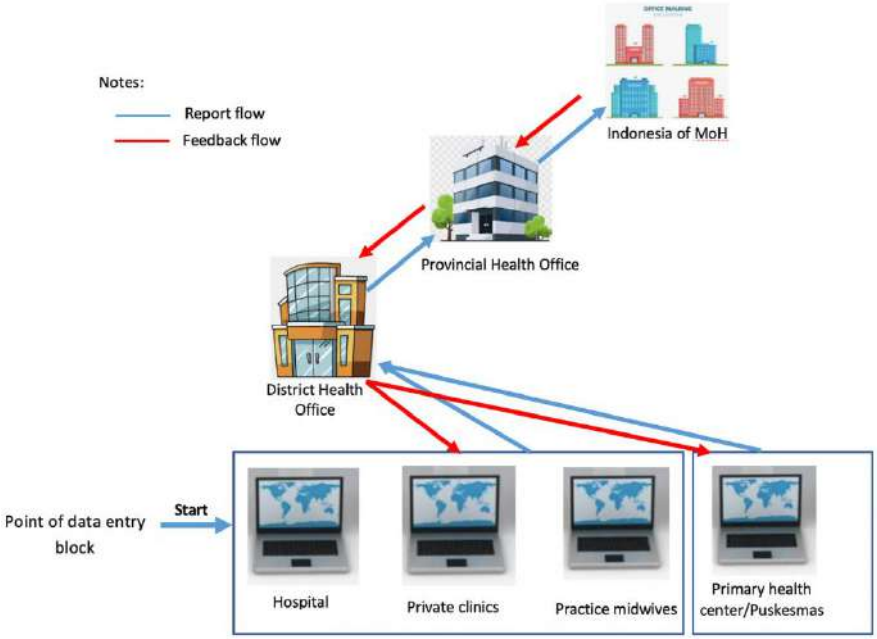

Figure 2. Visual organizing framework of SIMUNDU – DIY Province, Indonesia

At the beginning of SIMUNDU development, essential functions included database administrators, interface designers, and server administrators, and their interplay facilitated the smooth operation of the system. Training specific to SIMUNDU was integrated with other training, typically immunization-related training. This enabled to sharing of resources with other programs, thus ensuring viability. The training was delivered in the district/city health office: most of our respondents in PHC, UPS dan DHO/CHO stated they participated in this inhouse training with 87.6%, 72% and 75% - respectively. Training typically consisted of short training and included practice on the trainee's device and how to operate the system both in online and offline mode. Day-to-day operations were carried out autonomously by the staff, through adjusting their work to protect time to enter the data. Some informants reported that staff members divided tasks effectively to ensure work was carried out effectively.

Leading - the success of SIMUNDU implementation is arguably related to strong leadership. Informants noted that managers played a crucial role in bridging the immunization program with the system design, closely monitoring the initial implementation process, and creating an enabling environment.

I try to combine supporting and managing the people involved and monitoring them. Currently, I monitor whether [SIMUNDU] can run optimally as our users are health facilities. I also monitor program development and the system's output.

[SIMUNDU] was born from program managers, primary health centers, Districts, and DIY health offices wanting to build systems together. We – DIY health office - give them motivation in every meeting.

I see that [management] is very good at networking. Staff data entry in the field always said that these people are very kind.

The role of IT in developing SIMUNDU was also reported to be significant. They helped develop the system and supported correct data entry by assisting data entry operators who experienced technical issues or helping resolve inconsistencies in the data records. Acknowledgment of staff efforts was also an important lever to maintain motivation and buy-in.

In the early days of SIMUNDU's development, the system was challenging to operate, as it wasn't as stable as it is now. I praise the enthusiasm and dedication of the users).

Managing **quality assurance** was critical to avoid data duplication or missing entries. This process was not regulated by specific Standard Operating Procedures but was addressed during training and monitored monthly. In addition, the DIY health office provided negative incentives to health facilities that were not providing complete records and provided regular feedback from monitoring and evaluation exercises.

We found that 94.2%, 100%, and 100% of survey respondents in PHC, UPS, and DHO, respectively, reported their work had been monitored regarding SIMUNDU. More than half of the respondents in PHC and UPS facilities were observed at least once in 2019-2020. At the PHC level, more than 48.3% reported that staff from the district/city level conducted the monitoring, and 45.7% said that the DIY health office staff conducted monitoring. Furthermore, 40% of respondents from UPS facilities were monitored by PHC. Almost all survey respondents reported receiving feedback from the monitoring, mainly from the District/City and DIY health offices. Forty percent of respondents from UPS facilities reported receiving feedback from PHC. Immunization coordinators from the District/City health offices said that the DIY health office provided them with feedback.

In a [evaluation] meeting, DIY health office or district health office showed the progress of our data entry – correct or not, proper or not

Another resource that influences the successful implementation of SIMUNDU is the size of the DIY province. This province is quite a small geographic area. Because it consists of five districts and one city, this province is relatively easy to monitor across all phases, from planning through monitoring and evaluation.

System performance

While SIMUNDU predominantly contains individual-level immunization records, it also serves as a source for aggregation and can synergize with other information systems. Notably, SIMUNDU can link to the DHIS2 and generate immunization-specific reports per Ministry of Health requirements. These reports are sent to the upper levels directly if SIMUNDU is operated online or submitted via email if SIMUNDU is operated offline.

This functionality had an essential role in ensuring the acceptability and adoption of the system.

Informants noted how transitioning from paper-based tools to an electronic system made data entry easier and reduced errors. It also facilitated the implementation of protocols for data storage and security. It enabled follow-up and defaulter tracking. Finally, integration with the DHIS2 meant reduced workload for the staff.

We can do faster tracking of children who may have immunizations in different locations. For example, when the first dose of a vaccine is given in Bantul, the second immunization in Yogyakarta can be connected and detected with the SIMUNDU system.

Using SIMUNDU makes it easier to detect what data and immunizations are missing since we enter data from the children's birth through the end of the immunization schedule. So, we will know where they missed any vaccine.

The benefit of using SIMUNDU is first: we know the situation of immunizations more accurately….so we say that our predictions are real for planning for the future… So, our budget, staff, facilities can be more effective and efficient in providing services.

Colleagues from the mother and child health (KIA) program enter via the KIA "Sembada." So, this data will appear automatically in SIMUNDU because the two-system are connected.

SIMUNDU is user-friendly and can be flexibly operated offline or online, allowing the responsible staff to maintain data entry irrespective of connectivity. The percentage of using SIMUNDU online in PHC, UPS and DHO was 82.3%, 96% and 100%, respectively.

People behavior

The survey showed that staff commitment was critical for the successful implementation of SIMUNDU, as indicated by their willingness to work overtime and bring home the data to enter into the system.

I take it [the data] home too, for example, after immunization sessions– in my clinic, immunization runs four times per month, every week. So, when the session is finished, we can take it home, [and] do the entry at home while relaxing

Some determinants that facilitated the implementation of SIMUNDU were the societal culture of helping others and responsibility and commitment to the team. An enabling environment allowed people to view SIMUNDU as a shared responsibility and a collective endeavor. Informants also noted the high motivation of dedicated staff.

That's all; we cannot judge by money [people kindness, culture, and behavior]; it's essential to explain how good people are in Yogyakarta. I was in another place before, and I could not find people's kindness like in Yogyakarta - different characters.

The second thing is that we need human resources concerned and love with data; otherwise, even though we have a good system, it will amount to nothing without good human resources. But when people are concerned about data, good implementation will come more easily.

Other characteristics, such as the culture of helping others and responsibility and commitment to tasks, revealed from the interviews, were critical determinants in the successful implementation of SIMUNDU.

Resource: material, human and financial

Infrastructure and equipment emerged as critical factors to introducing and sustaining SIMUNDU implementation. Some desktops were specifically allocated to the immunization program, and some had to be shared with other programs' staff. Other data entry officers reported using laptops or personal smartphones. The survey found that in PHC, as much as 36.3% of data entry clerks used their laptops to enter data into SIMUNDU. In UPS facilities, nearly 40.7% reported using office PCs, and in the DHO, more than half of the respondents stated they used an office-supplied laptop. The majority of respondents said their current device was sufficient to perform their work on SIMUNDU. Regarding internet access, 64.6% of PHC staff and 67.7% of UPS staff reported using the office internet connection to enter data into SIMUNDU. However, 75% of DHO respondents reported no internet source.

Management of financial resources was also crucial. Key informant interviews revealed no special allocation of funds to SIMUNDU in the initial stages. Resources were leveraged by sharing activities such as monitoring visits or transportation with other programs, thus allowing cost efficiencies. Integration with other programs proved critical to ensuring sustainability.

SIMUNDU's budget comes from the state budget called as Anggaran Pendapatan dan Belanja Negara (APBN). Every year the APBN allocates funding envelop for immunization to DIY and other provinces, where the budget is apportioned across the program [not explicitly written for SIMUNDU]

Human resources are critical to the operation of SIMUNDU. According to respondents, SIMUNDU data entry clerks must have patience, work carefully and not rush, be interested in data, be responsible, and have basic computer skills such as Ms word and Ms excel. Our survey showed that most data entry clerks in PHC and UPS facilities had a diploma level of education (>80%), while at the managerial level (DHO), 75% of respondents had a bachelor's degree (Table 2). Our survey shows that 19.4% and 9.1% of respondents in PHC and UPS, respectively, had low computer literacy.

Various data entry clerks looked for strategies to resolve their obstacles to entering data to SIMUNDU. Among them, they increased their computer skills by taking private computer courses. In addition, some of them learned from other colleagues at their

offices. To deal with the accumulation of data needing to be entered in SIMUNDU, staff sometimes took data home for entry purposes because there is insufficient time during work hours since they have several other duties. If data entry clerks faced SIMUNDU trouble, informants said they asked for help from those who might have more information, for example, the district person in charge.

> *If we found obstacles, we asked people in charge in PHC – asking for a solution or sharing by WhatsApp – or sometimes I asked the IT person in the DIY health office.*

Potential threats

To date, SIMUNDU can be said to have had successful implementation. Several obstacles were encountered and addressed during implementation. The potential constraints on implementing SIMUNDU are individual capacity, technical or IT issues, and high workload.

Computer literacy of staff was identified as one of the main issues. Internet connectivity was another obstacle to implementation, as not a good network supported all health facilities equally. The survey shows that 64.6% and 67.7% of PHC and UPS staff used office internet, while others had to rely on their home internet.

Another issue that emerged was related to incomplete and inconsistent records; for example, the child's date of birth or name spelling not matching across different entries, making it difficult to have a unique and consistent record for each child. An example of this inconsistency of the child's date of birth or name spelling among different entries makes it challenging to record immunization information consistently. Even though these were temporary and were promptly resolved, these system failures were an issue for staff, who were already juggling a very tight schedule in the office, as they caused some delay. As shown by the survey, almost all respondents in PHC, UPS dan DHO stated that they have other responsibilities besides operating SIMUNDU; the percentages were 97.3%, 88% and 100% - respectively.

Opportunities

Informants said that SIMUNDU is a good system for immunization data. SIMUNDU has become necessary for program managers and policymakers because it facilitates monitoring coverage and informing planning and programming. Currently, SIMUNDU is stable, thus is easier to manage than when it was in the development phase. This means that the system is not as reliant on the core workforce that has been heavily involved since inception and will possibly accommodate changes in the workforce. The hopes expressed by data entry clerks are that SIMUNDU would be easier to operate, and system errors did not occur. In addition, informants revealed the need for refresher SIMUNDU training so that their understanding of SIMUNDU would not be lost.

In my opinion, SIMUNDU is the best program in DIY which is a collaboration between program managers and IT. It will continue to be implemented because it is a necessity. It has been stably used for more than five years, meaning this is needed.

If I have the tool, in this case, SIMUNDU, when it is stable, whoever will hold it, I am sure that anyone can operate it. It means that it doesn't matter if we have people shifting (jobs).

In the future, if SIMUNDU is still used, other reports are not necessary. Now we have two different reports: SIMUNDU and stock card of vaccine – each stand-alone and need a separate report.

Based on the informants' statements, SIMUNDU is likely to be developed broader. The DIY health office is open to any party learning and implementing SIMUNDU in their region. However, informants advised that SIMUNDU must have a strong commitment from the data entry staff and management sides. The leadership in DIY has shown willingness to assign staff to other provinces who have expressed interest in SIMUNDU for orientation to the system,

Discussion

Robust health information systems (HIS) are essential components of robust health systems (12). Having a timely Immunization Information System (IIS) that collects individual information and vaccine recipient's history to improve immunization services is essential to personalize vaccination information, communicate targeted information as a decision support system, and record vaccination hesitancy (13). Here, we provide evidence of how an immunization information system has been implemented in practice.

Sistem Informasi Imunisasi Terpadu (SIMUNDU) or Integrated Immunization Information System in the DIY province enabled the creation of individual immunization records for children. SIMUNDU allows users and managers to collect, store and analyze data on utilization of immunization services, including following up individual children and creating cohort data. Currently, DIY is the only province in Indonesia – out thirty-four - that uses an IIS. This work has shed light on the strengths and underlying barriers of implementing an IIS in this context. The objective of this study was to draw lessons that inform sustainable scale-up in other regions and possibly at the national level.

This study studied the potential factors that facilitate or pose a barrier to SIMUNDU implementation. Individual capacity, system trouble, and high workload were barriers to implementation. We identified management, system performance, people's behavior, and resources as determinants for SIMUNDU's strength that influenced implementation outcomes: the acceptability, implementation cost, and adoption of this innovation (14).

Despite several obstacles encountered during the implementation of SIMUNDU, we see that this innovation is well accepted by the stakeholders involved. The first stakeholder group is data entry clerks, who accept several aspects of SIMUNDU: data entry content,

ease of input to the system (not complex), and comfort using SIMUNDU compared to the previous system. The second stakeholder group is managers; they accepted this system well and felt there was a benefit in this innovation, namely the output in cohort data to help them monitor and improve immunization coverages.

Having an excellent managerial process – meaning proper planning, monitoring, and evaluation - is one reason SIMUNDU has survived and been viable for the last 5 years. Managers use their power to encourage the beliefs and actions of other people (15). This requires a dedicated and robust process for the whole of the management process cycle. SIMUNDU was born from the need for credible data at the DIY health office to assist in carrying out its duties at the managerial and operator levels. At the managerial level, the disease prevention and control department and the IT department collaborated to create a system readily accepted by users. Immunization and IT programmers played a central role from the beginning of the design throughout the implementation process with appropriate coordination and communication. Their ability to do so was facilitated by the full support of their respective superiors.

SIMUNDU is cost-effective in several ways. During the introductory period of SIMUNDU implementation, immunization programmers, IT officers, and other staff assisted in disseminating SIMUNDU to all existing districts. This was done side by side with other programs, making it cost and time-efficient for managers and staff. As mentioned, organizing activities is certainly not easy, but it can be carried out well, even sustainably, by sharing resources. Additionally, SIMUNDU maintenance does not require high costs because the DIY Health Office developed and maintained the system. Thus, the IT department can develop improvement processes and tailor them to user needs without additional cost. In addition, the location of affordable services (health facilities) is also part of cost-effectiveness.

A good program without good leadership could fail in its implementation, and even if it was initially successful, it might not be sustainable (16). In the context of SIMUNDU, support from leadership and the involvement of good people at managerial levels may have facilitated the program's adoption. The level of SIMUNDU uptake was good because all health facilities providing immunization services have successfully used this system, and it has been running well. The adoption of SIMUNDU was facilitated by the strong networks of the main person in charge of SIMUNDU. Communication, care, and attention to staff concerns positively affected staff performance. They feel well supported and are treated kindly – this means that they carry out their work joyfully. Several informants brought up this theme who stated that the person who played an essential role in SIMUNDU was the immunization program manager.

The monitoring and evaluation mechanisms of SIMUNDU were also important. Preferred monitoring and evaluation activities include monthly reports and direct discussion with staff during site monitoring visits. The immunization program manager suggested this approach to maintain data quality and system sustainability. These chosen

mechanisms allow program managers to know the actual conditions in the field and the obstacles faced to inform decisions about the follow-up actions that must be taken. This supports the ongoing development and learning of SIMUNDU as a tool for data collection, analysis, and visualization tool, provides benefits for managers to carry out monitoring and evaluation. The same point was stated by previous research in India about the innovation of health management information systems for primary health care agrees that this can provide essential benefits (17).

Human resources are determinants of health information system implementation (18). The people's behavior affects how the system works, develops, and survives (19),(20). In the case of SIMUNDU, implementation was facilitated by the caring character, networks, and meticulous attitude towards data of both the program manager and IT team. From the staff's point of view, the local culture of helping each other and doing their job correctly and responsibly is translated into staff that carries out their duties with enthusiasm and high commitment. Although facilities, funding and volume of human resources are limited, the people involved are highly motivated and supportive. Socio-cultural values, attitudes and beliefs held by staff have contributed to the successful implementation of SIMUNDU.

Despite the clear strengths of SIMUNDU, there are potential obstacles to its sustainability in the future. These obstacles can be divided into human variables and technical variables. From the human variables side, unequal individual capacities at the operator level can cause obstructions during data entry in the field. Another potential future obstacle is the staff's high workload because generally, they have to do other tasks besides SIMUNDU data entry. From the interview results, the data entry clerks have tried finding strategies to overcome this additional workload burden, such as doing data entry at home and overtime at the office. But from the health system perspective, if this is not anticipated and a strategy to address it is implemented, it may become unsustainable to expect staff to continue to do overtime. This will potentially interfere with the data's quality and overall harm SIMUNDUsustainability.

This study may have a limitation related to the survey data collection procedure, whereas we monitored the respondent response and asked them to fill the gap left. However, this step is taken to anticipate respondents dropping out due to incomplete answers due to someone's carelessness, which can impact the inaccuracy of the data we collect.

Conclusion and recommendation

From this study, we know that SIMUNDU is a promising immunization reporting system. In-depth interviews revealed the potential for scale-up of this program to other areas. Although obstacles exist, the benefits and strengths outweigh them. Our findings show that to maintain the continuity of SIMUNDU, some actions should be taken, such as providing regular training to the data entry clerks, as the system is constantly being updated. In addition, there is a need to layering the management structure to anticipate

staff rotation or retiring. Lastly, appropriate motivation, incentives, and support for data entry clerks must be ensured.

Despite resource constraints, it was still possible to run SIMUNDU. Initially, there was no special allocation funding for SIMUNDU, so the program ran side-by-side with other health programs in the DIY health office. This mechanism allowed cost-efficiency. There were three prominent persons in charge of developing SIMUNDU: 1) IT person responsible for system creation and maintenance, 2) the immunization program manager responsible for the strategic development of SIMUNDU, and 3) data entry clerks who are accountable for careful data entry into SIMUNDU. When seen from a facility perspective, SIMUNDU does not require expensive equipment – all that is needed is a computer or phone and internet access. An excellent managerial process that consists of planning, monitoring and evaluation and feedback influences the success of SIMUNDU to date from the DIY province. This required appropriate planning, organizing, leading, and controlling.

Three recommendations stemmed from this study, addressed to the DIY health office, the national government, and researchers. First, to guarantee continuity and sustainability and reduce the system's dependency on the particular person or party, SIMUNDU management and maintenance should be related to others with the competency and interest in a good reporting system. Furthermore, existing human resources should be strengthened in preparation for scaling up SIMUNDU in other regions or at a national level; this is necessary to avoid vacant positions when DIY province staff are seconded to requests for mentoring from other areas. Second, the bottom-up approach during SIMUNDU development and implementation positively impacts this system and makes it is feasible and viable to use. The approach to scaling up SIMUNDU should be stepwise, considering each region's specific characteristics and problems. Therefore, it is vital to develop a readiness map and a timeline for the roll-out of SIMUNDU in a particular region. Third, further research is needed on the impact of SIMUNDU on immunization coverage, for instance, through a before and after comparative study with a 2–3-year time window in a low-performing region.

Declarations

Ethics approval and consent to participate

This study was approved by the Ethical Review Board of Universitas Ahmad Dahlan, Yogyakarta, Indonesia (ethical approval code: 012005021). Before data collection began, consent to participate was obtained from research subjects (both survey and key informant interviews).

Adherence to national and international regulations

Not applicable

Consent for publication

Before data collection begins, approval that data is taken for publication purposes is obtained from research subjects (both surveys and key informant interviews).

Availability of data and materials

The datasets generated and or analyzed for this study can be requested to the corresponding author.

Competing interests

The authors declare that they have no competing interests

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Authors' contributions

SS, TAW, RR, ASDN and MF designed the study. SS, TWS, SKW, SAM collected the data. SS and RR conducted data analysis. SS developed the paper with inputs and comments from MF on each draft. All authors agree with the manuscript's results and conclusions.

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Authors' information:

The authors alone are responsible for the views expressed in this article. They do not necessarily represent the views, decisions, or policies of the institutions affiliated with them.

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I. DESK EVALUATION CHECKLIST

AIM: To review what is available to tackled objectives 1 to 3, and identify issues to be explored further through the survey or more in-depth through the interviews

	History of SIMUNDU development	**Source**
1	SIMUNDU goals	Report
2	Simundu initiation and the story	
3	People or stakeholder involved in the beginning	
4	The budget needed from the beginning until recently. How much, which slot was allocated	Report and documentation
5	The justification that SIMUNDU developed using internal funding	Report
	SIMUNDU resources requirement	
1	The guideline that exists for SIMUNDU operation at any level - Point of data entry - District health office - Provincial health office	Report
2	The computer or IT and power/ electricity requirement to operate SIMUNDU at any level	
3	The skill needed for staff that operates SIMUNDU at any level	
4	Rooms/building requirements for SIMUNDU at any level?	
	SIMUNDU implementation	
1	SIMUNDU training held from the beginning until current implementation since there was changing of the system at least 3 times: 1) Puskesmas as point data entry 2) Offline system all point data entry 3) Online system all point data entry	Report
2	The person in charge conducts SIMUNDU training	Report, documentation
3	Guideline for SIMUNDU training	
	Data quality aspect	
	Timelines	
1	The agreement of reports via SIMUNDU be reported to upper level every month, for every level	Report
2	Number and % of districts that submitted on time. Follow cohort time since implementation **OR** Number of point data entry delayed the report	Report and routine evaluation document
3	Which point of data entry has poor and good timelines?	
	Accuracy	
1	Is there any case of inaccurate data found during the implementation?	Report and routine evaluation document
2	Is there any irrelevant data between the report and the real data?	

3	The percentage (ratio) of data errors	
Completeness		
1	Number of variables should be entered in each level	Report and routine evaluation document
2	The number of missing or zero value	
3	Number and % of point of data entry < 90% **non-missing values**	
4	Number and % of point of data entry < 75% **non-missing values**	
5	In which variables usually missing occurred?	
6	Which point data entry major or frequent have missing values?	
Data duplication		
1	The number of duplication report occurred	Report and routine evaluation document
2	The number (percentage) of point data entry who did duplication data report and which point data entry	
3	The number of under report occurred.	
	The number (percentage) of point data entry who did under data report and which point data entry	
Accessibility		
1	SIMUNDU data availability, easily, quickly, retrievable	Observe SIMUNDU
2	Can users easily obtain and analyze the data?	
Managerial Process		
Planning		
1	Who is involved in the planning of SIMUNDU? What role?	Report and routine evaluation document
2	Assessment of the readiness for implementation? How, who? What aspect been assessed?	
3	Performance assessment among health facilities?	
Implementing		
1	Dissemination about SIMUNDU. When was it introduced? By whom? When? Where? How often	Report and routine evaluation document
2	The training when SIMUNDU was introduced. By whom? When? Where? How often	
Monitoring and Evaluation		
1	Who is responsible for monitoring and evaluation?	Report and routine evaluation document
2	How often?	
3	What aspect been monitored? For what purpose?	
4	Did the barrier found during implementation?	Routine evaluation document
5	System development and maintenance. Who, how?	Report and routine evaluation document

II. SURVEY INSTRUMENT for RESPONDENT IN POINT OF DATA ENTRY

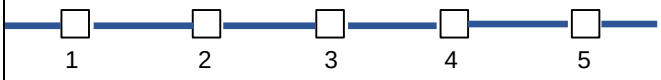
AIM: To gather more knowledge on the factors affecting data quality (obj.1), but also to illustrate how SIMUNDU was introduced and sustained (obj. 2 and 3).

Respondent: immunization coordinator and data entry staff in Puskesmas (PHC),clinic, hospital and midwives' practice.

A. Respondent identity		
1	Name	
2	Sex	☐ Male ☐ Female
3	Date of birth (Date/Month/Year)	
4	Age (years old)	
5	Role/ position (mention!)	
6	Education. Write your last degree!	
7	Name of health facility	
8	Address	
9	How many health facilities under the supervising of your office?	
10	Your phone number	
11	How far your office from your domicile?	_____ km _____ hour of travel
12	Who entered the immunization data into SIMUNDU	1. Myself 2. Others: Who? _____
13	How long have you been in the immunization program?	
14	Do you have other responsibilities/task beside in the immunization	☐ Yes ☐ No If you ✓ YES: How many _____ *(write number)* mention all the task is _____ _____

15	Do you ever participate in the SIMUNDU training/ BIMTEK?	☐ Yes ☐ No If you ✓ YES, state: When_____ Where_____ By whom_____ Did any guideline used on that training? _____
16	In your opinion, how is your computer skill	☐ Very poor ☐ Poor ☐ OK ☐ Good ☐ Very good In case you ✓ "very poor or poor," please answer this below questions: Have you ever communicate about your problem ☐ Yes ☐ No If you answer YES, explain with WHOM you communicate_____ What is the follow up to your complaint? _____ If your answer NO, explain why you do not communicate it_____
B. SIMUNDU timeliness		
1	When SIMUNDU reports should be submitted to your upper-level unit? (Date per Month)	
2	Have you been reporting SIMUNDU on time?	1. Yes 2. No Explain WHY to your answer?
3	Usually, when you input toddler's immunization data to SIMUNDU?	1. Every day 2. Every week 3. Every month

		4. Other (explain)
4	Do you find a barrier to providing the SIMUNDU report on time? Explain	
C. SIMUNDU accuracy		
1	Have you ever experienced that the data you reported did not match the actual data in the field?	☐ Yes ☐ No Write your explanation to your answer!
2	Have you ever verified the data that you enter to SIMUNDU with your immunization register?	☐ Yes ☐ No Write your explanation to your answer!
3	What do you do when facing that case?	
D. SIMUNDU completeness		
1	In your opinion, does the input variable to SIMUNDU is a lot?	☐ Yes ☐ No, Explain your answer
2	Which part of the SIMUNDU variable that usually you the error/missed to input? (Explain it and why it happens)	
3	In your opinion, does data completeness on SIMUNDU is essential.	☐ Yes ☐ No, Explain your answer
E. SIMUNDU accessibility		
Give your response to the statement below		

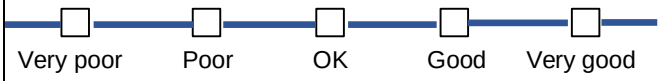
1	The SIMUNDU is easy to use	 Strongly disagree Strongly disagree.
2	Do you use SIMUNDU data for a specific purpose?	☐ Yes ☐ No, If you ✓ YES, what purpose is:
F. Data duplication		
1	Do you have experience with **under**-reporting on SIMUNDU?	☐ Yes ☐ No, Explain WHY to your answer!
2	Do you have experience in **over**-reporting on SIMUNDU?	☐ Yes ☐ No, Explain WHY to your answer!
3	Do you think under/over-reporting implies SIMUNDU?	☐ Yes ☐ No, Explain WHY to your answer!
G. SIMUNDU resources		
1	What type of computer that you used to SIMUNDU entry?	☐ PC ☐ Laptop
2	Is it an office facility or your own?	☐ Office facility ☐ Your own ☐ Other, explain_____
3	The specification of your PC or laptop? *Your answer in G1*	Need to be completed with minimum requirements according to IT's information and a desk review. We will add later.
4	Do you feel your current device supports your work on SIMUNDU?	☐ Yes ☐ No, Explain WHY to your answer!

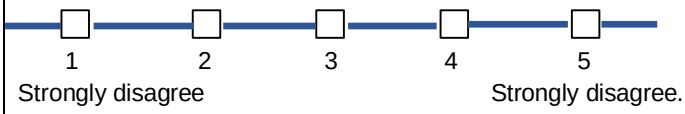
5	What is an internet source for SIMUNDU used?	☐ Office facility ☐ Mobile phone data package ☐ Other, explain_____ Do you think it supports your work on SIMUNDU? ☐ Yes ☐ No, Explain WHY to your answer!
6	What is the power source in your office?	☐ PLN (State company) ☐ Genset ☐ Other, explain_____ Do you have a problem related to the power source? ☐ Yes ☐ No, Explain WHY to your answer!
7	Do you have a room/table to do your job/task/responsibilities in your office?	☐ Yes ☐ No ☐ Other explain_____
8	In your opinion, on five scales. At what level of your report on time?	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 Very poor Very good
9	What is your barrier to performing SIMUNDU reporting seen from the facility aspect?	
10	What is your barrier to performing SIMUNDU reporting seen from yourself?	**Choose an option that relevant to you! You allow choosing more than one.** ☐ It is difficult to enter the data to SIMUNDU. ☐ I don't have time to enter the data to SIMUNDU. ☐ I have other tasks to do ☐ I do not have computer skill s.

		☐ I was never getting training on operating SIMUNDU. ☐ It is not essential to do ☐ Other, explain_____
H. Managerial process		
1	What is the goal of SIMUNDU implementation?	
2	Do you think, are you have sufficient skill to use SIMUNDU?	
3	Have you participated in the SIMUNDU dissemination?	☐ Yes ☐ No If you ✓ YES, answer the question below: Who did the dissemination_____ When it was held_____ Where it was held_____
4	Who is monitor your work on SIMUNDU?	
5	How often, SIMUNDU been evaluated?	_____ Who did the evaluation_____
6	Did you receive the feedback related to the result of the evaluation of immunization data that you enter on SIMUNDU?	☐ Yes ☐ No If you ✓ YES, answer next question: By whom_____
7	When you experience trouble with SIMUNDU, what do you do? Who are you contacting?	I did_____ I contacted_____

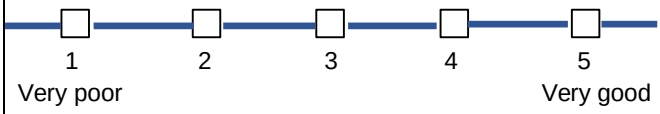
III. SURVEY INSTRUMENT for RESPONDENT at DHO/CHO and PHO

AIM: To gather more knowledge on the factors affecting data quality (obj.1), but also to illustrate how SIMUNDU was introduced and sustained (obj. 2 and 3). **Respondent:** DHO/CHO, PHO		
I. Respondent identity		
1	Name	
2	Sex	☐ Male ☐ Female
3	Date of birth (Date/Month/Year)	
4	Age (years old)	
5	Role/ position (mention!)	
6	Education. Write your last degree!	
7	Name of health facility	
8	Address	
9	How many health facilities under the supervising of your office?	
10	Your phone number	
11	How far your office from your domicile?	_____ km _____ hour of travel
12	What is your task related SIMUNDU?	
13	How long have you been in the immunization program?	
14	Do you have other responsibilities/task beside in the immunization	☐ Yes ☐ No If you ✓ YES: How many _____ *(write number)* mention all the task is _____ _____
15	Do you ever participate in the SIMUNDU training/ BIMTEK?	☐ Yes ☐ No If you ✓ YES, state: When_____ Where_____

		By whom_____ Did any guideline used on that training? _____
16	In your opinion, how is your computer skill	 Very poor Poor OK Good Very good In case you ✓ "very poor or poor," please answer this below questions: Have you ever communicate about your problem ☐ Yes ☐ No If you answer YES, explain with WHOM you communicate_____ What is the follow up to your complaint? _____ If your answer NO, explain why you do not communicate it_____
A. SIMUNDU timeliness		
1	When SIMUNDU reports should be submitted to your upper-level unit? (Date per Month)	
2	Have you been reporting SIMUNDU on time?	☐ Yes ☐ No Explain WHY to your answer?
3	Do you find a barrier to providing the SIMUNDU report on time? Explain	
B. SIMUNDU accuracy		
1	Have you ever experienced that the data you reported	☐ Yes ☐ No Write your explanation to your answer!

	did not match the actual data in the field?	
2	What do you do when facing that case?	
	C. SIMUNDU completeness	
1	Which part of the SIMUNDU variable that usually you the error/missed to input? (Explain it and why it happens)	
2	In your opinion, does data completeness on SIMUNDU is essential.	☐ Yes ☐ No, Explain your answer
	D. SIMUNDU accessibility	
Give your response to the statement below		
1	The SIMUNDU is easy to use	
2	Do you use SIMUNDU data for a specific purpose?	☐ Yes ☐ No, If you ✓ YES, what purpose is:
	E. Data duplication	
1	Do you have experience with **under**-reporting on SIMUNDU?	☐ Yes ☐ No, Explain WHY to your answer!
2	Do you have experience in **over**-reporting on SIMUNDU?	☐ Yes ☐ No, Explain WHY to your answer!
3	Do you think under/over-reporting implies SIMUNDU?	☐ Yes ☐ No, Explain WHY to your answer!

	F. SIMUNDU resources	
1	What type of computer that you used to SIMUNDU entry?	☐ PC ☐ Laptop
2	Is it an office facility or your own?	☐ Office facility ☐ Your own ☐ Other, explain_____
3	The specification of your PC or laptop? *Your answer in G1*	Need to be completed with minimum requirements according to IT's information and a desk review. We will add later.
4	Do you feel your current device supports your work on SIMUNDU?	☐ Yes ☐ No, Explain WHY to your answer!
5	What is an internet source for SIMUNDU used?	☐ Office facility ☐ Mobile phone data package ☐ Other, explain_____ Do you think it supports your work on SIMUNDU? ☐ Yes ☐ No, Explain WHY to your answer!
6	What is the power source in your office?	☐ PLN (State company) ☐ Genset ☐ Other, explain_____ Do you have a problem related to the power source? ☐ Yes ☐ No, Explain WHY to your answer!
7	Do you have a room/table to do your job/task/responsibilities in your office?	☐ Yes ☐ No ☐ Other explain_____

8	In your opinion, on five scales. At what level of your report on time?	
9	What is your barrier to performing SIMUNDU reporting seen from the facility aspect?	
10	What is your barrier to performing SIMUNDU reporting seen from yourself?	**Choose an option that relevant to you! You allow choosing more than one.** ☐ It is difficult to enter the data to SIMUNDU. ☐ I don't have time to enter the data to SIMUNDU. ☐ I have other tasks to do ☐ I do not have computer skills ☐ I was never getting training on operating SIMUNDU. ☐ It is not essential to do ☐ Other, explain_____
	G. Managerial process	
1	What is the goal of SIMUNDU implementation?	
2	Do you think, are you have sufficient skill to use SIMUNDU?	
3	Have you participated in the SIMUNDU dissemination?	☐ Yes ☐ No If you ✓ YES, answer the question below: Who did the dissemination_____ When it was held_____ Where it was held_____
4	Who is monitor your work on SIMUNDU?	
5	Do you analyze data from SIMUNDU?	☐ Yes ☐ No If you ✓ YES, answer the question below:

		For what purpose? _____
6	How often, SIMUNDU been evaluated?	_____ Who did the evaluation_____
7	Did you receive the feedback related to the result of the evaluation of immunization data that you enter on SIMUNDU?	☐ Yes ☐ No If you ✓ YES, answer next question: By whom_____
8	When you experience trouble with SIMUNDU, what do you do? Who are you contacting?	I did_____ I contacted_____

IV. KEY INFORMANT INTERVIEW GUIDELINE	
AIM: To elucidate the factors identified in the previous steps and also tell the successful story of SIMUNDU implementation from its introduction and throughout the 5 years of implementation**.**	
Proposed Key Informant: Note: *The key informants will be identified after the quantitative phase ben analyzed* *The interview will be stopped when saturation has been reached.*	
The head of the provincial health office	1) What is the goal of SIMUNDU development? 2) From which slot the funding is taken? 3) How has the government seen the sustainability of SIMUNDU? How to reach sustainability? 4) How useful is SIMUNDU? 5) What is the barrier during the SIMUNDU implementation?
The head of district/city health office	1) What is your opinion about SIMUNDU? 2) Is it useful for you and your district? For what purpose? 3) How you use this system? 4) Do you think SIMUNDU is essential to keep? Why?
Immunization coordinator in provincial, district/city HO	1) What is your opinion about SIMUNDU? 2) Is it useful for you and your district? For what purpose? Explain

	3) How you use this system? Explain. 4) Do you think SIMUNDU is essential to keep? Why? Explain
IT department in PHO	1) Tell me about the history of SIMUNDU? 2) Do you think that this system already stable? 3) What aspect should be improved? 4) What aspect is lacking? 5) What is your suggestion to maintain SIMUNDU sustainability?
Hospital Private clinic Midwives practice Posyandu PHC in rural and urban	1) Do you think you have sufficient capacity to use SIMUNDU? 2) What barrier that you found on using SIMUNDU? 3) How you solved this 4) What aspect should be improved? 5) What aspect is lacking?

Table 1. Respondent response during the survey

Questions	PHC (n= 113) n (%)	UPS (n=25) n (%)	DHO/CHO (n= 4) n (%)
Among the two systems – Offline and Online – which one do you prefer?			
ONLINE	93 (82.3)	24 (96.0)	4 (100)
OFFLINE	20 (17,7)	1 (4.0)	0 (0.0)
Do you carry out any other work/duties besides SIMUNDU?			
No	3 (2,7)	3 (12.0)	0 (0.0)
Yes	110 (97,3)	22 (88.0)	4 (100)
Who is the main person in charge of doing data entry to SIMUNDU in your office?			
Myself	96 (85.0)	18 (72.0)	3 (75.0)
Other	17 (15.0)	7 (28.0)	1 (25.0)
How long have you been in charge of entering immunization data using SIMUNDU?			*
<1 year	8 (7.1)	5 (20.0)	
1-2 year	7 (6.2)	15 (60.0)	
2-3 year	16 (14.2)	1 (4.0)	
3-4 year	17 (15.0)	1 (4.0)	
>4 year	65 (57.5)	3 (12.0)	
How long have you been in charge of managing SIMUNDU?	*	*	
<1 year			1 (25.0)
1-2 year			0 (0.0)
2-3 year			0 (0.0)
3-4 year			0 (0.0)
>4 year			3 (75.0)
23. Of the several items below, which ones you can operate to support work at SIMUNDU?			
Excel spreadsheet			
Extract file	61 (23.6)	14 (32.6)	1 (20.0)
Export-import file	42 (16.3)	4 (9.3)	1 (20.0)
Email/browsing	58 (22.5)	6 (14.0)	1 (20.0)
Other	92 (35.7)	18 (41.9)	2 (40.0)
Respondent allows selecting more than one response.	5 (1.9)	1 (2.3)	0 (0.0)
Barrier perception			
Have you ever had difficulty operating SIMUNDU?			
Yes	93 (82.3)	16 (64.0)	2 (50.0)
No	20 (17.7)	9 (36.0)	2 (50.0)
When experienced with difficulties in operating SIMUNDU, with whom you discuss to ask solutions?			
Puskesmas / PHC			
District health office	17 (9.6)	13 (56.6)	0 (0.0)
DIY health office	73 (41.0)	6 (26.1)	0 (0.0)
Other (staff in other health facilities)	66 (37.1)	2 (8.7)	2 (100)
Respondent allows selecting more than one response.	22 (12.4)	2 (8.7)	0 (0.0)

Are you satisfied with the follow-up taken from the results of the consultation?			
No	1 (1.1)	0 (0.0)	0 (0.0)
Yes	92 (98.9)	16 (100)	4 (100)
Report Timeliness			
In SIMUNDU OFFLINE that has been running so far, have you sent the report according to the specified date?			
No	17 (15.0)	4 (16.0)	1 (25.0)
Yes	87 (77.0)	21 (84.0)	3 (75.0)
I'm operating SIMUNDU online.	9 (8.0)	0	0 (0.0)
On the SIMUNDU OFFLINE. Did you experience any obstacles in the SIMUNDU data entry on time?			*
No	67 (59.3)	16 (64.0)	
Yes	46 (40.7)	9 (36.0)	
On the SIMUNDU OFFLINE. Did you have any obstacles in reporting SIMUNDU data on time?			*
Difficulties on the export file	10 (17.2)	4 (36.4)	
Difficulties on email or sending files	13 (22.4)	0	
Difficulties in the extracted file	9 (15.5)	2 (18.2)	
Other	26 (44.8)	5 (45.5)	
Pada SIMUNDU ONLINE, when do you input your baby/toddler data into SIMUNDU			*
The same day after the service is finished	37 (25.7)	4 (16.0)	
<1 week after service	50 (34.7)	10 (40.0)	
One week - 1 month after service	48 (33.3)	10 (40.0)	
> 1 month after service	9 (6.3)	1 (4.0)	
In the ONLINE system, do you have any obstacles in entering data in SIMUNDU timely?			*
No	52 (46.0)	14 (56.0)	
Yes	61 (54.0)	11 (44.0)	
In OFFLINE systems – in 5 scales. How many do you assess the timeliness of the reports you have provided so far?			
1	0 (0.0)	1 (4.0)	0
2	3 (2.7)	1 (4.0)	0
3	36 (31.9)	9 (36.0)	0
4	60 (53.1)	12 (48.0)	3 (75.0)
5	14 (12.4)	1 (8.0)	1 (25.0)
Data Accuracy			
Have you ever found the data entered at SIMUNDU to be different from the data in the immunization service register?			*
No	29 (25.7)	14 (56.0)	
Yes	84 (74.3)	11 (44.0)	
Data verification			
Have you ever verified the data between the data in SIMUNDU and the data in the immunization service register?			*
No	5 (4.4)	8 (32.0)	

Yes	108 (95.6)	17 (68.0)	
When is data verification done?			*
Monthly	42 (38.9)	10 (58.8)	
Bimonthly	4 (3.7)	2 (11.8)	
Three months	23 (21.3)	1 (5.9)	
Semester	17 (15.7)	1 (5.9)	
Other	22 (20.4)	3 (17.6)	
Data completeness			
According to you, are there a lot of menus/items to input into SIMUNDU?			*
No	51 (45.1)	18 (72.0)	
Yes	62 (54.9)	7 (28.0)	
In your opinion, is the completeness of the menu/item entries in SIMUNDU important?			*
No	1 (0.9)	2 (8.0)	
Yes	112 (99.1)	23 (92.0)	
SIMUNDU accessibility			
Do you agree with the statement that "SIMUNDU is easy to operate?			
Agree	108 (95.6)	23 (92.0)	4 (100)
Disagree	5 (4.4)	2 (8.0)	0 (0.0)
Did you analyse the SIMUNDU data?		*	
No	26 (23.0)		0 (0.0)
Yes	88 (77.0)		(4)100)
Over/Under reporting			
Do you have any experience finding data on children/babies in the Immunization Service Register that are not reported to SIMUNDU?			
No	36 (31.9)	13 (52.0)	0 (0.0)
Yes	77 (68.1)	12 (48.0)	4 (100)
Do you have the experience of finding children data in the Immunization Service Register that entry with more than one?			
No	38 (33.6)	15 (60.0)	1 (25.0)
Yes	75 (66.4)	10 (40.0)	3 (75.0)
According to you, does under or over-reporting have an impact on the achievements of the immunization program?			
No	5 (4.4)	1 (4.0)	1 (25.0)
Yes	108 (95.6)	24 (96.0)	3 (75.0)
Facility and infrastructure			
What type of computer do you most use to enter data in SIMUNDU?			
Private laptop	41 (36.3)	4 (14.8)	1 (25.0)
Laptop – office facility	38 (33.6)	4 (14.8)	2 (50.0)
PC – office facility	32 (28.3)	11 (40.7)	1 (25.0)
PC - private	0	0 (0.0)	0 (0.0)
Handphone	0	7 (25.9)	0 (0.0)
Other	2 (1.8)	1 (3.7)	0 (0.0)
Does your current computer/handphone/laptop support your work on operating SIMUNDU?			
No	11 (9.7)	0 (0.0)	1 (25.0)
Yes	102 (90.3)	25 (100)	3 (75.0)

Where are your internet sources from?			
None	0 (0.0)	0 (0.0)	3 (75.0)
Office facility (Wifi)	102 (64.6)	21 (67.7)	1 (25.0)
Data packages pay with their own money	48 (30.4)	9 (29.0)	0
Data packages paid by the office	1 (0.6)	0	0
Other	7 (4.4)	1 (3.2)	0
Respondent allows selecting more than one response			
Is the internet facility that you use, suit your needs for data entry SIMUNDU?			
No	18 (15.9)	2 (8.0)	1 (25.0)
Yes	95 (84.1)	23 (92.0)	3 (75.0)
Where is the source of your electricity?			
PLN	114 (80.9)	25 (80.6)	4 (100)
Genset	27 (19.1)	6 (19.4)	0
None	0	0	0
Other	0	0	0
Respondent allows selecting more than one response.			
Do you have any problems with electricity during SIMUNDU entry?			
No	78 (69.0)	24 (96.0)	4 (100)
Yes	35 (31.0)	1 (4.0)	0
From your side, what are the obstacles in SIMUNDU reporting?			
It is difficult for data entry at SIMUNDU	7 (3.7)	2 (6.1)	0
Do not have time	18 (9.4)	7 (21.2)	1 (20.0)
Have another assignment	95 (49.7)	16 (48.5)	2 (40.0)
My computer skill is poor	37 (19.4)	3 (9.1)	0
Never received SIMUNDU training	11 (5.8)	2 (6.1)	1 (20.0)
Other	23 (12.0)	3 (9.1)	1 (20.0)
Respondent allows selecting more than one response			
Managerial Process			
Do you know the purpose of SIMUNDU development in DIY?			
No	18 (15.9)	6 (24.0)	0
Yes	95 (84.1)	19 (76.0)	4 (100)
Have you ever participated in SIMUNDU in house training?			
No	14 (12.4)	7 (28.0)	1 (25.0)
Yes	99 (87.6)	18 (72.0)	3 (75.0)
When did you last take part in the SIMUNDU in house training?			
< 1 year ago	42 (42.4)	11 (61.1)	0
> 1 year ago	57 (57.6)	7 (38.9)	2 (100)
Which institution conducts SIMUNDU in house training, that you ever attended?			
Puskesmas (PHC)	0 (0.0)	2 (8.0)	0
District/City health office	56 (38.9)	15 (60.0)	0
DIY health office	88 (61.1)	7 (28.0)	0
Other	0 (0.0)	1 (4.0)	2 (100)
Respondent allows selecting more than one response			
What training guides are used during training?			
PPT	80 (49.1)	12 (56.1)	2 (50.0)

Word – hard copy	32 (19.6)	2 (9.5)	1 (25.0)
Word - soft file	36 (22.1)	2 (9.5)	1 (25.0)
Other	15 (9.2)	5 (23.8)	0
Have you ever been monitored and evaluated regarding SIMUNDU?			
No	10 (8.8)	6 (24.0)	0
Yes	103 (91.2)	19 (76.0)	4 (100)
In the last year (July 2019-July 2020), how many times monitoring and evaluation been conducted?			
>2 times	17 (16.5)	2 (10.5)	2 (50.0)
One time	57 (55.3)	11 (57.9)	1 (25.0)
1-2 times	29 (28.2)	6 (31.6)	1 (25.0)
Who did monitor and evaluation SIMUNDU on your place?			
Puskesmas (PHC)	11 (7.0)	11 (39.3)	0
District/City health office	81 (51.3)	8 (28.6)	0
DIY health office	65 (41.1)	8 (28.6)	4 (100)
Other	1 (0.6)	2 (3.6)	0
Respondent allows selecting more than one response			
Did you receive any feedback on the results of the SIMUNDU monitoring and evaluation?			
No	6 (5.8)	0 (0.0)	0
Yes	97 (94.2)	19 (100)	4 (100)
Who gave feedback on the M&E results?			
Puskesmas (PHC)	7 (4.6)	10 (40.0)	0
District/City health office	73 (48.3)	8 (32.0)	0
DIY health office	69 (45.7)	6 (24.0)	4 (100)
Other	2 (1.3)	1 (4.0)	0
Respondent allows selecting more than one response			
In the last year ((July 2019 - July 2020), have you ever monitored the health facility under your supervision?	*	*	
Yes			4 (100)
No			0
Have you ever participated in the dissemination of M&E results as well as updating knowledge?			
No	28 (24.8)	16 (64.0)	0
Yes	85 (75.2)	9 (36.0)	4 (100)
Who is organizing the dissemination of M&E results as well as updating the knowledge?			
Puskesmas (PHC)	3 (2.5)	0 (0.0)	0
District/City health office	53 (44.2)	6 (60.0)	1 (25.0)
DIY health office	63 (52.5)	4 (40.0)	3 (75.0)
Other	1 (0.8)	0 (0.0)	0
Respondent allows selecting more than one response			

*data not applicable

BMC Health Services Research

Introducing and implementing an immunization information system in Indonesia province of Daerah Istimewa Yogyakarta: lessons for scale-up

--Manuscript Draft--

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Abstract:	Background : Immunization is undeniable as a critical aspect to safe children from any infections. To increase the coverage of immunization, valid and real-time data is needed. Accordingly, having a good report system is essential that rolled as defaulter tracking to prevent the children's immunization failure. DIY health office develops an individual electronic immunization registry and succeeds implemented it for more than five years. It is the only individual-based record system in Indonesia that has survived for such a long time. To date, there is no systematic assessment of this system. Therefore, this research aimed to examine SIMUNDU's introduction and implementation process to draw lessons that could inform scalability and sustainability across the country. Methods : An explanatory sequential mixed-method design was used in this study by involving 142 and 9 participants quantitative and qualitative study - respectively. Entry data clerk in all level of health facility was systematically selected to participate in the survey. While in the key informant interview, the informant was selected based on the survey result. The descriptive and thematic approach was employed to analyze the quantitative and qualitative data – respectively. Integration between the two approaches was accomplished in the interpretation of the result by comparison and contrast. Results : Three core themes emerged from our analysis that describes the SIMUNDU success journey as an electronic immunization registry: system strengths, potential threats and opportunities. Conclusions : The individual electronic immunization registry has been implemented well and it may contribute to increasing immunization coverage in DIY. Stakeholders should consider the sustainability of this system by providing related resources and consider scale-up nationally by looking at this promising program.
Corresponding Author:	Sulistyawati Sulistyawati, PhD Ahmad Dahlan University: Universitas Ahmad Dahlan Yogyakarta, Yogyakarta INDONESIA
Corresponding Author E-Mail:	sulistyawati.suyanto@ikm.uad.ac.id
Corresponding Author Secondary Information:	
Corresponding Author's Institution:	Ahmad Dahlan University: Universitas Ahmad Dahlan
Corresponding Author's Secondary Institution:	
First Author:	Sulistyawati Sulistyawati, PhD
First Author Secondary Information:	
Order of Authors:	Sulistyawati Sulistyawati, PhD Trisno Agung Wibowo, MPH Rokhmayanti Rokhmayanti, MPH Andri Setyo Dwi Nugroho, MPH Tri Wahyuni Sukesi, PhD

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eachIntroducing and implementing an immunization information system in Indonesia province of Daerah Istimewa Yogyakarta: lessons for scale-up

Sulistyawati Sulistyawati, MPH, PhD[1*]
Trisno Agung Wibowo, MPH[2]
Rokhmayanti Rokhmayanti, MPH[1]
Andri Setyo Dwi Nugroho, MPH[2]
Tri Wahyuni Sukesi, MPH, PhD[1]
Siti Kurnia Widi Hastuti, MPH[1]
Surahma Asti Mulasari, MPH, PhD[1]
Marta Feletto, PhD[3]

[1] Faculty of Public Health, Universitas Ahmad Dahlan, Yogyakarta, Indonesia
[2] Daerah Istimewa Yogyakarta (DIY) Health Office, Yogyakarta, Indonesia
[3] Alliance for Health Policy and Systems Research, World Health Organization, Geneva, Switzerland

*Corresponding author: sulistyawati.suyanto@ikm.uad.ac.id.
Kampus 3 - Jl. Prof Dr Soepomo, Janturan, Umbulharjo, Yogyakarta, Indonesia.

Abstract

Background: Immunization is undeniable as a critical aspect of safe children from infections. To increase the coverage of immunization, valid and real-time data is needed. Accordingly, having a good report system is essential that rolled as defaulter tracking to prevent the children's immunization failure. DIY health office developed an individual electronic immunization registry and successfully implemented it for more than five years. It is the only individual-based record system in Indonesia that has survived for such a long time. To date, there is no systematic assessment of this system. Therefore, this research aimed to examine SIMUNDU's introduction and implementation process to draw lessons that could inform scalability and sustainability across the country.

Methods: An explanatory sequential mixed-method design was used in this study by involving 142 and 9 participants quantitative and qualitative study - respectively. Entry data clerk in all level of health facility was systematically selected to participate in the survey. While in the key informant interview, the informant was selected based on the survey result. The descriptive and thematic approach was employed to analyze the quantitative and qualitative data. Integration between the two approaches was accomplished in the interpretation of the result by comparison and contrast.

Results: Three core themes emerged from our analysis that describes the SIMUNDU success journey as an electronic immunization registry: system strengths, potential threats and opportunities.

Conclusions: The individual electronic immunization registry has been implemented well, and it may contribute to increase immunization coverage in DIY. Stakeholders should consider the sustainability of this system by providing related resources and consider scale-up nationally by looking at this promising program.

Keywords: immunization, electronic immunization registry, immunization information system, interoperability, implementation research

Background

Neonatal and childhood vaccination is an essential component of infectious disease prevention and an absolute human right (1),(2). Vaccination has been proven to reduce the burden of infectious disease globally (3). According to the WHO, in 2020 estimated 23 million children under one year of age did not receive their essential vaccinations. Of these, 60% live in just ten countries, one of which is Indonesia (4). Indonesia is the fourth most populous country globally. It is composed of thousands of islands organized into 34 provinces. Various geographical and cultural factors influence population inequalities to access to health services (5). In 2001, the Indonesian government's decentralization policy was enacted. This was an excellent strategy to foster development by engaging regional resources (6). However, this strategy was not without consequence. One major concern is the fragmentation of the Health Information System (HIS).

Indonesia's federal structure results in provinces and districts being relatively independent of the national Ministry of Health. This means that information systems at provincial and district levels are locally regulated (7). For instance, *Pemantauan Wilayah Setempat* (PWS) is a management tool used to monitor coverage of specific health services in an administrative boundary. It can be paper- or electronic-based, depending on the service and region. PWS-KIA is the monitoring system specific to maternal and child health (KIA), including immunization. Data recorded in the PWS-KIA are reported to the District or City Health Office, which reports to the Province Health Office, which transmits the data to the central level through simple emails if reporting is done in excel, or through various information systems including Komdat, SiTT, SIHA, PISPK, SIKDA Generik. In some provinces only, PWS-KIA data feeds into the DHIS2. Regional information systems have varying data quality, which reflects inequities in resources across regions. This adds to data integration challenges at the national level (7),(8) and affects strategic policymaking.

In the context of Indonesia's federal system, Daerah Istimewa Yogyakarta (DIY) Province has the authority to regulate and use its budget within its four districts (Sleman, Gunungkidul, Bantul, Kulonprogo) and Yogyakarta city. Regarding childhood vaccination, DIY is among the top ten performing provinces in the country, with 97.7 % complete basic immunization coverage in 2019 (9). Immunization services are provided by Primary Health Centres (*Puskesmas*), as well as private clinics, hospitals, and midwives' practices (typically referred to as *Unit Pelayanan Swasta* (UPS).

In 2014, the DIY Health Office introduced an electronic immunization registry named SIMUNDU (*Sistem Informasi Imunisasi Terpadu*/ Integrated Immunization Information System). An electronic immunization registry is a tool for recording individual children's immunization histories. An electronic registry serves essential functions at all levels of the health system. The service delivery level can facilitate individual follow-up of vaccination status and enable health workers to identify children due for vaccination and those who missed their vaccinations (defaulters). At the district and higher levels, it allows for monitoring vaccination coverage by the vaccine, dose, cohort, and other variables – and can support microplanning and vaccine management.

SIMUNDU was designed to link with the PWS-KIA for immunization and interoperability with the DHIS2. While it predominantly contains individual-level immunization records, SIMUNDU also serves as a source for aggregation and can synergize with the *Pemantauan Wilayah Setempat* (PWS) reporting system. For this reason, it can be considered an Immunization Information System (IIS). This means that data from City and District levels feed into Provincial and National levels *(Personal communication with DIY immunization program officer).*

The original prototype was designed by the information and technology (IT) department of DIY Health Office to be operated offline. In DIY, three out of the four districts and the city introduced the system in 2015. The final district introduced it in 2017. At this stage, the point of data entry was the Puskesmas only. By 2018, UPS facilities were also equipped with SIMUNDU and could enter data into the system. In 2019, the prototype was further developed to operate online. The online version was rolled out in 2020 (Figure 1). As of May 2021, 79.4% of all Puskesmas and UPS facilities were complying. This average rate masks, however, the fact that while all PHCs adopt SIMUNDU, it is more challenging to enforce its use in UPC facilities (Suyani 2020, oral communication, 2020 May 11)

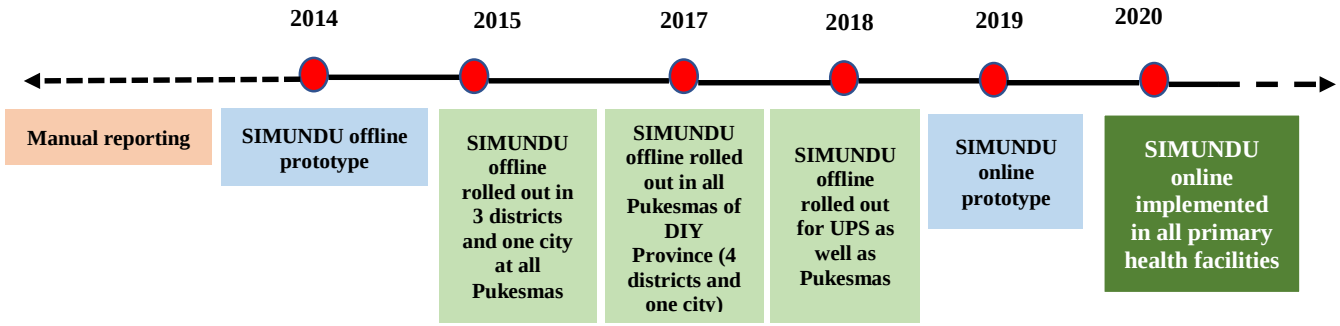

Figure 1. SIMUNDU's development and introduction

When a child receives a vaccination in a health facility, information on the child and the vaccination is entered in SIMUNDU as an individual child record. Each record includes an individual identifier, child's socio-demographic characteristics (e.g., name, gender, date of birth, name of parents, address), the antigen administered, and the date and place of vaccination. SIMUNDU has been recently updated to allow recording of vaccinations administered in schools (e.g., Human papillomavirus (HPV), Difteri Toxoid (DT), Tetanus Difteri (TD), and Measles-Rubella (MR)) – at this stage, only in aggregate form. Furthermore, SIMUNDU is being developed to record COVID-19 vaccinations in health facilities and those carried out in masse.

Monitoring is conducted every month to assess data completeness across health facilities, while an evaluation is conducted every year. These exercises have allowed the identification of several challenges related to implementing the system (e.g., workload, staff turnover, and rotation) and data quality (e.g., accuracy and timeliness). However, no systematic assessment of the system has been conducted to date.

SIMUNDU is the first immunization information system ever introduced in Indonesia. Other districts and provinces have shown interest in rolling it out, and the Ministry of Health has acknowledged the innovation. The objective of this work was to examine SIMUNDU's introduction and implementation process to draw lessons that could inform scalability and sustainability across the country.

Methods

From May to October 2020, we examined the experience of introducing and implementing an immunization information system in the DIY province using a sequential mixed-method design, where each step informed the next (10). First, we conducted a desk review of all relevant documentation available in the DIY health office – e.g., staff notes, meeting notes and monitoring notes – documenting SIMUNDU development and management processes. We also examined online documents, including health profiles and regulations on health reporting systems in Indonesia. This served as the initial source of data and provided an overview of who was involved and their role in developing and implementing SIMUNDU. This informed the survey design that we conducted as a second step. The survey was conducted with staff responsible for entering data in SIMUNDU across Puskesmas and UPS facilities and staff responsible for managing the system at the district and city level. Sampling and recruitment strategies are outlined in Table 1.

Table 1. Survey sampling

Level of the data entry and reporting system	Total number of facilities/ offices	Study population	Sampling strategy	Recruitment	Sample size
Puskesmas/Primary Health Centre (PHC)	121	Immunization coordinator and data entry clerk	All facilities	Open invitation across all facilities	115
Hospital (Central, General, Maternity and Pediatric)	65	Immunization coordinator and data entry clerk	Randomly selected 2 facilities per district/city (2*5=10)	Open invitation across selected facilities	8
Clinic	73	Immunization coordinator and data entry clerk	Randomly selected 2 facilities per district/city (2*5=10)	Open invitation across selected facilities	7
Midwives' Practice	271	Immunization coordinator and data entry clerk	Randomly selected 2 facilities per district/city (2*5=10)	Open invitation across selected facilities	110
District/City Health Office	5	Immunization coordinator	Total sampling	Open invitation	6*
			Total		**146**

*As the immunization coordinator had recently changed, the former was also invited.

All immunization coordinators and data entry clerks from all primary health facilities and the District/City Health Office were invited to participate in this survey. For UPS facilities, we randomly selected two clinics, two midwives' practices, and two hospitals per district and city and invited all of their staff involved in SIMUNDU data entry and management.

We developed and pre-tested an online survey in Bahasa Indonesia to inquire about SIMUNDU implementation, processes, and outcomes (*Sup.1*). All participants provided consent to participate in the survey. All participants were invited to the DIY health office to fill out the survey on their laptops. Having all participants in a room allowed researchers to monitor potential gaps in responses in real-time and follow-up with individual participants on-site to fill any gaps. Data were then exported into and analyzed in Microsoft Excel.

Next, we conducted key informant interviews to explore the challenges of implementing the system both from a practice and managerial standpoint. Each interview was conducted by three researchers with a different role: main interviewer, observer, and field note taker. SS, RR, TWS, SKW, and SAM were involved in the interviews. All of them were female with a public health background and worked as lecturers and researchers at university. An interview guide was developed by the research group and was consulted with the expert prior used for the interview. The interview takes approximately 30 minutes.

Informants were purposefully selected among survey participants to follow up on the range of perspectives that had emerged from the survey. As informed by the desk review, others were chosen for their management functions. The informant and interviewer did not know each other prior to the interview. Informants were invited to Province Health Office for interview purposes due to COVID-19 pandemic reasons. Before the interview, the informant was informed about the study and asked to sign the informed consent. All invited informants agreed to participate. A total of nine key informants were interviewed in Bahasa Indonesia language. The face-to-face interviews were recorded with consent from the informants. After the interview, the interviewer summarized our field notes to the informant for correction.

Thematic analysis was conducted using Quirkos qualitative tool following Braun and Clarke's approaches (11). Researchers familiarized themselves with the data, searching for initial codes and allowing themes to emerge. SS was the main coder during the analysis. Then the result of the coding reviewed together among the research group continued with defining and naming the core themes, analyzed the data for each of the core themes, triangulated information from the desk review, the survey, and the interviews. Themes were generated from the data during the analysis.

Results

Findings from the study are presented across the three core themes that emerged from the analysis, notably system strengths, potential threats, and opportunities, drawing from the qualitative and quantitative data collected (Figure 2).

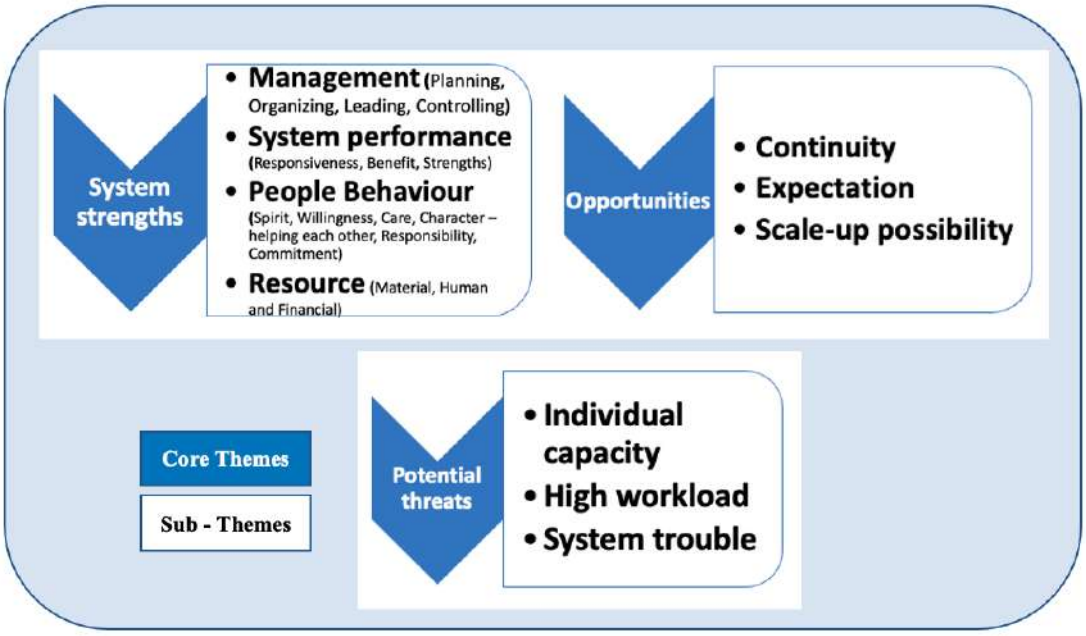

Figure 2. Strengths, potential threats, and opportunities for scale-up

System's Strengths

Factors contributing to the success of SIMUNDU include management, system performance, people's behavior, and resources.

Management

Management factors relate to SIMUNDU development and all levels of the management chain (**planning, organizing, leading, and controlling**). SIMUNDU arose due to concerns from the DIY health office immunization section around data quality, including inaccurate data, duplicate or missing data and lack of timely data, and the need to support follow-up and appropriate planning. SIMUNDU was designed to address these challenges and needs.

To our knowledge, [SIMUNDU development] started with a problem: estimates of the target population varied depending on the data source.

Yes, I think [SIMUNDU management team] started to tire of managing a large volume of data with dubious validity. They need to know the situation in each district.

Effective management of SIMUNDU from development to implementation has been highlighted as an essential determinant of its success. Here, we review its management across the critical functions of Planning, Organizing, Leading, and Controlling.

Careful Planning has been ensured at each stage of SIMUNDU development and implementation. These stages include an initial business plan, training on and socialization to SIMUNDU, and a staff replacement plan to respond to turnover or retirement of staff in charge of operating or entering data into SIMUNDU. The parties involved in planning included the head disease prevention and control department, IT personnel, and immunization program staff from the DIY health office.

Organizing - the organization of SIMUNDU is carried out at several levels. The top-level is at the level of the DIY health office, the second level is at the district/city health office, and the third level is the level of the health facilities (figure 2). A third party was also involved in developing the system interface.

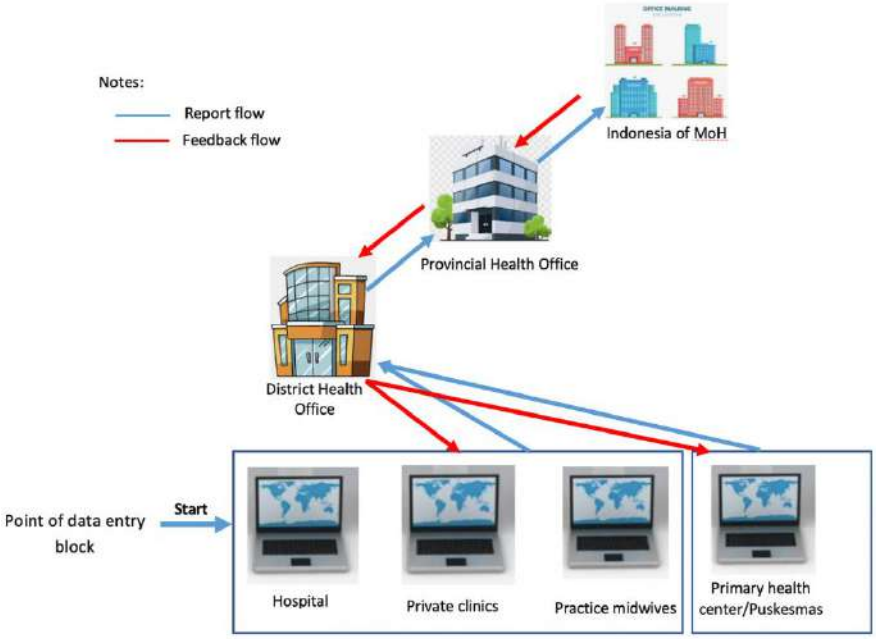

Figure 2. Visual organizing framework of SIMUNDU – DIY Province, Indonesia

At the beginning of SIMUNDU development, essential functions included database administrators, interface designers, and server administrators, and their interplay facilitated the smooth operation of the system. Training specific to SIMUNDU was integrated with other training, typically immunization-related training. This enabled to sharing of resources with other programs, thus ensuring viability. The training was delivered in the district/city health office: 70% of survey respondents indicated they had benefited. Training typically consisted of short training and included practice on the trainee's device and how to operate the system both in online and offline mode. Day-to-day operations were carried out autonomously by the staff, through adjusting their work

to protect time to enter the data. Some informants reported that staff members divided tasks effectively to ensure work was carried out effectively.

Leading - the success of SIMUNDU implementation is arguably related to strong leadership. Informants noted that managers played a key role in bridging the immunization program with the system design, closely monitoring the initial implementation process, and creating an enabling environment.

I try to combine supporting and managing the people involved and monitoring them. Currently, I monitor whether [SIMUNDU] can run optimally as our users are health facilities. I also monitor program development and the system's output.

[SIMUNDU] was born from program managers, primary health centers, Districts, and DIY health offices wanting to build systems together. We – DIY health office - give them motivation in every meeting.

I see that [management] is very good at networking. Staff data entry in the field always said that these people are very kind.

The role of IT in developing SIMUNDU was also reported to be significant. They helped develop the system and supported correct data entry by assisting data entry operators who experienced technical issues or helping resolve inconsistencies in the data records. Acknowledgment of staff efforts was also an important lever to maintain motivation and buy-in.

In the early days of SIMUNDU's development, the system was challenging to operate, as it wasn't as stable as it is now. I praise the enthusiasm and dedication of the users).

Managing **quality assurance** was critical to avoid data duplication or missing entries. This process was not regulated by specific Standard Operating Procedures but was addressed during training and monitored monthly. In addition, the DIY health office provided negative incentives to health facilities that were not providing complete records and provided regular feedback from monitoring and evaluation exercises.

We found that 90%, 76%, and 100% of survey respondents in PHC, UPS, and DHO, respectively, reported their work had been monitored regarding SIMUNDU. More than half of the respondents in Puskesmas and UPS facilities were observed at least once in 2019. At the PHC level, more than 50% reported that staff from the district/city level conducted the monitoring, and >40% reported that the DIY health office staff conducted monitoring. Furthermore, almost 40% of respondents from UPS facilities were monitored by Puskesmas. Nearly 100% of survey respondents stated they received feedback from the monitoring, mainly from the District/City and DIY health offices. Forty percent of respondents from UPS facilities reported receiving feedback from Puskesmas. Immunization coordinators from the District/City health offices reported that the DIY health office provided them with feedback.

In a [evaluation] meeting, DIY health office or district health office showed the progress of our data entry – correct or not, proper or not

Another resource that influences the successful implementation of SIMUNDU is the size of the DIY province. This province is quite a small geographic area. Because it consists of five districts and one city, this province is relatively easy to monitor across all phases, from planning through monitoring and evaluation.

System performance

While SIMUNDU predominantly contains individual-level immunization records, it also serves as a source for aggregation and can synergize with other information systems. Notably, SIMUNDU can link to the DHIS2 and generate immunization-specific reports as per Ministry of Health requirements. These reports are sent to the upper levels directly if SIMUNDU is operated online or submitted via email if SIMUNDU is operated offline. This functionality had an essential role in ensuring the acceptability and adoption of the system.

Informants noted how transitioning from paper-based tools to an electronic system made data entry easier and reduced errors. It also facilitated the implementation of protocols for data storage and security. It facilitated follow-up and defaulter tracking. Finally, integration with the DHIS2 meant reduced workload for the staff.

We can do faster tracking of children who may have immunizations in different locations. For example, when the first dose of a vaccine is given in Bantul, then the second immunization in Yogyakarta can be connected and detected with the SIMUNDU system.

Using SIMUNDU makes it easier to detect what data and immunizations are missing since we enter data from the children's birth through the end of the immunization schedule. So, we will know where they missed any vaccine.

The benefit of using SIMUNDU is first: we know the situation of immunizations more accurately….so, we say that our predictions are real for planning for the future… So, our budget, staff, facilities can be more effective and efficient in providing services.

Colleagues from the mother and child health (KIA) program enter via the KIA "Sembada." So, this data will appear automatically in SIMUNDU because the two-system are connected.

SIMUNDU is user-friendly and can be flexibly operated offline or online, allowing the responsible staff to maintain data entry irrespective of connectivity. More than 80% of survey respondents indicated they use the online version of SIMUNDU, and less than 20% of them operate the system offline.

People behavior

The survey showed that staff commitment was critical for the successful implementation of SIMUNDU, as indicated by their willingness to work overtime and bring home the data to enter into the system.

I take it [the data] home too, for example, after immunization sessions– in my clinic, immunization runs four times per month, every week. So, when the session is finished, we can take it home, [and] do the entry at home while relaxing

Some determinants that facilitated the implementation of SIMUNDU were the societal culture of helping others and responsibility and commitment to the team. An enabling environment helped people view SIMUNDU as a shared responsibility and a collective endeavor. Informants also noted the high motivation of dedicated staff.

That's all; we cannot judge by money [people kindness, culture, and behavior]; it's essential to explain how good people are in Yogyakarta. I was in another place before, and I could not find people's kindness like in Yogyakarta - different characters.

The second thing is that we need human resources who are concerned and love with data; otherwise, even though we have a good system, it will amount to nothing without good human resources. But when people are concerned about data, good implementation will come more easily.

Other characteristics, such as the culture of helping others and responsibility and commitment to tasks, revealed from the interviews, were critical determinants in the successful implementation of SIMUNDU.

Resource: human, financial, and material resources

Infrastructure and equipment emerged as critical factors to introducing and sustaining SIMUNDU implementation. Some desktops were specifically allocated to the immunization program, and some had to be shared with other programs' staff. Other data entry officers reported using laptops or personal smartphones. The survey found that in Puskesmass, almost 40% of data entry clerks used their private laptops to enter data into SIMUNDU. In UPS facilities, nearly 41% reported using office-supplied PCs, and in the DHO, more than half of the respondents stated they used an office-supplied laptop. The majority of respondents reported their current device was sufficient to perform their work on SIMUNDU. Regarding internet access, more than 60% of PHC and UPS staff reported using the office internet connection to enter data into SIMUNDU. However, 75% of DHO respondents reported no internet source found during SIMUNDU monitoring.

Management of financial resources was also crucial. Key informant interviews revealed no special allocation of funds to SIMUNDU in the initial stages. Resources were leveraged by sharing activities such as monitoring visits or transportation with other

programs, thus allowing cost efficiencies. Integration with other programs proved critical to ensuring sustainability.

SIMUNDU's budget comes from the state budget called as Anggaran Pendapatan dan Belanja Negara (APBN). Every year the APBN allocates funding envelop for immunization to DIY and other provinces, where the budget is apportioned across the program [not explicitly written for SIMUNDU]

Human resources are critical to the operation of SIMUNDU. According to respondents, SIMUNDU data entry clerks must have patience, work carefully and not rush, be interested in data, be responsible, and have basic computer skills such as Ms word and Ms excel. Our survey showed that most data entry clerks in PHC and UPS facilities had a diploma level of education (>80%), while at the managerial level (DHO), 75% of respondents had a bachelor's degree, suggesting that they have good computer literacy. Our survey shows that less than 20% and 9% of respondents in PHC and UPS, respectively, had low computer literacy.

Various data entry clerks looked for strategies to resolve their obstacles to entering data to SIMUNDU. Among them, they increased their computer skills by taking private computer courses. In addition, some of them learned from other colleagues at their offices. To deal with the accumulation of data needing to be entered in SIMUNDU, staff sometimes took data home for entry purposes because there is insufficient time during work hours since they have several other duties. If data entry clerks faced SIMUNDU trouble, informants said they asked for help from those who might have more information, for example, the district person in charge.

If we found obstacles, we asked people in charge in PHC – asking for a solution or sharing by WhatsApp – or sometimes I asked the IT person in the DIY health office.

Potential threats

The potential constraints on implementing SIMUNDU are individual capacity, technical or IT issues, and high workload. To date, SIMUNDU can be said to have had successful implementation. But it does not mean there were no obstacles faced. However, the important thing is how these obstacles were dealt with.

Computer literacy of staff was identified as one of the main issues. Internet connectivity was another obstacle to implementation, as not a good network supported all health facilities equally. As shown by the survey, only about 60% of Puskesmas and UPS staff used office internet, while others had to rely on their home internet.

Another issue that emerged was related to incomplete and inconsistent records; for example, the child's date of birth or name spelling not matching across different entries, making it difficult to have a unique and consistent record for each child. During the development stage, the system interface had to be incrementally finetuned, and some system failures made it challenging to enter the data. Even though these were temporary

and were promptly resolved, these system failures were an issue for staff, who were already juggling a very tight schedule in the office, as they caused some delay. As shown by the survey, for more than 97% of respondents, entering data in SIMUNDU was not their only responsibility or function – they also had other tasks.

Opportunities

Informants said that SIMUNDU is a good system for immunization data. SIMUNDU has become necessary for program managers and policymakers because it facilitates monitoring coverage and informing planning and programming. Currently, SIMUNDU is stable, thus is easier to manage than when it was in the development phase. This means that the system is not as reliant on the core workforce that has been heavily involved since inception and will possibly accommodate changes in the workforce. The hopes expressed by data entry clerks are that SIMUNDU would be easier to operate, and system errors did not occur. In addition, informants revealed the need for refresher SIMUNDU training so that their understanding of SIMUNDU would not be lost.

In my opinion, SIMUNDU is the best program in DIY which is a collaboration between program managers and IT. It will continue to be implemented because it is a necessity. It has been stably used for more than five years, meaning this is needed.

If I have the tool, in this case, SIMUNDU, when it is stable, whoever will hold it, I am sure that anyone can operate it. It means that it doesn't matter if we have people shifting (jobs).

In the future, if SIMUNDU is still used, other reports are not necessary. Now we have two different reports: SIMUNDU and stock card of vaccine – each stand-alone and need a separate report.

Based on the informants' statements, SIMUNDU is likely to be developed on a broader scale. The DIY health office is open to any party learning and implementing SIMUNDU in their region. However, informants advised that SIMUNDU must have a strong commitment from the data entry staff and management sides. The leadership in DIY has shown willingness to assign staff to other provinces who have expressed interest in SIMUNDU for orientation to the system,

Discussion

Robust health information systems (HIS) are essential components of strong health systems (12). Having a timely Immunization Information System (IIS) that collects individual information and vaccine recipient's history to improve immunization services is essential to personalize vaccination information, communicate targeted information as a decision support system, and record vaccination hesitancy (13). Here, we provide evidence of how an immunization information system has been implemented in practice.

Sistem Informasi Imunisasi Terpadu (SIMUNDU) or Integrated Immunization Information System in the DIY province enabled the creation of individual immunization records for children. SIMUNDU allows users and managers to collect, store and analyze data on utilization of immunization services, including following up individual children and creating cohort data. Currently, DIY is the only province in Indonesia – out thirty-four - that uses an IIS. This work has shed light on the strengths and underlying barriers of implementing an IIS in this context. The objective was to draw lessons that inform sustainable scale-up in other regions and possibly at the national level.

This study studied the potential factors that facilitate or pose a barrier to SIMUNDU implementation. We identified management, system performance, people's behavior, and resources as determinants for SIMUNDU's strength that influenced implementation outcomes: the acceptability, implementation cost, and adoption of this innovation (14). Individual capacity, system trouble, and high workload were barriers to implementation.

Despite several obstacles encountered during the implementation of SIMUNDU, we see that this innovation is well accepted by the stakeholders involved. The first stakeholder group is data entry clerks, who accept several aspects of SIMUNDU: data entry content, ease of input to the system (not complex), and comfort using SIMUNDU compared to the previous system. The second stakeholder group is managers; they accepted this system well and felt there was a benefit in this innovation, namely the output in cohort data to help them monitor and improve immunization coverages.

Having an excellent managerial process – meaning proper planning, monitoring, and evaluation - is one reason SIMUNDU has survived and been viable for the last 5 years. Managers use their power to encourage the beliefs and actions of other people (15). This requires a dedicated and robust process for the whole of the management process cycle. SIMUNDU was born from the need for credible data at the DIY health office to assist in carrying out its duties at the managerial and operator levels. At the managerial level, the disease prevention and control department and the IT department collaborated to create a system readily accepted by users. Immunization and IT programmers played a central role from the beginning of the design throughout the implementation process with appropriate coordination and communication. Their ability to do so was facilitated by the full support of their respective superiors.

SIMUNDU is cost-effective in several ways. During the introductory period of SIMUNDU implementation, immunization programmers, IT officers, and other staff assisted in disseminating SIMUNDU to all existing districts. This was done side by side with other programs, making it cost and time-efficient for managers and staff. As mentioned, organizing activities is certainly not easy, but it can be carried out well, even sustainably, by sharing resources. Additionally, SIMUNDU maintenance does not require high costs because the DIY Health Office developed and maintained the system. Thus, the IT department can develop improvement processes and tailor them to user needs

without additional cost. In addition, the location of affordable services (health facilities) is also part of cost-effectiveness.

A good program without good leadership could fail in its implementation, and even if it was initially successful, it might not be sustainable (16). In the context of SIMUNDU, support from leadership and the involvement of good people at managerial levels may have facilitated the program's adoption. The level of SIMUNDU uptake was good because all health facilities providing immunization services have successfully used this system, and it has been running well. The adoption of SIMUNDU was facilitated by the strong networks of the main person in charge of SIMUNDU. Communication, care, and attention to staff concerns positively affected staff performance. They feel well supported and are treated kindly – this means that they carry out their work joyfully. Several informants brought up this theme who stated that the person who played an essential role in SIMUNDU was the immunization program manager.

The monitoring and evaluation mechanisms of SIMUNDU were also important. Preferred monitoring and evaluation activities include monthly reports and direct discussion with staff during site monitoring visits. The immunization program manager suggested this approach to maintain data quality and system sustainability. These chosen mechanisms allow program managers to know the real conditions in the field and the obstacles faced to inform decisions about the follow-up actions that must be taken. This supports the ongoing development and learning of SIMUNDU as a tool for data collection, analysis, and visualization tool, provides benefits for managers to carry out monitoring and evaluation. The same point was stated by previous research in India about the innovation of health management information systems for primary health care agrees that this can provide essential benefits (17).

Human resources are determinants of the success of health information system implementation (18). The people's behavior affects how the system works, develops, and survives (19),(20). In the case of SIMUNDU, implementation was facilitated by the caring character, networks, and meticulous attitude towards data of both the program manager and IT team. From the staff's point of view, the local culture of helping each other and doing their job correctly and responsibly is translated into staff that carries out their duties with enthusiasm and high commitment. Although facilities, funding and volume of human resources are limited, the people involved are highly motivated and supportive. Socio-cultural values, attitudes and beliefs held by staff have contributed to the successful implementation of SIMUNDU.

Despite the clear strengths of SIMUNDU, there are potential obstacles to its sustainability in the future. These obstacles can be divided into human variables and technical variables. From the human variables side, unequal individual capacities at the operator level can cause obstructions during data entry in the field. Another potential future obstacle is the staff's high workload because generally, they have to do other tasks besides SIMUNDU data entry. From the interview results, the data entry clerks have tried finding strategies

to overcome this additional workload burden, such as doing data entry at home and overtime at the office. But from the health system perspective, if this is not anticipated and a strategy to address it is implemented, it may become unsustainable to expect staff to continue to do overtime. This will potentially interfere with the data's quality and overall harm SIMUNDUsustainability.

From this study, we know that SIMUNDU is a promising immunization reporting system. Although obstacles exist, the benefits and strengths outweigh them. In-depth interviews revealed the potential for scale-up of this program to other areas. Our findings show that to maintain the continuity of SIMUNDU, some actions should be taken, such as providing regular training to the data entry clerks, as the system is constantly being updated. In addition, there is a need to layering the management structure to anticipate staff rotation or retiring. Lastly, appropriate motivation, incentive, and support for data entry clerks need to be ensured.

Conclusions

SIMUNDU was developed in 2014 by the DIY health office. It was introduced in 2015 across the province and has been successfully implemented. However, there was no systematic evaluation of the data collected to date's accuracy, completeness, and timeliness. The benefit of SIMUNDU can be seen from the outputs generated, such as the cohort data that allows the immunization staff to track and observe each child's immunization progress, which may contribute to the increase in immunization coverage in this region.

Despite resource constraints, it was still possible to run SIMUNDU. Initially, there was no special allocation funding for SIMUNDU, so the program ran side-by-side with other health programs in the DIY health office. This mechanism allowed cost-efficiency. There were three prominent persons in charge of developing SIMUNDU: 1) IT person responsible for system creation and maintenance, 2) the immunization program manager responsible for the strategic development of SIMUNDU, and 3) data entry clerks who are accountable for careful data entry into SIMUNDU. When seen from a facility perspective, SIMUNDU does not require expensive equipment – all that is needed is a computer or phone and internet access. The fair managerial process influenced the success of SIMUNDU to date from the DIY province. This required appropriate planning, organizing, leading, and controlling.

Three recommendations stemmed from this study, addressed to the DIY health office, the national government, and researchers. First, to guarantee continuity and sustainability and reduce the system's dependency on the particular person or party, SIMUNDU management and maintenance should be related to others with the competency and interest in a good reporting system. Furthermore, existing human resources should be strengthened in preparation for scaling up SIMUNDU in other regions or at a national level; this is necessary to avoid vacant positions when DIY province staff are seconded

to requests for mentoring from other areas. Second, the bottom-up approach to developing and implementing SIMUNDU has shown that the system is feasible and viable. The approach to scaling up SIMUNDU should be stepwise, considering each region's specific characteristics and problems. Therefore, it is vital to develop a readiness map and a timeline for the roll-out of SIMUNDU in a particular region. Third, further research is needed on the impact of SIMUNDU on immunization coverage, for instance, through a before and after comparative study with a 2–3-year time window in a low-performing region.

Declarations

Ethics approval and consent to participate

This study was approved by the Ethical Review Board of Universitas Ahmad Dahlan, Yogyakarta, Indonesia (ethical approval code: 012005021). Before data collection began, consent to participate was obtained from research subjects (both survey and key informant interviews).

Adherence to national and international regulations

Not applicable

Consent for publication

Before data collection begins, an approval that data is taken for publication purposes is obtained from research subjects (both surveys and key informant interviews).

Availability of data and materials

The datasets generated and/or analyzed for this study can be requested to the corresponding author.

Competing interests

The authors declare that they have no competing interests

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Authors' contributions

SS, TAW, RR, ASDN and MF designed the study. SS, TWS, SKW, SAM collected the data. SS and RR conducted data analysis. SS developed the paper with inputs and comments from MF on each draft. All authors agree with the manuscript's results and conclusions.

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Authors' information:

The authors alone are responsible for the views expressed in this article. They do not necessarily represent the views, decisions, or policies of the institutions affiliated with them.

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Revisi 2

Reviewer 1

Dear Reviewer 1, thank you very much for your excellent comments and inputs to this manuscript; we appreciate it. Our response to all your comments and input is presented in the table below.

Reviewer 1: Overall Comments: This article makes and important contribution by highlighting the transition and use of digital data systems in tracking childhood immunization in Indonesia. The authors provided a strong description of the system's rollout, enabling factors, challenges, and opportunities. The article could be strengthened by providing additional information from the survey to support the quotes presented. Also, the article would benefit from having short (1 paragraph) limitations and recommendations sections. (The last paragraph of the conclusion is well done and could be expanded for a recommendation section)	Study limitation has been added on Page 16 Line 1, and we have improved the link between conclusions and recommendations.
Abstract: Line 31 "To increase the coverage of immunization, valid and real-time data is needed. Accordingly, having a good report system is essential that rolled as defaulter tracking to prevent the children's immunization failure" Please reword this sentence, as it is difficult to understand the meaning of the word "rolled".	*The sentence has been reworded to improve readability and understanding.* *See abstract, page 1, line 24*
Line 40: Reword to: An explanatory sequential mixed-method design was used in this study which collected quantitative data from 142 participants and quantitative data from 9 participants.	Thank you for your input; the correction can be found in the methods section of the abstract – Page 1, line ??
Background: Pg 2 Line 22: Add "the" before provincial	Thank you for your correction. We made the chance, see page 2, line 33
Pg 2 Line 44: Changes to "with 97.7% of children completing basic immunization coverage in 2019"	Thank you for your correction. We made the chance, see page 2, line 43
Methods: Overall: Note the procedures that were used for transcription and translation of qualitative data (if not conducted in and analyzed in the same language). For quantitative data collection, was the survey	Thank you for your input. We improved clarity and added information on the transcription and translation process in the method section – Page 5.
* Pg 5 Line 12: The text states "All participants were invited to the DIY health office * to fill out the survey on their laptops. Having all participants in a room allowed * researchers to monitor potential gaps in responses in real-time and follow-up with *individual participants on-site to fill any gaps."	We have addressed this point in the methods session, page 5, line 15

It is important to note the potential for bias that this method introduces into the data collection - monitoring the answering of questions and asking participants to fill in gaps left. This can be noted in the discussion section or in limitations.	
* Pg 5 line 25: Was the interview guide semi-structured? Did the researchers ask probing questions (not on the interview guide) depending on the answers?	Yes, we used a semi-structured interview that allowed the interviewer to probe questions. This information has been added to Page 5.
* Add a few sentences/paragraphs on limitations of the study	Study limitation has been added on Page 16
Results: Overall: The data and information presented appears to rely heavily on the 9 qualitative interviews. The section refers very little the answers from the survey.	Thank you for flagging that findings from the survey seem under-represented in the results section. We have worked through this section to better highlight the contribution of survey data.
If possible, add more of the survey data into the results section, and attribute the information to the survey.	We have worked through the results section to better highlight the contribution of survey data, and attribute each finding to its source (either interviews or surveys).
Additionally, ensure that data is presented fully instead of rounding off the point estimates and writing "more than or less than 50%. Instead, state the true % - example 52.3%.	All percentages have been changed to the true %
Change the highlights/red text so it is consistent for each sub section of the results.	All red highlight has been changed to make it consistent all sections
* Pg 9 line 52 (and elsewhere where survey data is presented)" Present the quantitative results fully - instead of saying "More than 80% of survey respondents", give the actual statistic (for example 81.2%).	All percentages have been changed to the true %
* Pg 11 line 42-44: reword: A number of obstacles were encountered and addressed during implementation.	We have reworded as suggested. See page 13, line 4
* Pg 11 line 53: replace ";" with "." After the first sentence. Then change sentence two to read: "An example of this inconsistency of child's date of birth or name spelling among different entries, making it difficult to consistently record immunization information.	We have reworded the sentence based on the suggestion. See page 13, lines 11
Discussion: Overall, gives a good overview of the results and opportunities, however, it can be difficult to follow at points. * Pg 15 lin 45: Reword: "The fair managerial	We have made an additional effort to improve clarity and readability throughout the manuscript. We have also addressed the specific point you are flagging at page 16, line 13 – clarifying

process influenced the success of SIMUNDU to date from the DIY province." What does "the fair managerial process mean? Please reword or explain this better	that we are meaning the quality of the leadership.
* Pg 16 line 1-2: "Second, the bottom-up approach to developing and implementing SIMUNDU has shown that the system is feasible and viable." Can this be reworded? It is difficult to understand as written.	We have made an additional effort to improve clarity and readability throughout the manuscript, and this specific point at page 16, line 25.
* Pg 16 line 8-9: How would the information from a study like this be useful? Please state it the paper. Third, further research is needed on the impact of SIMUNDU on immunization coverage, for instance, through a before and after comparative study with a 2-3-year time window in a low-performing region.	We are focusing on how information from this study can inform sustainability and recommendations for scale-up. Conclusions and recommendations are developed accordingly.

Reviewer 2

Dear Reviewer 2, thank you very much for your excellent comments and inputs to this manuscript; we appreciate it. Our response to all your comments and input is presented in the table below.

General Comments: Immunization information systems are an important infrastructure. Authors describe the implementation and evaluation of a system in Indonesia for children. However, methods are very unclear. Perhaps the manuscript could be restructured to describe the implementation first, because it is very unclear if the information was obtained from the methods or not? Seems some of the implementation data was obtained from documents review. Then use the survey and key informant information as an evaluation of the system?	 The manuscript starts indeed with describing how SIMUNDU was developed and implemented first (section on background), and then goes into detailing the data collection methods. In this section, we have outlined a sequential approach to data collection consisting of a desk review, followed by a survey followed by qualitative interviews. Your point about clarity is well taken: we have made an additional effort to improve clarity and readability throughout the manuscript.
Title: Recommend changing to "Implementation of an immunization information system in Indonesia province of Daerah Istimewa Yogyakarta: lessons for scale-up	We followed your recommendations, though we also want to maintain the reference to introduction.
Abstract: Background - change safe to save	Thank you for flagging the typo. This was addressed in the abstract, page 1, line 23
Authors use abbreviations in the abstract that should be defined such as DIY, SIMUNDU	The acronyms DIY dan SIMUNDU have been spelled out in the abstract. See page 1, line 26 and 30
Background: Page 2, paragraph 2. Please provide a definition of the DHIS2 since it is used later	DHIS2 has been spelled out on Page 2, line 35 DHIS2 means The District Health Information System 2

Page 2, paragraph 3. Authors describe primary health centers as puskesmas or PHC in other areas of the manuscript.	Puskesmas has been changed to PHC throughout the manuscript
Please be consistent in terminology and if going to use PHC please define it here.	Puskesmas has been changed to PHC throughout the manuscript
Page 3, paragraph 2. This paragraph uses both puskesmas and PHCs	Puskesmas has been changed to PHC throughout the manuscript
Page 3, paragraph 3. Please use English diphtheria	Difteri has been changed to Diphtheria (page 3, line 33)
Page 3, paragraph 3, - please explain how the school information is being loaded into SIMUNDU in aggregate	This is clarified on page 3, line 34. Vaccinations administered in schools are loaded into SIMUNDU in the form of aggregate data only, as opposed to individual children immunization history - as is the case in health facilities. Aggregate as opposed to individual-based records.
Methods: Page 4, paragraph 2. Last sentence. Please explain the difference between staff responsible and immunization coordinator are they the same. The table uses immunization coordinator. Also here use puskesmas versus PHC. Are you also using private clinics and hospitals as in the table.	Let me explain as follow: Staff responsible for entering the data in PHC and UPS consist mainly of data entry clerks at the facility level. Immunization coordinators are mainly found at district/city and provincial level, and have managerial responsibilities. We have worked through the text to improve clarity on these different roles. Yes, UPS consists of some health facilities such as private clinics and hospitals.
Table 1. Seems a small sample for the clinic and hospital versuse PHC and UPS - is there a reason?	Based on the information that has been collected before we executed the survey and considering that the characteristics of each group are almost the same, together with the provincial health office, we agreed to take 2 units per district randomly. We consider this as one of our study limitations. See page 16, line 37
Page 5, paragraph 1. Again are the immunization coordinators the staff responsible and would all facilities have an immunization coordinator.	The modification has been made on Page 4. Immunization coordinator only in district/city, while data entry clerk in all health facility invited
Page 5, paragraph 1, last sentence. Authors state all staff involved with data entry and management. Authors need to be clearer who completed surveys - seems the samples are not consistent across all practices does that mean that private clinics for example had much fewer staff involved with SIMUNDU than UPS for example?	Immunization coordinator only in district/city, while data entry clerk in all health facility invited. While all PHCs were included in the survey, and all data clerks working at this level invited to participate, only a sample of UPS clinics was selected and data clerks from these selected clinics invited. This explains why only a small

	number of UPS staff, compared to staff from public sector, participated in the survey. Table 1 illustrates the sample process in detail.
Page 5, paragraph 2. Please describe the survey in more depth - how was it developed, how many questions, what types of questions? Any demographic data of the respondents? Usually, a key informant's interview would be done first to then inform the survey. So, methods are slightly different approach. How was the survey data used to drive the key informant interviews.	Detailed information about the survey has been added on Page 5, paragraph 1. Then how was information from the quantitative study used in qualitative study was completed on Page 5, Paragraph 2. Since we used to explain why a particular case like this or like that, we should know first the existing situation in the field, it is why in this research we used explanatory sequential mixed-method design, where quantitative data were completed first then the finding was used to inform the qualitative phase – referred to *Fetters MD, Curry LA, Creswell JW. Achieving integration in mixed methods designs - Principles and practices. Health Serv Res. 2013;48(6 PART2):2134–56.* I have added more information about the approach in the methods section, Page 4, paragraph 1.
Results: Authors do not present any of the survey data from 146 respondents? Only key themes and not sure where the key themes are from - the survey or the key informant interviews. Were the themes already developed when the survey was developed?	Dear reviewer, We have added table 2 and table 3 for the informant's characteristics on Page 6 and 7. Regarding the survey result, we will add it as a supplementary file because it has many pages. This supplementary will replace the questionnaire that we attached before. We have worked through the results section to better highlight the contribution of survey data, and attribute each finding to its source (either interviews or surveys). The themes arose from the analysis of qualitative data. Yet, findings from both the survey and the interviews fed into the analysis of these core themes, to cross-validate the findings
Author reporting of the results seem to mix the introduction and the use of SIMUNDU. Perhaps authors could describe the implementation as part of the background and introduction and then use the survey data and key informants as the results of the system. But it is not clear because authors do not provide enough information to evaluate the survey and the key informant interviews.	We are not sure we understand this comment. The manuscript starts with describing how SIMUNDU was developed and implemented first (section on background), and then goes into detailing the data collection methods. In this section, we have outlined a sequential approach to data collection consisting of a desk review, followed by a survey followed by qualitative interviews. What we can appreciate from this feedback however, is that the manuscript would benefit from more clarity so we have made an additional effort to improve it.

Page 6, paragraph 2. This provides a lot of information about why the system was implemented. Did this come from the survey or the desk review?	Information from the different approaches is integrated in the analysis. While the 3 approaches were implemented sequentially for the stated reason (each step would inform the next), they all contribute to shed light on the process, and we use them as source of triangulation and integration.
Throughout the authors mentioned the survey showed? But how? What were the questions, how many respondents, etc.	Thank you for your question. We have added the requested information in the methods section Table 1, page 4. We also added the survey result will add as supplementary due to the page length.
Page 9, paragraph 3. The authors provide some survey data - this is helpful. Need to see this in all sections to understand.	We have worked through all sections to better highlight the contribution of survey data, and attribute each finding to its source (either interviews or surveys).
Page 11. Also has some survey data presented by the authors but it is difficult to interpret with not all sections containing survey data.	We have worked through all sections to better highlight the contribution of survey data, and attribute each finding to its source (either interviews or surveys).
Discussion Page 13, paragraph 1. Authors provide a nice summary here, but are these questions that were included in the survey.	Page 13, Par. 1: Sistem Informasi Imunisasi Terpadu (SIMUNDU) or Integrated Immunization Information System in the DIY province enabled the creation of individual immunization records for children. SIMUNDU allows users and managers to collect, store and analyze data on utilization of immunization services, including following up individual children and creating cohort data. Currently, DIY is the only province in Indonesia – out thirty-four - that uses an IIS. This work has shed light on the strengths and underlying barriers of implementing an IIS in this context. The objective was to draw lessons that inform sustainable scale-up in other regions and possibly at the national level. This is a background description of SIMUNDU; this is documentary information to set the foundations for the study.
Conclusion Authors should include recommendations and be identified as lessons for scale-up in the discussion instead of conclusion. Conclusion contains background information, that should be deleted. The conclusion should offer a succinct concl	We think that the conclusion is best suited for the recommendations we are putting forward as we intend them as sort of action points moving forward. We nonetheless accept the reviewer's suggestion to streamline the conclusion and have addressed it.

Introduction and implementation of an immunization information system in Indonesia province of Daerah Istimewa Yogyakarta: lessons for scale-up

Sulistyawati Sulistyawati, MPH, PhD[1*]
Trisno Agung Wibowo, MPH[2]
Rokhmayanti Rokhmayanti, MPH[1]
Andri Setyo Dwi Nugroho, MPH[2]
Dr. Tri Wahyuni Sukesi, MPH[1]
Siti Kurnia Widi Hastuti, MPH[1]
Dr. Surahma Asti Mulasari, MPH[1]
Marta Feletto, PhD[3]

[1] Faculty of Public Health, Universitas Ahmad Dahlan, Yogyakarta, Indonesia
[2] Daerah Istimewa Yogyakarta (DIY) Health Office, Yogyakarta, Indonesia
[3] Alliance for Health Policy and Systems Research, World Health Organization, Geneva, Switzerland

*Corresponding author: sulistyawati.suyanto@ikm.uad.ac.id.
Kampus 3 - Jl. Prof Dr Soepomo, Janturan, Umbulharjo, Yogyakarta, Indonesia.

Abstract

Background: Immunization is undeniably critical to save children from infections. To increase vaccination coverage, valid and real-time data is needed. Accordingly, it is essential to have a good report system that serves as defaulter tracking to prevent children's immunization failure. Daerah Istimewa Yogyakarta (DIY) health office introduced an electronic immunization registry and successfully implemented it for more than five years. It is the only individual-based record system in Indonesia that has been sustainably operated for such a long time. Yet, no systematic assessment of this system had been conducted to date. This study examines Sistem Informasi Imunisasi Terpadu (SIMUNDU) introduction and implementation process in order to draw lessons that could inform scalability and sustainability across the country.

Methods: This study used an explanatory sequential mixed-method design, which collected quantitative data from 142 participants and qualitative data from 9 participants. Entry data clerk in health facility was systematically selected to participate in the survey. While in the key informant interview, the informant was selected based on the survey result. A descriptive and thematic approach was adopted to analyze the quantitative and qualitative data. Results from across the two approaches were integrated for comparison and contrast.

Results: Findings are presented according to three core themes emerged from the data: system strengths, potential threats, and opportunities for scale up. Strengths -i.e. factors contributing to the success of SIMUNDU - include management, system performance, people's behavior, and resources. Potential threats to sustaining the system include individual capacity, technical or system issues, and high workload. Opportunities – i.e promising factor that SIMUNDU can be operated sustainably – such as continuity, expectation and scale up possibility.

Conclusions: SIMUNDU is a promising innovation for the entire country, beyond DIY. There is agreement about the potential for scale-up of this IIS to other provinces. Experience of implementing this system in DIY over the past five years has shown that the benefits outweigh the challenges, and SIMUNDU has grown into a robust and yet user-friendly system.

Keywords: immunization, electronic immunization registry, immunization information system, interoperability, implementation research

Background

Neonatal and childhood vaccination is an essential component of infectious disease prevention and an absolute human right (1),(2). Vaccination has been proven to reduce the burden of infectious disease globally (3). According to the WHO, in 2020 estimated 23 million children under one year of age did not receive their essential vaccinations. Of these, 60% live in just ten countries, one of which is Indonesia (4). Indonesia is the fourth most populous country globally. It is composed of thousands of islands organized into 34 provinces. Various geographical and cultural factors influence population inequalities to access to health services (5). In 2001, the Indonesian government's decentralization policy was enacted. This was an excellent strategy to foster development by engaging regional resources (6). However, this strategy was not without consequence. One primary concern was the fragmentation of the Health Information System (HIS).

Indonesia's federal structure results in provinces and districts being relatively independent of the national Ministry of Health. This means that information systems at the provincial and district levels are locally regulated (7). For instance, *Pemantauan Wilayah Setempat* (PWS) is a management tool used to monitor coverage of specific health services in an administrative boundary. Depending on the service and region, it can be paper- or electronic-based. PWS-KIA is the monitoring system specific to maternal and child health (KIA), including immunization. PWS-KIA data are reported to the District or City Health Office, go to Province Health Office, and finally report to the main level. Generally, the data is in excel; it will report via emails or various information systems, including Komdat, SiTT, SIHA, PISPK, SIKDA Generik. PWS-KIA data feeds into the District Health Information System 2 (DHIS2) in some provinces. Regional information systems have varying data quality, which reflects inequities in resources across regions. This adds to data integration challenges at the national level (7),(8) and affects strategic policymaking.

In the context of Indonesia’s federal system, Daerah Istimewa Yogyakarta (DIY) Province has the authority to regulate and use its budget within its four districts (Sleman, Gunungkidul, Bantul, Kulonprogo) and Yogyakarta city. Regarding childhood vaccination, DIY is among the top ten performing provinces in the country, with 97.7 % of children completing basic immunization coverage in 2019 (9). Immunization services are provided by Primary Health Centres or Puskesmas (PHC), as well as private clinics, hospitals, and midwives' practices (typically referred to as *Unit Pelayanan Swasta* or UPS).

In 2014, the DIY Health Office introduced an electronic immunization registry named SIMUNDU (*Sistem Informasi Imunisasi Terpadu*/ Integrated Immunization Information

System). An electronic immunization registry is a tool for recording individual children's immunization histories. An electronic registry serves essential functions at all levels of the health system. At the district and higher levels, it allows for monitoring vaccination coverage by the vaccine, dose, cohort, and other variables – and can support microplanning and vaccine management. The service delivery level can facilitate individual follow-up of vaccination status and enable health workers to identify children due for vaccination and those who missed their vaccinations (defaulters).

SIMUNDU was designed to link with the PWS-KIA for immunization and interoperability with the DHIS2. While it predominantly contains individual-level immunization records, SIMUNDU also serves as a source for aggregation and can synergize with the *Pemantauan Wilayah Setempat* (PWS) reporting system. For this reason, it can be considered an Immunization Information System (IIS). This means that data from City and District levels feed into Provincial and National levels *(Personal communication with DIY immunization program officer)*.

The original prototype was designed by the information and technology (IT) department of DIY Health Office to be operated offline. In DIY, three out of the four districts and the city introduced the system in 2015. The final district introduced it in 2017. At this stage, the point of data entry was the PHC only. By 2018, UPS facilities were also equipped with SIMUNDU and could enter data into the system. In 2019, the prototype was further developed to operate online. The online version was rolled out in 2020 (Figure 1). As of May 2021, 79.4% of all PHC and UPS facilities were complying. This average rate masks, however, the fact that while all PHCs adopt SIMUNDU, it is more challenging to enforce its use in UPC facilities (Suyani 2020, oral communication, 2020 May 11).

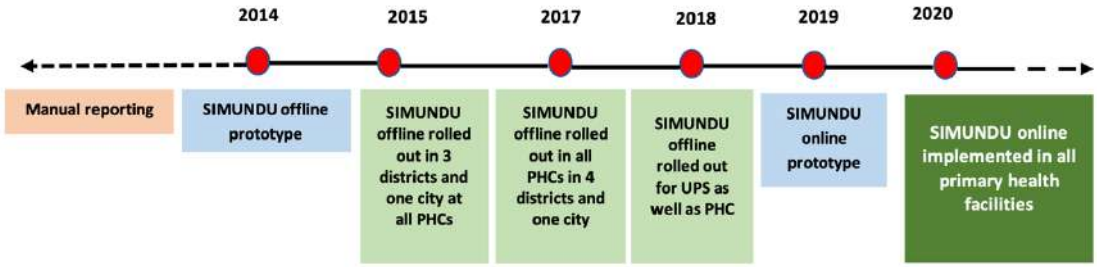

Figure 1. SIMUNDU's development and introduction

When a child receives a vaccination in a health facility, information on the child and the vaccination is entered in SIMUNDU as an individual child record. Each record includes a personal identifier, the child's socio-demographic characteristics (e.g., name, gender, date of birth, name of parents, address), the antigen administered, and the date and place of vaccination. SIMUNDU has been recently updated to allow recording of vaccinations administered in schools (e.g., Human papillomavirus (HPV), Diphtheria Toxoid (DT), Tetanus-Diphtheria (TD), and Measles-Rubella (MR), though in the form of aggregate data only. Furthermore, SIMUNDU has being developed to record COVID-19 vaccinations in health facilities and those carried out in masse.

Monitoring is conducted every month to assess data completeness across health facilities, while an evaluation is conducted every year. These exercises have allowed the identification of several challenges related to implementing the system (e.g., workload, staff turnover, and rotation) and data quality (e.g., accuracy and timeliness). However, no

systematic assessment of the system has been conducted to date. SIMUNDU is the first immunization information system ever introduced in Indonesia. Other districts and provinces have shown interest in rolling it out, and the Ministry of Health has acknowledged the innovation. The objective of this work was to examine SIMUNDU's introduction and implementation process to draw lessons that could inform scalability and sustainability across the country.

Methods

From May to October 2020, we examined the experience of introducing and implementing an immunization information system in the DIY province using an explanatory sequential mixed-method design, where each step informed the next (10). First, we conducted a desk review of all relevant documentation available in the DIY health office – e.g., staff notes, meeting notes and monitoring notes – documenting SIMUNDU development and management processes. We also examined online documents, including health profiles and regulations on health reporting systems in Indonesia. This served as the initial source of data and provided an overview of who was involved and how, in developing and implementing SIMUNDU. This informed the survey design that we conducted as a second step. The survey targeted any staff responsible for entering data in SIMUNDU (i. e. data clerks) across all PHC and selected UPS facilities and anystaff responsible for managing the system at the district and city level (i.e. immunization coordinators). Sampling and recruitment strategies are outlined in Table 1.

Table 1. Survey participant

Level of the data entry and reporting system	Total number of facilities/ offices	Study population	Sampling strategy	Recruitment	Sample size
Primary Health Centre (PHC)	121	Data entry clerks	All facilities	Open invitation across all facilities	113
UPS - Central, General, Maternity and Pediatric Hospitals	65	Data entry clerks	Randomly selected 2 facilities per district/city (2*5=10)	Open invitation across selected facilities	8
UPS - Clinics	73	Data entry clerks	Randomly selected 2 facilities per district/city (2*5=10)	Open invitation across selected facilities	7
UPS - Midwives' Practices	271	Data entry clerks	Randomly selected 2 facilities per district/city (2*5=10)	Open invitation across selected facilities	10
District/City Health Office	5	Immunization coordinators	Total sampling	Open invitation	4*
			Total		**142**

*When the immunization coordinator had recently changed, the former was also invited.

All immunization coordinators in each district/city and data entry clerks from all primary health facilities (PHC) were invited to participate in this survey. As to UPS facilities. we randomly selected two clinics, two midwives' practices, and two hospitals per district/city, and invited all of their staff involved in SIMUNDU data entry and management.

We developed and pre-tested an online survey in Bahasa Indonesia to inquire about SIMUNDU implementation, processes, and outcomes across PHC, UPS clinics, district or city and province offices. The questionnaire consisted of close-ended and Likert scale questions – ranging from 45 to 50 depending on the target type of facility and/or level of the health system – and enquired about respondents' socio-demographic characteristics as well as the process of implementing and managing SIMUNDU. Some questions provided an additional field for clarifying the reason for a particular choice of answer.

All participants were invited to the DIY health office to fill out the survey on their laptops, with their prior consent. Having all participants in a room allowed researchers to monitor any missing or incomplete responses in real-time and follow-up with individual participants on-site to fill any gaps. We don't believe this may have introduced any significant bias as researchers would simply flag any missing response and invite respondents to address those. Data were then exported into and analyzed in Microsoft Excel. An exploratory analysis of the survey data informed the topic areas that qualitative interviews would delve into.

Similarly, some informants were purposefully selected among survey participants to follow up on the range of perspectives that had emerged from the survey. Other informants had been identified at the desk review stage, and chosen for their management functionsSeleced informants were invited to the DIY Health Office for the purpose of the interview, and COVID-19 prevention protocol was observed. Every informant was informed about the study and asked to sign the informed consent. All invited informants agreed to participate. A total of nine 30-minute semi-structured interviews were conducted in Bahasa Indonesia language, and recorded with prior consent from participants.The interview team consisted of three researchers with the respective task of running the interview, observing and taking notes. A research assistant transcribed all interviews in Bahasa Indonesia language.

Thematic analysis was conducted using Quirkos qualitative tool following Braun and Clarke's approaches (11). Researchers familiarized themselves with the data, searching for initial codes and allowing themes to emerge. The principal investigator led the coding process, and led the research team in defining and naming the core themes emerging from the data, organizing and analyzing the data across the themes, and triangulating information from the desk review, the survey, and the interviews. This stage was also performed in Bahasa Indonesia. Data were translated to English only at sub-theme and core themes.

Results

Characteristic participant

a. Quantitative study

In total, 142 respondents participated in this study spread across five districts or cities in the DIY province. Most respondents came from Gunungkidul District, PHC, UPS, and DHO, 24.8%, 24%, and 25%, respectively. For all research units, the majority are women. At the UPS and DHO/CHO levels, most respondents aged 41-45 years, i.e., 28.3% and 75%, respectively, while at the UPS level, the majority aged 25-30 years (56.0%). For education level, PHC and UPS are dominated by Diploma 3 graduates, namely 86.7% and 80%, respectively, while in DHO/CHO, it is predominantly undergraduate graduates (75%) (Table 2)

Table 2. Characteristic respondent in three groups of respondents

Characteristic	PHC (n= 113) n (%)	UPS (n=25) n (%)	DHO/CHO (n= 4) n (%)
District/City			
Bantul	23 (20.4)	5 (20.0)	1 (25.0)
Gunungkidul	28 (24.8)	6 (24.0)	1 (25.0)
Yogyakarta	17 (15.0)	4 (16.0)	0 (0.0)
Kulonprogo	21 (18.6)	4 (16.0)	1 (25.0)
Sleman	24 (21.2)	6 (24.0)	1 (25.0)
Sex			
Male	3 (2.7)	0 (0.0)	2 (50.0)
Female	110 (97.3)	25 (100)	2 (50.0)
Age			
< 25	0 (0.0)	5 (20.0)	0 (0.0)
25-30	3 (2.7)	14 (56.0)	0 (0.0)
31-35	30 (26,5)	3 (12.0)	0 (0.0)
36-40	19 (16.8)	1 (4.0)	0 (0.0)
41-45	32 (28.3)	0 (0.0)	3 (75.0)
46-50	18 (15.9)	0 (0.0)	1 (25.0)
>50	11 (9.7)	2 (8.0)	0 (0.0)
Education			
Master	0 (0.0)	1 (4.0)	1 (25.0)
Bachelor	5 (4.4)	1 (4.0)	3 (75.0)
Diploma 4	9 (8.0)	2 (8.0)	0 (0.0)
Diploma 3	98 (86.7)	20 (80.0)	0 (0.0)
Senior high school	1 (0.9)	1 (4.0)	0 (0.0)

b. Qualitative study

Nine informants were recruited to provide the required information to explore deeper into the quantitative study results. They hold roles as managers and staff at DHO/CHO, PHC, and UPS. Among the nine informants, 2 were men, and 7 were women. Three informants graduated from masters, one bachelor's, and five diploma graduates (Table 3).

Table 3. Informants' characteristics for the qualitative study

Sex	Age (years)	Education	Position	Subject group	Informant's code
Female	56	Magister	Head of disease prevention and control department at PHO level	Managerial	M 01
Male	57	Magister	The former of disease prevention and control section at PHO level	Managerial	M 02
Male	54	Bachelor	Immunization programmer at PHO level	Managerial	M 03
Female	47	Magister	IT Person	Managerial	M 04
Female	34	Diploma	Data entry at the PHC level	Staff	S 01
Female	25	Diploma	Data entry at UPS level	Staff	S 02
Female	31	Diploma	Data entry at UPS level	Staff	S 03
Female	42	Diploma	Data entry at the PHC level	Staff	S 04
Female	24	Diploma	Data entry at the PHC level	Staff	S 05

c. Finding

Findings from the study are organized and presented across the three core themes that emerged from the qualitative analysis, notably system strengths, potential threats, and opportunities for scale-up. Yet, data from both the qualitative and quantitative data fed into the analysis of these core themes, to cross-validate the findings (Figure 2. Detailed findings from the survey are presented in Table Supplement 1.

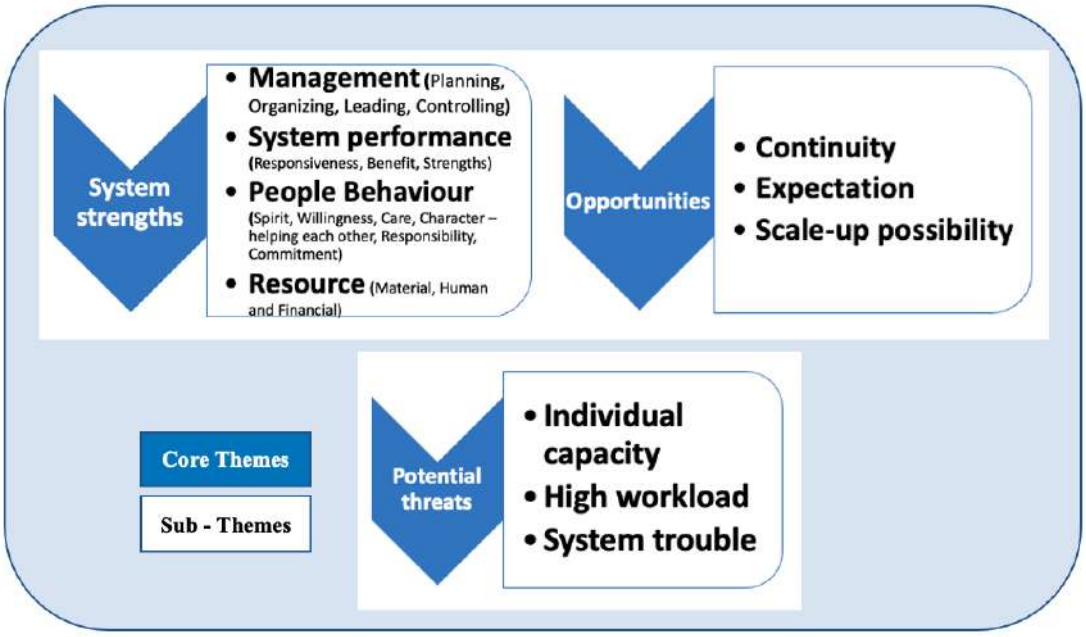

Figure 2. Strengths, potential threats, and opportunities for scale-up

System's Strengths

Factors contributing to the success of SIMUNDU include management, system performance, people's behavior, and resources.

Management

SIMUNDU arose due to concerns from the DIY health office immunization section around data quality, notably the need to address issues related to data inaccuracy, duplicate or missing data and lack of timely data, and the need of quality data to support follow-up and appropriate planning. The need for SIMUNDU arose from these challenges and needs.

To our knowledge, [SIMUNDU development] started with a problem: estimates of the target population varied depending on the data source.

Yes, I think [SIMUNDU management team] started to tire of managing a large volume of data with dubious validity. They need to know the situation in each district.

Effective management of SIMUNDU from development to implementation was highlighted as an essential determinant of its success across the critical functions of Planning, Organizing, Leading, and Controlling.

Careful **Planning** was ensured at each stage of SIMUNDU development and implementation. These stages included developing an initial business plan, providing training on and socialization to SIMUNDU, and developing a staff replacement plan to respond to turnover or retirement of staff in charge of operating the system or entering data. The parties involved in planning included the head of disease prevention and control department, IT personnel, and immunization program staff from the DIY health office.

Organizing - the organization of SIMUNDU is carried out at several levels. The top level is the DIY health office, the second level is the district/city health office, and the third level is health facilities (Figure 2). A third party was also involved in developing the system interface.

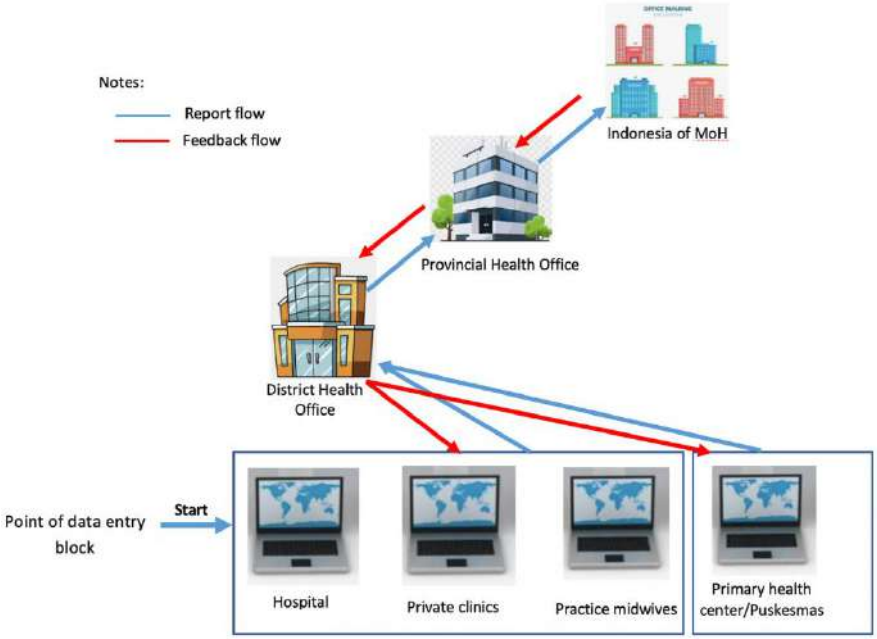

Figure 2. Visual organizing framework of SIMUNDU – DIY Province, Indonesia

At the beginning of SIMUNDU development, essential functions included database administrators, interface designers, and server administrators, and their interplay facilitated the smooth operation of the system. Training specific to SIMUNDU was integrated with other training, typically immunization-related training. This enabled to share resources with other programs, thus ensuring viability. The training was delivered in the district/city health office: 87.6%, 72% and 75% of survey respondents from PHC, UPS and DHO/CHO respectively had participated in in-house training. Training typically consisted of short sessions and included practice on the trainee's device on how to operate the system in both online and offline mode. Informants indicated that day-to-day operations were carried out autonomously by the staff, through flexibly adjusting their work to protect time to enter the data. And this seemed to work effectively.

Leading - the success of SIMUNDU implementation is arguably related to strong leadership. Informants noted that managers played a crucial role in bridging the needs of the immunization program with the system design, closely monitoring the initial implementation process, and creating an enabling environment.

I try to combine supporting and managing the people involved and monitoring them. Currently, I monitor whether [SIMUNDU] can run optimally as our users are health facilities. I also monitor program development and the system's output.

[SIMUNDU] was born from program managers, primary health centers, Districts, and DIY health offices wanting to build systems together. We – DIY health office - give them motivation in every meeting.

I see that [management] is very good at networking. Staff data entry in the field always said that these people are very kind.

The role of IT in developing SIMUNDU was also reported to be significant. They helped develop the system and supported correct data entry by assisting data entry operators whenever these encountered technical issues or helping resolve inconsistencies in the data records. Acknowledgment of staff efforts was also an important lever to maintain motivation and buy-in.

In the early days of SIMUNDU's development, the system was challenging to operate, as it wasn't as stable as it is now. I praise the enthusiasm and dedication of the users.

The **controlling** function - consisting in **quality** assurance management - was critical to avoid data duplication or missing entries, and ultimately ensure data quality. This process was not regulated by specific Standard Operating Procedures but was addressed during training and monitored monthly. In addition, the DIY health office provided negative incentives to health facilities that were not submitting complete records and provided regular feedback from monitoring and evaluation exercises.

Specifically, 94.2%, 100%, and 100% of survey respondents in PHC, UPS, and DHO respectively, reported their work had been subject to monitoring. More than half of the respondents in PHC and UPS facilities had been observed by supervisors while performing data entry at least once over the past year. At the PHC level, 48.3% of survey respondents had been subject to monitoring from the district/city office's team, and 45.7% received monitoring from DIY health office's staff. Conversely, 40% of respondents from UPS facilities were monitored by PHC's staff. Almost all survey respondents reported receiving feedback from the monitoring, mainly from the District/City and DIY health offices. Forty percent of respondents from UPS facilities reported receiving feedback from PHC. Immunization coordinators from the District/City health offices received feedback from the DIY health office.

In a [evaluation] meeting, DIY health office or district health office showed the progress of our data entry – correct or not, proper or not

It is worth noting that DIY province is quite a small geographic area. Because it consists of only five districts and one city, this province is relatively easy to monitor across all phases, from planning through monitoring and evaluation.

System performance

While SIMUNDU predominantly contains individual-level immunization records, it also serves as a source for aggregation and can synergize with other information systems. Notably, SIMUNDU can link to the DHIS2 and generate immunization-specific reports as per Ministry of Health's requirements. These reports are sent to the upper levels automatically if SIMUNDU is operated online or submitted via email if SIMUNDU is operated offline. This functionality has had an essential role in ensuring the acceptability and adoption of the system.

Informants noted how transitioning from paper-based tools to an electronic system made data entry easier and reduced errors. It also facilitated the implementation of protocols for data storage and security. It enabled follow-up and defaulter tracking. Finally, integration with the DHIS2 meant reduced workload for the staff.

We can do faster tracking of children who may have received vaccinations in different locations. For example, when the first dose of a vaccine is given in Bantul and the second one in Yogyakarta, the record can be linked within SIMUNDU.

SIMUNDU makes it easier to detect what data and vaccinations are missing since we enter data from the children's birth through the end of the immunization schedule. So, we will know where they miss any vaccine.

The benefit of using SIMUNDU is first: we know the situation of immunizations more accurately….so our vaccine forecasting is more accurate …. and our budget, staff, facilities can be more effective and efficient in providing services.

Colleagues from the mother and child health (KIA) program enter the data via the KIA "Sembada." So, this data will appear automatically in SIMUNDU because the two-system are connected.

SIMUNDU is user-friendly and can be flexibly operated either offline or online, allowing the responsible staff to maintain data entry irrespective of connectivity. 82.3%, 96% and 100% of survey respondents from PHC, UPS and DHO respectively reported to operate SIMUNDU online.

People's behavior

The interview showed that staff commitment was critical for the successful implementation of SIMUNDU, as indicated by their willingness to work overtime and bring home the data to enter into the system.

I take it [the data] home too, for example, after immunization sessions– in my clinic, immunization runs four times per month, every week. So, when the session is finished, we can take the data home, [and] do the entry at home while relaxing

This dedication was confirmed by the interviews, which spoke to a societal culture of helping others and responsibility and commitment to the team. This contributed to shape an environment where people approach SIMUNDU as a shared responsibility and a collective endeavor. Informants also noted the high motivation of dedicated staff.

That's all; we cannot judge by money [people kindness, culture, and behavior]; it's essential to explain how good people are in Yogyakarta. I was in another place before, and I could not find people's kindness like in Yogyakarta - different characters.

The second thing is that we need human resources concerned and love for data; otherwise, even though we have a good system, it will amount to nothing without good

human resources. But when people are concerned about data, good implementation will come more easily.

Resource: material, human and financial

Infrastructure and equipment emerged as critical factors to introducing and sustaining SIMUNDU implementation. Some desktops were specifically allocated to the immunization program, and some had to be shared with other programs' staff. Other data entry officers reported using their own laptop or smartphone (36.3% of survey respondents from PHC). In UPS facilities, 40.7% reported using office desktops, and in the DHO, more than half of the respondents stated they used an office-supplied laptop. The majority of respondents – regardless the type of facility - said their current device was sufficient to perform their work on SIMUNDU. Regarding connectivity, 64.6% of PHC survey respondents and 67.7% of UPS's reported operating SIMUNDU online relying on the office's internet connection.

Management of financial resources was also crucial. According to the key informants, no special funds were allocated to SIMUNDU in the initial stages. Resources were leveraged through sharing activities – e.g. monitoring visits or transportation - with other programs, thus allowing cost efficiencies. Integration with other programs proved critical to ensuring sustainability.

SIMUNDU's budget comes from the state budget called as Anggaran Pendapatan dan Belanja Negara (APBN). Every year the APBN allocates a funding envelop for immunization to DIY and other provinces, where the budget is apportioned across the program [not explicitly written budget for SIMUNDU]

Human resources are critical to the operation of SIMUNDU. According to interview, SIMUNDU data entry clerks must have patience, work carefully and not rush, be interested in data, be responsible, and have basic computer skills such as Ms word and Ms excel. As shown by the survey, the large majority of SIMUNDU-operating staff was educated: at least 80% of data entry clerks in either PHC or UPS facilities have secondary education (>80%), while at the managerial level (DHO), 75% of respondents have a bachelor's degree (Table 2). Yet, 19.4% and 9.1% of respondents from PHC and UPS facilities, respectively have low computer literacy.

Various data entry clerks looked for strategies to resolve the obstacles they encountered when entering data to SIMUNDU. Based on the interviews, some clerks furthered their computer skills by taking private computer classes. Others learned from other colleagues at their offices, or reached out for help to the district person in charge. To deal with the accumulation of data needing to be entered in SIMUNDU, staff would sometimes work at home after office hours, as their busy schedule at work did not allow time for data entry.

If we found obstacles, we asked people in charge in PHC – asking for a solution or sharing by WhatsApp – or sometimes I asked the IT person in the DIY health office.

Potential threats

As of today, SIMUNDU can be said to be a successful experience. Yet, a number of obstacles were encountered and addressed during implementation. Potential threats to sustaining the system include individual capacity, technical or system issues, and high workload. Staff computer literacy was identified as one of the main challenges to sustainability. Internet connectivity was another obstacle, as not all health facilities were equally supported by a good network. The survey shows that 64.6% and 67.7% of PHC and UPS staff used office internet, while others had to rely on their home internet.

Further, incomplete and inconsistent records – such as differing child's date of birth or name spelling across relevant entries - make it challenging to consistently record immunization information. These challenges have arisen during implementation, and were promptly addressed. Yet, they had an impact on staff who was already juggling busy schedule in the office, causing delays in data entry. As shown by the survey, almost all respondents stated having other responsibilities besides operating SIMUNDU – notably 97.3%, 88% and 100% of participants from PHC, UPS and district and city offices respectively.

Opportunities

Informants appreciated SIMUNDU asa good system for immunization data. SIMUNDU has become necessary for program managers and policymakers because it allows to monitor coverage and can inform planning and programming. Currently, SIMUNDU is stable, thus is easier to manage than when it was in the development phase. It is also viable, and no longer requires heavy reliance on the core workforce that started the system. The hopes expressed by data entry clerks in the interviews are that SIMUNDU is easier to operate, and system errors are less frequent. Informants also stressed the need for refresher training to ensure knowledge and practice of the system is not lost.

In my opinion, SIMUNDU is the best program in DIY which is a collaboration between program managers and IT. It will continue to be implemented because it is a necessity. It has been stably used for more than five years, meaning this is needed.

If I have the tool, in this case, SIMUNDU, when it is stable, whoever will be able to run it, I am sure that anyone can operate it. It means that it doesn't matter if we have people shifting (jobs).

In the future, if SIMUNDU is still used, other reports are not necessary. Now we have two different reports: SIMUNDU and stock card of vaccine – each stand-alone and need a separate report.

Based on the key informants' interviewerskwkkwkw, SIMUNDU is likely to be developed further / or expanded to other provinces. The DIY health office is open to support other provinces interested in introducing the system, for instance through lending staff for training and orientation. However, informants advised that successful introduction requires a strong commitment from both staff and management.

Discussion

Robust health information systems (HIS) are essential components of strong health systems (12). At the most basic level, immunization registries are systems that collect and report individual-level vaccine administration record data, thus facilitating individual follow-up of vaccination status. Registries also allow for the monitoring of vaccination coverage and facilitate analysis of AEFIs and surveillance data to inform the design of coverage interventions and outbreak investigations. When an electronic registry has interoperability with other electronic systems – such as the case with SIMUNDU – it is considered an IIS. (13). This paper presents lessons learned from DIY's experience implementing an IIS.

DIY is the only province in Indonesia – out of thirty-four - that uses an IIS. This work has shed light on the strengths and underlying barriers of implementing an IIS in this context. The objective of this study was to draw lessons that inform sustainable scale-up in other provinces and possibly at the national level. This study highlighted individual capacity, technical or system issues, and high workload as the major barriers to sustainability whereas management, system performance, people's behavior, and resources emerged as the main determinants of SIMUNDU's successful implementation, notably in improving acceptability, implementation costs, and adoption of this innovation (14).

Despite several obstacles encountered during the implementation of SIMUNDU, this study showed that this innovation was well accepted by key stakeholders involved. On one hand, data entry clerks noted that the system is rather user-friendly and allows to better organize the data and enhance its quality. On the other hand, managers noted the benefits this innovation brought about, namely in terms of the potential for cohort data to support planning and monitoring and ultimately improve immunization coverage.

Effective management - across planning, organizing, leading and controlling functions – is a crucial reason why SIMUNDU has been viable for over 5 years. Managers use their control to encourage the beliefs and actions of the staff with a dedicated and robust managerial process (15). SIMUNDU was born from the need for credible data to assist in carrying out DIY health office duties at the managerial and operational level. At the managerial level, the disease prevention and control department and the IT department collaborated in designing a system that was readily accepted by intended users. Immunization officers and IT programmers played a central role from the early stages of

development through implementation with effective coordination and communication, and they were helped in this task by the full support of their respective superiors.

SIMUNDU is cost-effective in several ways. During the introductory period of its implementation, immunization programmers, IT officers, and other staff assisted in introducing SIMUNDU in all districts in the province. This was done through integrating some of the activities across programs, thus building efficiencies in terms of time and costs for both managers and staff. Sharing resources across programs was critical in the first years, for building sustainability. Additionally, SIMUNDU maintenance does not require high costs because the DIY Health Office itself has developed the system and thus possesses in-house technical skills. The IT department has the capacity to monitor and improve processes and tailor them to user needs without much additional cost.

A good program without good leadership could fail in its implementation, and even if it was initially successful, it might not be sustainable (16). In the context of SIMUNDU, support from leadership and effective management facilitated the program's adoption. Uptake of the new system was good and all health facilities providing immunization services have successfully transitioned to SIMUNDU. The strong network of the main persons in charge of SIMUNDU also facilitated adoption. Good communication, care and attention to staff concerns positively affected staff performance. Theyfelt they were well supported and reated kindly, and this helped them carry out their work joyfully. According to several informants, the leadership of the DIY immunization program manager played an essential role to this effect.

The monitoring and evaluation mechanisms of SIMUNDU were also important. Preferred monitoring and evaluation activities include monthly reports and direct discussion with staff during site monitoring visits. The immunization program manager suggested this approach to maintain data quality and ensure system’s sustainability. These chosen mechanisms allow program managers to assess the actual practice in the field and the challenges faced to inform decisions about the follow-up actions to be taken. These processes supported the ongoing development of and learning from SIMUNDU as a tool for data collection, analysis, and visualization, as well as the benefits for managers to carry out monitoring and evaluation. The same statement was revealed by previous research in India about the innovation of health management information systems for primary health care agrees that this can provide essential benefits (17).

Human resources are a key determinant of successful implementation of any HIS (18). People's behavior affects how the system works, develops, and survives (19),(20). In the case of SIMUNDU, implementation was facilitated by a culture of care, established networks, and positive attitude towards data of both the program manager and IT team. From the staff's point of view, the local culture of helping each other and doing their job correctly and responsibly translated into staff carrying out their duties with enthusiasm and high commitment. Although facilities, funding and human resources were limited, the individuals involved were highly motivated and supportive.

Despite the many strengths of SIMUNDU, some obstacles may potentially challenge its sustainability in the long term. These obstacles can be divided into human variables and technical variables. From the human variables side, unequal distribution of capacity at the operational level can result in differing levels of data quality across facilities and districts. Staff workload is another challenge needing addressing, as their willingness to work overtime is not a sustainable strategy. System trouble was another obstacle during the introduction of SIMUNDU, but a qualified technician or developer solved it.

Conclusion and recommendation

SIMUNDU is a promising innovation for the entire country, beyond DIY. There is agreement about the potential for scale-up of this IIS to other provinces. Experience of implementing this system in DIY over the past five years has shown that the benefits outweigh the challenges, and SIMUNDU has grown into a robust and yet user-friendly system. Regular training to dedicated staff to strengthen their capacity as the system evolves and is updated, and a plan for anticipating and responding to staff turnover have proven critical strategies towards sustainability. SIMUNDU's success also rests on remarkable leadership, both in creating and enabling a supportive environment and in pursuing integration with other programs to share limited resources.

Recommendations stemming from this study address three different groups of stakeholders: the DIY health office, the national government, and researchers. First, to ensure continuity and sustainability and reduce the system's dependency on the particular person or party, SIMUNDU management and maintenance should be managed by people who have competency and interest in a good reporting system. Furthermore, a human resources plan should be developed in preparation for SIMUNDU roll-out in other provinces or at national level; this is necessary to avoid vacancies when DIY province staff are seconded to other areas for mentoring support. Second, the fact that SIMUNDU emerged from an actual need of immunization programme implementers, and saw these at the front-line of its development and implementation positively impacted its feasibility and viability. This suggests that the approach to scaling up SIMUNDU should be stepwise, considering each region's specific characteristics and needs. To this effect, a readiness map and a timeline may be developed for the roll-out of SIMUNDU in a particular region. Third, further research is needed to assess the impact of SIMUNDU on immunization coverage. Based on our conversations with stakeholders, it would be particularly relevant to focus on a low-performing region and observe the impact over a 2 to 3-year time window.

Study limitations

The empirical results reported herein should be considered in light of limitations. First, in the quantitative study, the result should be considered in the study sample size mainly for UPS health facility. In qualitative research that aims to explore, caution is needed in

interpreting the interview results. From these results, there is still a need for in-depth studies with different approaches, such as focus group discussions to confirm the results.

Declarations

Ethics approval and consent to participate

This study was approved by the Ethical Review Board of Universitas Ahmad Dahlan, Yogyakarta, Indonesia (ethical approval code: 012005021). Before data collection began, consent to participate was obtained from research subjects (both survey and key informant interviews).

Adherence to national and international regulations

Not applicable

Consent for publication

Before data collection begins, approval that data is taken for publication purposes is obtained from research subjects (both surveys and key informant interviews).

Availability of data and materials

The datasets generated and or analyzed for this study can be requested to the corresponding author.

Competing interests

The authors declare that they have no competing interests

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Authors' contributions

SS, TAW, RR, ASDN and MF designed the study. SS, TWS, SKW, SAM collected the data. SS and RR conducted data analysis. SS developed the paper with inputs and comments from MF on each draft. All authors agree with the manuscript’s results and conclusions.

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Authors' information:

The authors alone are responsible for the views expressed in this article. They do not necessarily represent the views, decisions, or policies of the institutions affiliated with them.

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Table 1. Respondent response duriWehang the survey

Questions	PHC (n= 113) n (%)	UPS (n=25) n (%)	DHO/CHO (n= 4) n (%)
Among the two systems – Offline and Online – which one do you prefer?			
ONLINE	93 (82.3)	24 (96.0)	4 (100)
OFFLINE	20 (17,7)	1 (4.0)	0 (0.0)
Do you carry out any other work/duties besides SIMUNDU?			
No	3 (2,7)	3 (12.0)	0 (0.0)
Yes	110 (97,3)	22 (88.0)	4 (100)
Who is the main person in charge of doing data entry to SIMUNDU in your office?			
Myself	96 (85.0)	18 (72.0)	3 (75.0)
Other	17 (15.0)	7 (28.0)	1 (25.0)
How long have you been in charge of entering immunization data using SIMUNDU?			*
<1 year	8 (7.1)	5 (20.0)	
1-2 year	7 (6.2)	15 (60.0)	
2-3 year	16 (14.2)	1 (4.0)	
3-4 year	17 (15.0)	1 (4.0)	
>4 year	65 (57.5)	3 (12.0)	
How long have you been in charge of managing SIMUNDU?	*	*	
<1 year			1 (25.0)
1-2 year			0 (0.0)
2-3 year			0 (0.0)
3-4 year			0 (0.0)
>4 year			3 (75.0)
23. Of the several items below, which ones you can operate to support work at SIMUNDU?			
Excel spreadsheet			
Extract file	61 (23.6)	14 (32.6)	1 (20.0)
Export-import file	42 (16.3)	4 (9.3)	1 (20.0)
Email/browsing	58 (22.5)	6 (14.0)	1 (20.0)
Other	92 (35.7)	18 (41.9)	2 (40.0)
Respondent allows selecting more than one response.	5 (1.9)	1 (2.3)	0 (0.0)
Barrier perception			
Have you ever had difficulty operating SIMUNDU?			
Yes	93 (82.3)	16 (64.0)	2 (50.0)
No	20 (17.7)	9 (36.0)	2 (50.0)
When experienced with difficulties in operating SIMUNDU, with whom you discuss to ask solutions?			
Puskesmas / PHC			
District health office	17 (9.6)	13 (56.6)	0 (0.0)
DIY health office	73 (41.0)	6 (26.1)	0 (0.0)
Other (staff in other health facilities)	66 (37.1)	2 (8.7)	2 (100)
Respondent allows selecting more than one response.	22 (12.4)	2 (8.7)	0 (0.0)

Are you satisfied with the follow-up taken from the results of the consultation?			
No	1 (1.1)	0 (0.0)	0 (0.0)
Yes	92 (98.9)	16 (100)	4 (100)
Report Timeliness			
In SIMUNDU OFFLINE that has been running so far, have you sent the report according to the specified date?			
No	17 (15.0)	4 (16.0)	1 (25.0)
Yes	87 (77.0)	21 (84.0)	3 (75.0)
I'm operating SIMUNDU online.	9 (8.0)	0	0 (0.0)
On the SIMUNDU OFFLINE. Did you experience any obstacles in the SIMUNDU data entry on time?			*
No	67 (59.3)	16 (64.0)	
Yes	46 (40.7)	9 (36.0)	
On the SIMUNDU OFFLINE. Did you have any obstacles in reporting SIMUNDU data on time?			*
Difficulties on the export file	10 (17.2)	4 (36.4)	
Difficulties on email or sending files	13 (22.4)	0	
Difficulties in the extracted file	9 (15.5)	2 (18.2)	
Other	26 (44.8)	5 (45.5)	
Pada SIMUNDU ONLINE, when do you input your baby/toddler data into SIMUNDU			*
The same day after the service is finished	37 (25.7)	4 (16.0)	
<1 week after service	50 (34.7)	10 (40.0)	
One week - 1 month after service	48 (33.3)	10 (40.0)	
> 1 month after service	9 (6.3)	1 (4.0)	
In the ONLINE system, do you have any obstacles in entering data in SIMUNDU timely?			*
No	52 (46.0)	14 (56.0)	
Yes	61 (54.0)	11 (44.0)	
In OFFLINE systems – in 5 scales. How many do you assess the timeliness of the reports you have provided so far?			
1	0 (0.0)	1 (4.0)	0
2	3 (2.7)	1 (4.0)	0
3	36 (31.9)	9 (36.0)	0
4	60 (53.1)	12 (48.0)	3 (75.0)
5	14 (12.4)	1 (8.0)	1 (25.0)
Data Accuracy			
Have you ever found the data entered at SIMUNDU to be different from the data in the immunization service register?			*
No	29 (25.7)	14 (56.0)	
Yes	84 (74.3)	11 (44.0)	
Data verification			
Have you ever verified the data between the data in SIMUNDU and the data in the immunization service register?			*
No	5 (4.4)	8 (32.0)	

Yes	108 (95.6)	17 (68.0)	
When is data verification done?			*
Monthly	42 (38.9)	10 (58.8)	
Bimonthly	4 (3.7)	2 (11.8)	
Three months	23 (21.3)	1 (5.9)	
Semester	17 (15.7)	1 (5.9)	
Other	22 (20.4)	3 (17.6)	
Data completeness			
According to you, are there a lot of menus/items to input into SIMUNDU?			*
No	51 (45.1)	18 (72.0)	
Yes	62 (54.9)	7 (28.0)	
In your opinion, is the completeness of the menu/item entries in SIMUNDU important?			*
No	1 (0.9)	2 (8.0)	
Yes	112 (99.1)	23 (92.0)	
SIMUNDU accessibility			
Do you agree with the statement that "SIMUNDU is easy to operate?			
Agree	108 (95.6)	23 (92.0)	4 (100)
Disagree	5 (4.4)	2 (8.0)	0 (0.0)
Did you analyse the SIMUNDU data?		*	
No	26 (23.0)		0 (0.0)
Yes	88 (77.0)		(4)100)
Over/Under reporting			
Do you have any experience finding data on children/babies in the Immunization Service Register that are not reported to SIMUNDU?			
No	36 (31.9)	13 (52.0)	0 (0.0)
Yes	77 (68.1)	12 (48.0)	4 (100)
Do you have the experience of finding children data in the Immunization Service Register that entry with more than one?			
No	38 (33.6)	15 (60.0)	1 (25.0)
Yes	75 (66.4)	10 (40.0)	3 (75.0)
According to you, does under or over-reporting have an impact on the achievements of the immunization program?			
No	5 (4.4)	1 (4.0)	1 (25.0)
Yes	108 (95.6)	24 (96.0)	3 (75.0)
Facility and infrastructure			
What type of computer do you most use to enter data in SIMUNDU?			
Private laptop	41 (36.3)	4 (14.8)	1 (25.0)
Laptop – office facility	38 (33.6)	4 (14.8)	2 (50.0)
PC – office facility	32 (28.3)	11 (40.7)	1 (25.0)
PC - private	0	0 (0.0)	0 (0.0)
Handphone	0	7 (25.9)	0 (0.0)
Other	2 (1.8)	1 (3.7)	0 (0.0)
Does your current computer/handphone/laptop support your work on operating SIMUNDU?			
No	11 (9.7)	0 (0.0)	1 (25.0)
Yes	102 (90.3)	25 (100)	3 (75.0)

Where are your internet sources from?			
None	0 (0.0)	0 (0.0)	3 (75.0)
Office facility (Wifi)	102 (64.6)	21 (67.7)	1 (25.0)
Data packages pay with their own money	48 (30.4)	9 (29.0)	0
Data packages paid by the office	1 (0.6)	0	0
Other	7 (4.4)	1 (3.2)	0
Respondent allows selecting more than one response			
Is the internet facility that you use, suit your needs for data entry SIMUNDU?			
No	18 (15.9)	2 (8.0)	1 (25.0)
Yes	95 (84.1)	23 (92.0)	3 (75.0)
Where is the source of your electricity?			
PLN	114 (80.9)	25 (80.6)	4 (100)
Genset	27 (19.1)	6 (19.4)	0
None	0	0	0
Other	0	0	0
Respondent allows selecting more than one response.			
Do you have any problems with electricity during SIMUNDU entry?			
No	78 (69.0)	24 (96.0)	4 (100)
Yes	35 (31.0)	1 (4.0)	0
From your side, what are the obstacles in SIMUNDU reporting?			
It is difficult for data entry at SIMUNDU	7 (3.7)	2 (6.1)	0
Do not have time	18 (9.4)	7 (21.2)	1 (20.0)
Have another assignment	95 (49.7)	16 (48.5)	2 (40.0)
My computer skill is poor	37 (19.4)	3 (9.1)	0
Never received SIMUNDU training	11 (5.8)	2 (6.1)	1 (20.0)
Other	23 (12.0)	3 (9.1)	1 (20.0)
Respondent allows selecting more than one response			
Managerial Process			
Do you know the purpose of SIMUNDU development in DIY?			
No	18 (15.9)	6 (24.0)	0
Yes	95 (84.1)	19 (76.0)	4 (100)
Have you ever participated in SIMUNDU in house training?			
No	14 (12.4)	7 (28.0)	1 (25.0)
Yes	99 (87.6)	18 (72.0)	3 (75.0)
When did you last take part in the SIMUNDU in house training?			
< 1 year ago	42 (42.4)	11 (61.1)	0
> 1 year ago	57 (57.6)	7 (38.9)	2 (100)
Which institution conducts SIMUNDU in house training, that you ever attended?			
Puskesmas (PHC)	0 (0.0)	2 (8.0)	0
District/City health office	56 (38.9)	15 (60.0)	0
DIY health office	88 (61.1)	7 (28.0)	0
Other	0 (0.0)	1 (4.0)	2 (100)
Respondent allows selecting more than one response			
What training guides are used during training?			
PPT	80 (49.1)	12 (56.1)	2 (50.0)

Word – hard copy	32 (19.6)	2 (9.5)	1 (25.0)
Word - soft file	36 (22.1)	2 (9.5)	1 (25.0)
Other	15 (9.2)	5 (23.8)	0
Have you ever been monitored and evaluated regarding SIMUNDU?			
No	10 (8.8)	6 (24.0)	0
Yes	103 (91.2)	19 (76.0)	4 (100)
In the last year (July 2019-July 2020), how many times monitoring and evaluation been conducted?			
>2 times	17 (16.5)	2 (10.5)	2 (50.0)
One time	57 (55.3)	11 (57.9)	1 (25.0)
1-2 times	29 (28.2)	6 (31.6)	1 (25.0)
Who did monitor and evaluation SIMUNDU on your place?			
Puskesmas (PHC)	11 (7.0)	11 (39.3)	0
District/City health office	81 (51.3)	8 (28.6)	0
DIY health office	65 (41.1)	8 (28.6)	4 (100)
Other	1 (0.6)	2 (3.6)	0
Respondent allows selecting more than one response			
Did you receive any feedback on the results of the SIMUNDU monitoring and evaluation?			
No	6 (5.8)	0 (0.0)	0
Yes	97 (94.2)	19 (100)	4 (100)
Who gave feedback on the M&E results?			
Puskesmas (PHC)	7 (4.6)	10 (40.0)	0
District/City health office	73 (48.3)	8 (32.0)	0
DIY health office	69 (45.7)	6 (24.0)	4 (100)
Other	2 (1.3)	1 (4.0)	0
Respondent allows selecting more than one response			
In the last year ((July 2019 - July 2020), have you ever monitored the health facility under your supervision?	*	*	
Yes			4 (100)
No			0
Have you ever participated in the dissemination of M&E results as well as updating knowledge?			
No	28 (24.8)	16 (64.0)	0
Yes	85 (75.2)	9 (36.0)	4 (100)
Who is organizing the dissemination of M&E results as well as updating the knowledge?			
Puskesmas (PHC)	3 (2.5)	0 (0.0)	0
District/City health office	53 (44.2)	6 (60.0)	1 (25.0)
DIY health office	63 (52.5)	4 (40.0)	3 (75.0)
Other	1 (0.8)	0 (0.0)	0
Respondent allows selecting more than one response			

*data not applicable

Revisi 3

Date:	04 Jul 2022
To:	"Sulistyawati Sulistyawati" sulistyawati.suyanto@ikm.uad.ac.id
From:	"BMC Health Services Research Editorial Office" Eloisa.HadeNolasco@springer.com
Subject:	Your submission to BMC Health Services Research - BHSR-D-21-00992R2

BHSR-D-21-00992R2
Introduction and implementation of an immunization information system in Indonesia province of Daerah Istimewa Yogyakarta: lessons for scale-up
Sulistyawati Sulistyawati; Trisno Agung Wibowo; Rokhmayanti Rokhmayanti; Andri Setyo Dwi Nugroho; Tri Wahyuni Sukesi; Siti Kurnia Widi Hastuti; Surahma Asti Mulasari; Marta Feletto
BMC Health Services Research

Dear Dr Sulistyawati,

Your manuscript 'Introduction and implementation of an immunization information system in Indonesia province of Daerah Istimewa Yogyakarta: lessons for scale-up' (BHSR-D-21-00992R2) has been assessed by our reviewers. They have raised a number of points which we believe would improve the manuscript and may allow a revised version to be published in BMC Health Services Research.

Their reports, together with any other comments, are below. Please also take a moment to check our website at https://www.editorialmanager.com/bhsr/ for any additional comments that were saved as attachments.
If you are able to fully address these points, we would encourage you to submit a revised manuscript to BMC Health Services Research.
Once you have made the necessary corrections, please submit online at:

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Please also ensure that your revised manuscript conforms to the journal style, which can be found at the Submission Guidelines on the journal homepage.

A decision will be made once we have received your revised manuscript, which we expect by 03 Aug 2022.

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Please be aware that we may investigate, or ask your institute to investigate, any unauthorised attempts to change authorship or discrepancies in authorship between the submitted and revised versions of your manuscript.

I look forward to receiving your revised manuscript and please do not hesitate to contact us if you have any questions.

Best wishes,

Milena Pavlova
BMC Health Services Research
https://bmchealthservres.biomedcentral.com/

Technical Comments:

Editor Comments:
We had to asked a third reviewer to assess the paper.

Below the comments of this reviewer. Please addressed them carefully.

The revised paper will be sent to all three reviewers.

We operate a transparent peer review process for this journal where reviewer reports are published with the article but the reviewers are not named (unless they opt in to include their name).

Reviewer reports:
Reviewer 3: This manuscript examines the roll-out of an immunization information system, SIMUNDU, in the DIY province of Indonesia. The authors aim to derive lessons for further scale-up and roll-out to other regions of Indonesia. To this end, the authors have succeeded in discovering the factors influencing success, and the challenges faced, in the implementation of SIMUNDU. I believe the results and discussion presented in this manuscript will aid the implementation of such systems more broadly across Indonesia, and possibly, in comparable countries/settings.

Specific comments - major
I can see that the manuscript has undergone extensive prior editing. Nonetheless, there remains formatting, spelling, and grammatical issues remain throughout the text. However, these will be solvable with another round of attentive and thorough copy editing. Perhaps the authors could consider the services of a professional academic writing/editing service to help? The quality of writing should not over-ride the overwhelmingly good work that the authors have done here.

Redo Figure 2 so that the text on the diagram is clearer, particularly the smaller text under "System strengths". I suggest re-doing the diagram for a more professional look, perhaps asking a graphic designer to help.

The presentation of quotations could be improved. Include quotation marks around the text, and indicate who gave the quote using a de-identified participant ID.

In the Discussion section, there is much discussion of strengths and positives, but relatively little coverage given on the negative side - things that could have been done better, and ongoing challenges. I suggest revisiting the negatives and expanding the discussion of these aspects.

Can you comment on the similarity of dissimilarity of DIY with other provinces of Indonesia, and how this might influence the recommendations and lessons learned? How likely would an implementation of SIMUNDU succeed if it were rolled out in other areas, using the lessons learned from DIY?
Sample size is mentioned in the "Study limitations" section, particularly for UPS Health Facilities. Whilst it is good to raise this issue, the implications of small sample size require further discussion. What impact might this have on the findings, their accuracy, and broader relevance?

I am not confident that the formatting of the paper is compliant with BMC HSR guidelines. I suggest revisiting the BMC HSR manuscript template/guidelines and ensure that the manuscript follows those rules.

Specific comments - minor
Below are some example suggestions of editorial changes to make. This is not an exhaustive list, and a copy editor will be able to spot and address many more.

Page 1, line 23: avoid opinion-piece style language like "undeniably". Change the opening sentence to begin "Immunization is critical to save …"

Page 1, line 26: here and throughout the manuscript, I think 'Health Office' should be capitalised. The sentence would then be "The Daerah Istimewa Yogyakarta (DIY) Health Office introduced …"

Page 2, line 2: change to "SIMUNDU is a promising innovation for Indonesia, beyond DIY."

Page 2, line 14: change to "According to the WHO, in 2020, an estimated …"

Page 2, line 31: change to "… data are in Microsoft Excel formats;"

Page 3, line 33: change to "Furthermore, SIMUNDU has been developed to …"

Page 4, line 4: change to "The objective of the work presented here was to …"

Page 4, line 19: space required between "any" and "staff"

Page 5, line 2: change to "For UPS facilities, we selected …"

Page 5, line 19: change to "… qualitative interviews would delve into further."

Page 5, line 23-24: fix grammar and spelling mistake. Should be "… their management functions. Selected informants were invited …"

Page 6, line 4: change "districts or cities" to "districts/cities"

Page 6, line 15: change to "… to explore the quantitative study results more deeply."

Page 7, line 7: change to "However, data from both …"

Page 8, line 17: at this point and throughout the manuscript, I suggest renaming these functions. My suggestion is to use the terms Planning, Organization, Leadership, and Control.

Page 8, line 22: change to "the Head of the Disease Prevention and Control Department, …"

Page 9, line 13: change to "This seemed to work effectively."

Page 10, line 1: change to "The role of IT workers in developing SIMUNDU was also significant. They helped develop the system and facilitated correct data entry by assisting data entry operators whenever technical issues arose. IT workers also helped resolve inconsistencies in data records."

Page 10, line 23: "health offices" should be capitalised, so it becomes "Health Offices"

Page 11, line 2: change to " SIMUNDU also facilitated …"

Page 12, line 25-26: change to "… have basic computer skills in word processing and spreadsheet software tools such as Microsoft Word and Excel, respectively."

Page 12, line 28: change to "… have a Bachelor degree (see Table 2). However, 19.4% and …"

Page 13, line 4: change to "However, a number of …"

Page13, line 20: change to "Informants appreciated SIMUNDU as a good system to manage immunization data."

Page 13, line 21-22: change to "… for program managers and policymakers; it allows them to monitor coverage and can help inform planning and programming."

Page 14, line 1: delete erroneous typing "kwkkwkw"

Page 14, line 19-24: change to "This study highlighted individual capacity, technical or system issues, and high workload as the major barriers to sustainability. Conversely, management, system performance, people's behavior, and available resources emerged as the main determinants of SIMUNDU's successful implementation - notably in improving acceptability, implementation costs, and adoption of this innovation (14)."

Page 15, line 18-19: change to "They felt that they were well-supported and treated kindly, and this helped them carry out their work joyfully."

Page 15, line 28: change to "… processes supported the ongoing development of, and learning from, SIMUNDU as a tool …"

Page 15, line 30-32: change to "The same sentiment was reflected in previous research undertaken in the India (17)."

Page 16, line 6-7: change to "Technical problems were another obstacle during the introduction of SIMUNDU, but qualified technicians/developers were able to solve these issues."

Page 16, line 27: add comma after "implementation", so that it becomes "… its development and implementation, positively impacted …"

Page 16, line 36-38: change to "First, the results of in the quantitative study must be considered with respect to the limited sample size, particularly for UPS Health Facilities."

Page 17, line 20: sentence is missing a full stop.

If you have been asked to edit the English language of the main text to improve readability and clarity, and would like the assistance of paid editing services to do this, we can recommend our affiliates, Nature Research Editing Service: https://authorservices.springernature.com/language-editing and American Journal Experts: https://www.aje.com/go/springernature.
Please note that use of an editing service is neither a requirement nor a guarantee of publication. Free assistance is available from our resources page: https://www.springernature.com/gp/researchers/campaigns/english-language-forauthors

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).

Where a mandatory section is not relevant to your study design or article type, for example, if your manuscript does not contain any individual persons data, please write 'Not applicable' in these sections.

For the 'Availability of data and materials' section, please provide information about where the data supporting your findings can be found. We encourage authors to deposit their datasets in publicly available repositories (where available and appropriate), or to be presented within the manuscript and/or additional supporting files. Please note that

identifying/confidential patient data should not be shared. Authors who do not wish to share their data must state that data will not be shared, and provide reasons for this in the manuscript text. For further guidance on how to format this section, please refer to BioMed Central's editorial policies page - http://www.biomedcentral.com/submissions/editorial-policies#availability+of+data+and+materials.

Declarations
- Ethics approval and consent to participate
- Consent to publish
- Availability of data and materials
- Competing interests
- Funding
- Authors' Contributions
- Acknowledgements
- Authors' Information

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Response to reviewer's comment to the paper entitled "Introduction and implementation of an immunization information system in Indonesia province of Daerah Istimewa Yogyakarta: lessons for scale-up"

No	Reviewer's comment	Authors response
1	Reviewer 3 This manuscript examines the roll-out of an immunization information system, SIMUNDU, in the DIY province of Indonesia. The authors aim to derive lessons for further scale-up and roll-out to other regions of Indonesia. To this end, the authors have succeeded in discovering the factors influencing success, and the challenges faced, in the implementation of SIMUNDU. I believe the results and discussion presented in this manuscript will aid the implementation of such systems more broadly across Indonesia, and possibly, in comparable countries/settings.	Dear Reviewer, Thank you for your positive impression of this paper, and we highly appreciate your input.
2	Specific comments - major I can see that the manuscript has undergone extensive prior editing. Nonetheless, there remains formatting, spelling, and grammatical issues remain throughout the text. However, these will be solvable with another round of attentive and thorough copy editing. Perhaps the authors could consider the services of a professional academic writing/editing service to help? The quality of writing should not over-ride the overwhelmingly good work that the authors have done here.	Dear Reviewer, Thank you for your concern. We understand about it. Our last author is a native speaker, and she will work on it. We will go to the professional language editor if she does not have sufficient time.
3	Redo Figure 2 so that the text on the diagram is clearer, particularly the smaller text under "System strengths". I suggest re-doing the diagram for a more professional look, perhaps asking a graphic designer to help.	Figure 2 has been re-produced and inserted in Page 12
4	The presentation of quotations could be improved. Include quotation marks around the text, and indicate who gave the quote using a de-identified participant ID.	The quotation mark has been added in all quotations, with participant ID at the end of the quote.
5	In the Discussion section, there is much discussion of strengths and positives, but relatively little coverage given on the negative side - things that could have been done better and ongoing challenges. I suggest revisiting the negatives and expanding the discussion of these aspects.	In the result (figure 2), we discussed the negative side of SIMUNDU but used the term "potential threat." However, we have also added limitation of SIMUNDU on page 25, line 18
6	Can you comment on the similarity of dissimilarity of DIY with other provinces of Indonesia, and how this might influence the recommendations and lessons learned? How likely would an implementation of SIMUNDU succeed if it were rolled out in other areas, using the lessons learned from DIY?	A description of DIY has been added on page 4, line 17. The possibility of scaling up successfully has been added on page 25, line 22
	The sample size is mentioned in the "Study limitations" section, particularly for UPS Health Facilities. Whilst it is good to raise this issue, the implications of small sample size require further discussion. What impact might this have on the findings, their accuracy, and broader relevance?	Study limitation about limited sample size on UPS has more discussed on page 27, line 10

7	I am not confident that the formatting of the paper is compliant with BMC HSR guidelines. I suggest revisiting the BMC HSR manuscript template/guidelines and ensure that the manuscript follows those rules.	The manuscript has now been adjusted with the author guideline in the journal, especially for using double line spacing
8	Specific comments - minor Below are some example suggestions of editorial changes to make. This is not an exhaustive list, and a copy editor will be able to spot and address many more.	
9	Page 1, line 23: avoid opinion-piece style language like "undeniably". Change the opening sentence to begin "Immunization is critical to save ..."	Thank you for your suggestion. A revision has been made Page: 2 Line: 2
10	Page 1, line 26: here and throughout the manuscript, I think 'Health Office' should be capitalised. The sentence would then be "The Daerah Istimewa Yogyakarta (DIY) Health Office introduced ..."	Thank you for your suggestion. A revision has been made Page: 2 Line: 5
11	Page 2, line 2: change to "SIMUNDU is a promising innovation for Indonesia, beyond DIY."	Thank you for your suggestion. A revision has been made Page: 2 Line: 2
12	Page 2, line 14: change to "According to the WHO, in 2020, an estimated ..."	Thank you for your suggestion. A revision has been made Page: 3 Line: 3
13	Page 2, line 31: change to "... data are in Microsoft Excel formats;"	Thank you for your suggestion. A revision has been made Page: 4 Line: 9
14	Page 3, line 33: change to "Furthermore, SIMUNDU has been developed to ..."	Thank you for your suggestion. A revision has been made Page: 6 Line: 14
15	Page 4, line 4: change to "The objective of the work presented here was to ..."	Thank you for your suggestion. A revision has been made Page: 7 Line: 3
16	Page 4, line 19: space required between "any" and "staff"	Thank you for your suggestion. A revision has been made Page: 7 Line: 18
17	Page 5, line 2: change to "For UPS facilities, we selected ..."	Thank you for your suggestion. A revision has been made Page: 8 Line: 5
18	Page 5, line 19: change to "... qualitative interviews would delve into further."	Thank you for your suggestion. A revision has been made Page: 9 Line: 7
19	Page 5, line 23-24: fix grammar and spelling mistake. Should be "... their management functions. Selected informants were invited ..."	Thank you for your suggestion. A revision has been made Page: 9 Line: 11
20	Page 6, line 4: change "districts or cities" to "districts/cities"	Thank you for your suggestion. A revision has been made Page: 10

		Line: 7
21	Page 6, line 15: change to "... to explore the quantitative study results more deeply."	Thank you for your suggestion. A revision has been made Page: 11 Line: 3
22	Page 7, line 7: change to "However, data from both ..."	Thank you for your suggestion. A revision has been made Page: 12 Line: 1
23	Page 8, line 17: at this point and throughout the manuscript, I suggest renaming these functions. My suggestion is to use the terms Planning, Organization, Leadership, and Control.	Thank you for your suggestion. A revision has been made Page: 13 Line: 7
24	Page 8, line 22: change to "the Head of the Disease Prevention and Control Department, ..."	Thank you for your suggestion. A revision has been made Page: 13 Line: 12
25	Page 9, line 13: change to "This seemed to work effectively."	Thank you for your suggestion. A revision has been made Page: 14 Line: 13
26	Page 10, line 1: change to "The role of IT workers in developing SIMUNDU was also significant. They helped develop the system and facilitated correct data entry by assisting data entry operators whenever technical issues arose. IT workers also helped resolve inconsistencies in data records."	Thank you for your suggestion. A revision has been made Page: 15 Line: 11
27	Page 10, line 23: "health offices" should be capitalised, so it becomes "Health Offices"	Thank you for your suggestion. A revision has been made Page: 15 Line: 21
28	Page 11, line 2: change to "SIMUNDU also facilitated ..."	Thank you for your suggestion. A revision has been made Page: 17 Line: 4
29	Page 12, line 25-26: change to "... have basic computer skills in word processing and spreadsheet software tools such as Microsoft Word and Excel, respectively."	Thank you for your suggestion. A revision has been made Page: 19 Line: 19
30	Page 12, line 28: change to "... have a Bachelor degree (see Table 2). However, 19.4% and ..."	Thank you for your suggestion. A revision has been made Page: 19 Line: 23
31	Page 13, line 4: change to "However, a number of ..."	Thank you for your suggestion. A revision has been made Page: 20 Line: 14
32	Page13, line 20: change to "Informants appreciated SIMUNDU as a good system to manage immunization data."	Thank you for your suggestion. A revision has been made Page: 21 Line: 7
33	Page 14, line 1: delete erroneous typing "kwkkwkw"	Thank you for your suggestion. A revision has been made Page: 22 Line: 4

34	Page 14, line 19-24: change to "This study highlighted individual capacity, technical or system issues, and high workload as the major barriers to sustainability. Conversely, management, system performance, people's behavior, and available resources emerged as the main determinants of SIMUNDU's successful implementation - notably in improving acceptability, implementation costs, and adoption of this innovation (14)."	Thank you for your suggestion. A revision has been made Page: 22 Line: 22
35	Page 15, line 18-19: change to "They felt that they were well-supported and treated kindly, and this helped them carry out their work joyfully."	Thank you for your suggestion. A revision has been made Page: 24 Line: 13
36	Page 15, line 28: change to "... processes supported the ongoing development of, and learning from, SIMUNDU as a tool ..."	Thank you for your suggestion. A revision has been made Page: 24 Line: 23
37	Page 15, line 30-32: change to "The same sentiment was reflected in previous research undertaken in the India (17)."	Thank you for your suggestion. A revision has been made Page: 25 Line: 1
38	Page 16, line 6-7: change to "Technical problems were another obstacle during the introduction of SIMUNDU, but qualified technicians/developers were able to solve these issues."	Thank you for your suggestion. A revision has been made Page: 25 Line: 16
39	Page 16, line 27: add comma after "implementation", so that it becomes "... its development and implementation, positively impacted ..."	Thank you for your suggestion. A revision has been made Page: 26 Line: 22
40	Page 16, line 36-38: change to "First, the results of in the quantitative study must be considered with respect to the limited sample size, particularly for UPS Health Facilities."	Thank you for your suggestion. A revision has been made Page: 27 Line: 8
41	Page 17, line 20: sentence is missing a full stop.	Thank you for your suggestion. A revision has been made Page: 28 Line: 10

Introduction and implementation of an immunization information system in Indonesia province of Daerah Istimewa Yogyakarta: lessons for scale-up

Sulistyawati Sulistyawati, MPH, PhD[1*]

Trisno Agung Wibowo, MPH[2]

Rokhmayanti Rokhmayanti, MPH[1]

Andri Setyo Dwi Nugroho, MPH[2]

Dr. Tri Wahyuni Sukesi, MPH[1]

Siti Kurnia Widi Hastuti, MPH[1]

Dr. Surahma Asti Mulasari, MPH[1]

Marta Feletto, PhD[3]

[1] Faculty of Public Health, Universitas Ahmad Dahlan, Yogyakarta, Indonesia

[2] Daerah Istimewa Yogyakarta (DIY) Health Office, Yogyakarta, Indonesia

[3] Alliance for Health Policy and Systems Research, World Health Organization, Geneva, Switzerland

*Corresponding author: sulistyawati.suyanto@ikm.uad.ac.id.

Kampus 3 - Jl. Prof Dr Soepomo, Janturan, Umbulharjo, Yogyakarta, Indonesia.

Abstract

Background: Immunization is critical to saving children from infections. To increase vaccination coverage, valid and real-time data is needed. Accordingly, it is essential to have a good report system that serves as defaulter tracking to prevent children's immunization failure. The Daerah Istimewa Yogyakarta (DIY) Health Office introduced an electronic immunization registry and successfully implemented it for over than five years. It is the only individual-based record system in Indonesia that has been sustainably operated for a long time. Yet, no systematic assessment of this system has been conducted to date. This study examines the Sistem Informasi Imunisasi Terpadu (SIMUNDU) introduction and implementation process to draw lessons that could inform scalability and sustainability across the country.

Methods: This study used an explanatory sequential mixed-method design, which collected quantitative data from 142 participants and qualitative data from 9 participants. Entry data clerk in a health facility was systematically selected to participate in the survey. While in the key informant interview, the informant was selected based on the survey result. A descriptive and thematic approach was adopted to analyze the quantitative and qualitative data. Results from across the two approaches were integrated for comparison and contrast.

Results: Findings are presented according to three core themes that emerged from the data: system strengths, potential threats, and opportunities for scale-up. Strengths -i.e. factors contributing to the success of SIMUNDU - include management, system performance, people's behavior, and resources. Potential threats to sustaining the system include individual capacity, technical or system issues, and high workload. Opportunities

– i.e promising factors that SIMUNDU can be operated sustainably – such as continuity, expectation and scale up possibility.

Conclusions: SIMUNDU is a promising innovation for Indonesia, beyond DIY. There is agreement about the potential for scale-up of this IIS to other provinces. Experience of implementing this system in DIY over the past five years has shown that the benefits outweigh the challenges, and SIMUNDU has grown into a robust yet user-friendly system.

Keywords: immunization, electronic immunization registry, immunization information system, interoperability, implementation research

Background

Neonatal and childhood vaccination is essential to infectious disease prevention and an absolute human right (1),(2). Vaccination has been proven to reduce the burden of infectious diseases globally (3). According to the WHO, in 2020, an estimated 23 million children under one year did not receive their essential vaccinations. Of these, 60% live in just ten countries, one of which is Indonesia (4). Indonesia is the fourth most populous country globally. It is composed of thousands of islands organized into 34 provinces. Various geographical and cultural factors influence population inequalities to access health services (5). In 2001, the Indonesian government's decentralization policy was enacted. This was an excellent strategy to foster development by engaging regional resources (6). However, this strategy was not without consequence. One primary concern was the Health Information System (HIS) fragmentation.

Indonesia's federal structure results in provinces and districts being relatively independent of the national Ministry of Health. This means that provincial and district-levels information systems are locally regulated (7). For instance, *Pemantauan Wilayah Setempat* (PWS) is a management tool used to monitor coverage of specific health services in an administrative boundary. Depending on the service and region, it can be paper- or electronic-based. PWS-KIA is the monitoring system specific to maternal and child health (KIA), including immunization. PWS-KIA data are reported to the District or City Health Office, go to Province Health Office, and finally reported to the main level. Generally, the data are in Microsoft Excel formats; it will report via emails or various information systems, including Komdat, SiTT, SIHA, PISPK, and SIKDA Generik. PWS-KIA data feeds into District Health Information System 2 (DHIS2). Regional information systems have varying data quality, which reflects inequities in resources across regions. This adds to data integration challenges at the national level (7),(8) and affects strategic policymaking.

In Indonesia's federal system, Daerah Istimewa Yogyakarta (DIY) Province has the authority to regulate and use its budget within its four districts plus one city (Sleman, Gunungkidul, Bantul, Kulonprogo and Yogyakarta). This province is classified as a small province in terms of area size and the number of regions inside (9). However, this region can be considered a representation of Indonesia when viewed from the geographical, socio-economic and heterogeneous population. Regarding childhood vaccination, DIY is among the top ten performing provinces in the country, with 97.7 % of children completing basic immunization coverage in 2019 (10). Immunization services are provided by Primary Health Centres or Puskesmas (PHC), as well as private clinics,

hospitals, and midwives' practices (typically referred to as *Unit Pelayanan Swasta* or UPS).

An electronic immunization registry is a tool for recording individual children's immunization histories. In 2014, the DIY Health Office introduced an electronic immunization registry named SIMUNDU (*Sistem Informasi Imunisasi Terpadu*/ Integrated Immunization Information System). An electronic registry serves essential functions at all levels of the health system. At the district and higher levels, it allows for monitoring vaccination coverage by the vaccine, dose, cohort, and other variables – and can support microplanning and vaccine management. The service delivery level can facilitate individual follow-up of vaccination status and enable health workers to identify children due for vaccination and those who missed their vaccinations (defaulters).

SIMUNDU was designed to link with the PWS-KIA for immunization and interoperability with the DHIS2. While it predominantly contains individual-level immunization records, SIMUNDU also serves as a source for aggregation and can synergize with the *Pemantauan Wilayah Setempat* (PWS) reporting system. For this reason, it can be considered an Immunization Information System (IIS). This means that City and District levels feed into Provincial and National levels *(Personal communication with DIY immunization program officer)*.

The original prototype was designed by the information and technology (IT) department of DIY Health Office to be operated offline. In DIY, three out of the four districts and the city introduced the system in 2015. The final district introduced it in 2017. At this stage, the point of data entry was the PHC only. By 2018, UPS facilities were also equipped with SIMUNDU and could enter data into the system. In 2019, the prototype was further

developed to operate online. The online version was rolled out in 2020 (Figure 1). As of May 2021, 79.4% of all PHC and UPS facilities complied. This average rate masks, however, the fact that while all PHCs adopt SIMUNDU, it is more challenging to enforce its use in UPC facilities (Suyani 2020, oral communication, 2020, May 11).

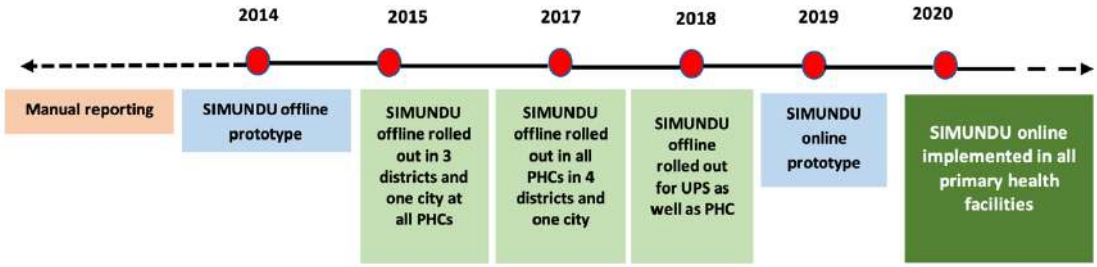

Figure 1. SIMUNDU's development and introduction

When a child receives a vaccination in a health facility, information on the child and the vaccination is entered in SIMUNDU as an individual child record. Each record includes a personal identifier, the child's socio-demographic characteristics (e.g., name, gender, date of birth, name of parents, address), the antigen administered, and the date and place of vaccination. SIMUNDU has been recently updated to allow the recording of vaccinations administered in schools (e.g., Human papillomavirus (HPV), Diphtheria Toxoid (DT), Tetanus-Diphtheria (TD), and Measles-Rubella (MR), though in the form of aggregate data only. Furthermore, SIMUNDU has been developed to record COVID-19 vaccinations in health facilities and those carried out in masse.

Monitoring is conducted monthly to assess data completeness across health facilities, while an evaluation is conducted yearly. These exercises have allowed the identification of several challenges related to implementing the system (e.g., workload, staff turnover, and rotation) and data quality (e.g., accuracy and timeliness). However, no systematic assessment of the system has been conducted to date. SIMUNDU is the first

immunization information system ever introduced in Indonesia. Other districts and provinces have shown interest in rolling it out, and the Ministry of Health has acknowledged the innovation. The work presented here aims to examine SIMUNDU's introduction and implementation process to draw lessons that could inform scalability and sustainability across the country.

Methods

From May to October 2020, we examined the experience of introducing and implementing an immunization information system in the DIY province using an explanatory sequential mixed-method design, where each step informed the next (11). First, we reviewed of all relevant documentation available in the DIY Health Office – e.g., staff notes, meeting notes and monitoring notes – documenting SIMUNDU development and management processes. We also examined online documents, including health profiles and regulations on health reporting systems in Indonesia. This served as the initial data source and provided an overview of who was involved and how in developing and implementing SIMUNDU. This informed the survey design that we conducted as a second step. The survey targeted any staff responsible for entering data in SIMUNDU (i. e. data clerks) across all PHC and selected UPS facilities and any staff responsible for managing the system at the district and city level (i. e., immunization coordinators). Sampling and recruitment strategies are outlined in Table 1.

Table 1. Survey participant

Level of the data entry and reporting system	Total number of facilities/ offices	Study population	Sampling strategy	Recruitment	Sample size
Primary Health Centre (PHC)	121	Data entry clerks	All facilities	Open invitation across all facilities	113
UPS - Central, General, Maternity and Pediatric Hospitals	65	Data entry clerks	Randomly selected 2 facilities per district/city (2*5=10)	Open invitation across selected facilities	8
UPS - Clinics	73	Data entry clerks	Randomly selected 2 facilities per district/city (2*5=10)	Open invitation across selected facilities	7
UPS - Midwives' Practices	271	Data entry clerks	Randomly selected 2 facilities per district/city (2*5=10)	Open invitation across selected facilities	10
District/City Health Office	5	Immunization coordinators	Total sampling	Open invitation	4*
			Total		**142**

*When the immunization coordinator had recently changed, the former was also invited.

All immunization coordinators in each district/city and data entry clerks from all primary health facilities (PHC) were invited to participate in this survey. For UPS facilities, we selected two clinics, two midwives' practices, and two hospitals per district/city and invited all of their staff to be involved in SIMUNDU data entry and management.

We developed and pre-tested an online survey in Bahasa Indonesia to inquire about SIMUNDU implementation, processes, and outcomes across PHC, UPS clinics, district or city and province offices. The questionnaire consisted of close-ended and Likert scale questions – ranging from 45 to 50 depending on the target type of facility and/or level of the health system – and enquired about respondents' socio-demographic characteristics as well as the process of implementing and managing SIMUNDU. Some questions provided an additional field for clarifying the reason for a particular answer choice.

All participants were invited to the DIY Health Office to complete the survey on their laptops, with their prior consent. All participants in a room allowed researchers to monitor any missing or incomplete responses in real time and follow up with individual participants on-site to fill any gaps. We don't believe this may have introduced any significant bias as researchers would simply flag any missing responses and invite respondents to address those. Data were then exported and analyzed in Microsoft Excel. An exploratory analysis of the survey data informed the topic areas that qualitative interviews explore into further.

Similarly, some informants were purposefully selected among survey participants to follow up on the range of perspectives that had emerged from the survey. Other informants had been identified at the desk review stage and chosen for their management functions. Selected informants were invited to the DIY Health Office for the interview, and COVID-19 prevention protocol was observed. Every informant was informed about the study and asked to sign the informed consent. All invited informants agreed to participate. A total of nine 30-minute semi-structured interviews were conducted in Bahasa Indonesia language and recorded with prior consent from participants. The interview team consisted of three researchers with the respective task of running the interview, observing and taking notes. A research assistant transcribed all interviews in Bahasa Indonesia language.

Thematic analysis was conducted using Quirkos qualitative tool following Braun and Clarke's approaches (12). Researchers familiarized themselves with the data, searching for initial codes and allowing themes to emerge. The principal investigator led the coding process, and led the research team in defining and naming the core themes emerging from the data, organizing and analyzing the data across the themes, and triangulating

information from the desk review, the survey, and the interviews. This stage was also performed in Bahasa Indonesia. Data were translated to English only at sub-theme and core themes.

Results

Characteristic participant

a. Quantitative study

In total, 142 respondents participated in this study spread across five districts/cities in the DIY province. Most respondents came from Gunungkidul District, PHC, UPS, and DHO, 24.8%, 24%, and 25%, respectively. For all research units, the majority are women. At the UPS and DHO/CHO levels, most respondents were aged 41-45 years, i.e., 28.3% and 75%, respectively, while at the UPS level, the majority were aged 25-30 years (56.0%). For education level, PHC and UPS are dominated by Diploma 3 graduates, namely 86.7% and 80%, respectively, while in DHO/CHO, it is predominantly undergraduate graduates (75%) (Table 2)

Table 2. Characteristic respondents in three groups of respondents

Characteristic	PHC (n= 113) n (%)	UPS (n=25) n (%)	DHO/CHO (n= 4) n (%)
District/City			
Bantul	23 (20.4)	5 (20.0)	1 (25.0)
Gunungkidul	28 (24.8)	6 (24.0)	1 (25.0)
Yogyakarta	17 (15.0)	4 (16.0)	0 (0.0)
Kulonprogo	21 (18.6)	4 (16.0)	1 (25.0)
Sleman	24 (21.2)	6 (24.0)	1 (25.0)
Sex			
Male	3 (2.7)	0 (0.0)	2 (50.0)
Female	110 (97.3)	25 (100)	2 (50.0)
Age			
< 25	0 (0.0)	5 (20.0)	0 (0.0)
25-30	3 (2.7)	14 (56.0)	0 (0.0)
31-35	30 (26,5)	3 (12.0)	0 (0.0)
36-40	19 (16.8)	1 (4.0)	0 (0.0)
41-45	32 (28.3)	0 (0.0)	3 (75.0)
46-50	18 (15.9)	0 (0.0)	1 (25.0)
>50	11 (9.7)	2 (8.0)	0 (0.0)

Education			
Master	0 (0.0)	1 (4.0)	1 (25.0)
Bachelor	5 (4.4)	1 (4.0)	3 (75.0)
Diploma 4	9 (8.0)	2 (8.0)	0 (0.0)
Diploma 3	98 (86.7)	20 (80.0)	0 (0.0)
Senior high school	1 (0.9)	1 (4.0)	0 (0.0)

b. Qualitative study

Nine informants were recruited to provide the required information to explore the quantitative study results more deeply. They serve as managers and staff at DHO/CHO, PHC, and UPS. Among the nine informants, 2 were men, and 7 were women. Three informants graduated with master's, one bachelor's, and five diplomas graduates (Table 3).

Table 3. Informants' characteristics for the qualitative study

Sex	**Age (years)**	**Education**	**Position**	**Subject group**	**Informant's code**
Female	56	Magister	Head of disease prevention and control department at PHO level	Managerial	M 01
Male	57	Magister	The former of the disease prevention and control section at the PHO level	Managerial	M 02
Male	54	Bachelor	Immunization programmer at the PHO level	Managerial	M 03
Female	47	Magister	IT Person	Managerial	M 04
Female	34	Diploma	Data entry at the PHC level	Staff	S 01
Female	25	Diploma	Data entry at the UPS level	Staff	S 02
Female	31	Diploma	Data entry at the UPS level	Staff	S 03
Female	42	Diploma	Data entry at the PHC level	Staff	S 04
Female	24	Diploma	Data entry at the PHC level	Staff	S 05

c. Finding

Findings from the study are organized and presented across the three core themes that emerged from the qualitative analysis, notably system strengths, potential threats, and

opportunities for scale-up. However, data from qualitative and quantitative data fed into the analysis of these core themes to cross-validate the findings (Figure 2. Detailed findings from the survey are presented in Table Supplement 1.

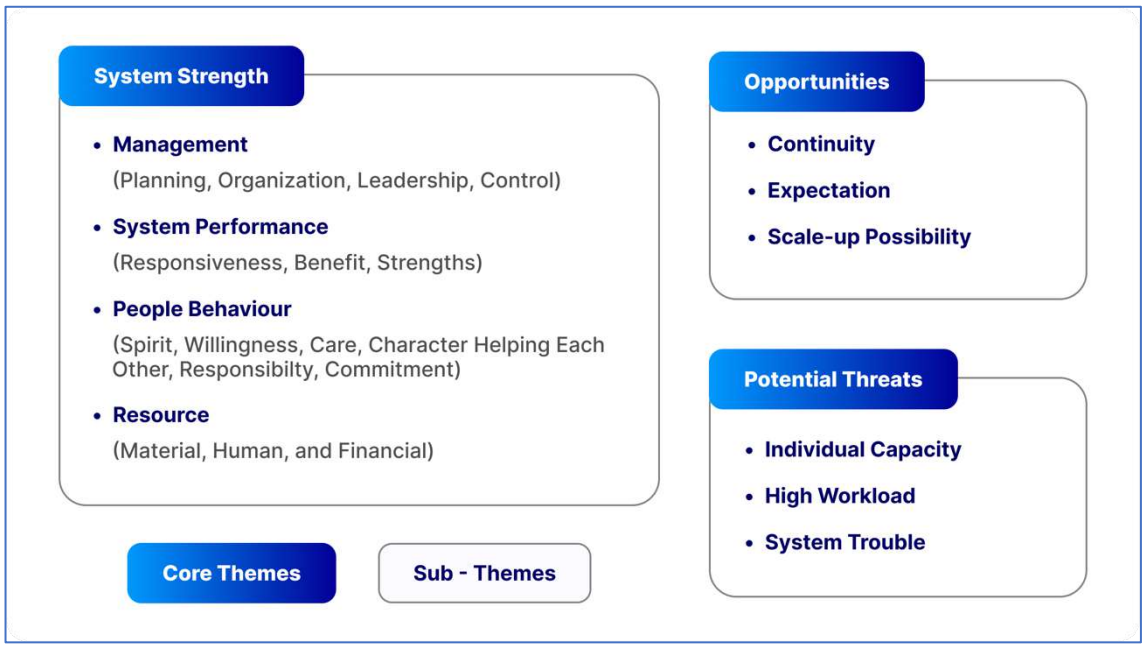

Figure 2. Strengths, potential threats, and opportunities for scale-up

System's Strengths

Factors contributing to the success of SIMUNDU include management, system performance, people's behavior, and resources.

Management

SIMUNDU arose due to concerns from the DIY Health Office immunization section around data quality, notably the need to address data inaccuracy, duplicate or missing data and lack of timely data, and the need for quality data to support follow-up and appropriate planning. The need for SIMUNDU arose from these challenges and needs.

"To our knowledge, [SIMUNDU development] started with a problem: estimates of the target population varied depending on the data source" (M02)

"Yes, I think [SIMUNDU management team] started to tire of managing a large volume of data with dubious validity. They need to know the situation in each district". (M04)

Effective management of SIMUNDU from development to implementation was highlighted as an essential determinant of its success across the critical functions of Planning, Organization, Leadership, and Control.

Careful **Planning** was ensured at each stage of SIMUNDU development and implementation. These stages included developing an initial business plan, providing training on and socialization to SIMUNDU, and developing a staff replacement plan to respond to turnover or retirement of staff in charge of operating the system or entering data. The parties involved in planning included the Head of the Disease Prevention and Control Department, IT personnel, and from the DIY Health Office immunization program staff.

Organization- the organization of SIMUNDU, is carried out at several levels. The top level is the DIY Health Office, the second level is the district/city health office, and the third level is health facilities (Figure 2). A third party was also involved in developing the system interface.

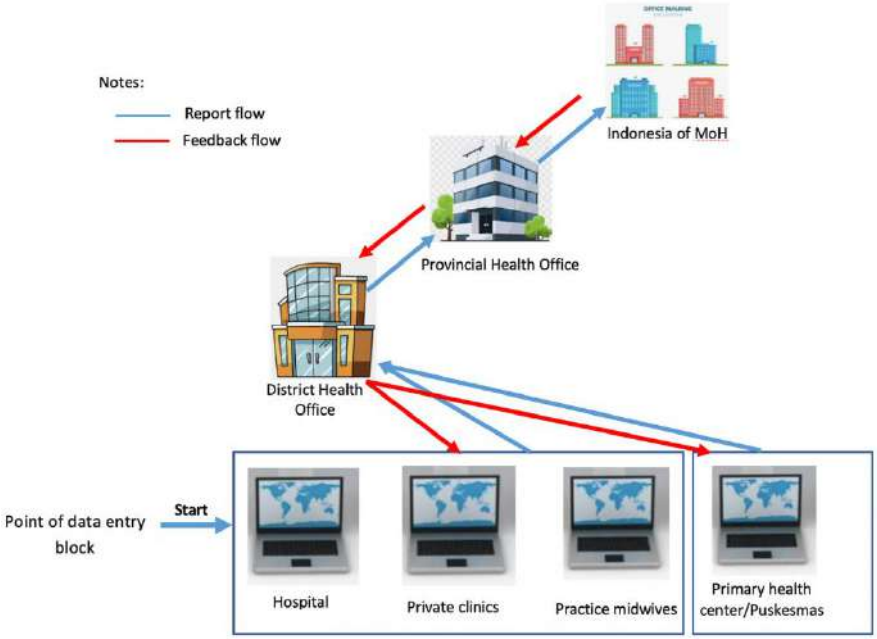

Figure 2. Visual organizing framework of SIMUNDU – DIY Province, Indonesia

At the beginning of SIMUNDU development, essential functions included database administrators, interface designers, and server administrators, and their interplay facilitated the system's smooth operation. Training specific to SIMUNDU was integrated with other training, typically immunization-related training. This enabled us to share of resources with other programs, thus ensuring viability. The training was delivered in the district/city health office: 87.6%, 72%, and 75% of survey respondents from PHC, UPS, and DHO/CHO, respectively had participated in in-house training. Training typically consisted of short sessions and included practice on the trainee's device to operate the system in both online and offline mode. Informants indicated that day-to-day operations were carried out autonomously by the staff through flexibly adjusting their work to protect the time to enter the data. This seemed to work effectively.

Leadership - the success of SIMUNDU implementation is arguably related to strong leadership. Informants noted that managers played a crucial role in bridging the needs of

the immunization program with the system design, closely monitoring the initial implementation process, and creating an enabling environment.

"I try to combine supporting and managing and monitoring the people imvolved. Currently, I monitor whether [SIMUNDU] can run optimally as our users are health facilities. I also monitor program development and the system's output." (M01)

"[SIMUNDU] was born from program managers, primary health centers, Districts, and DIY Health Offices wanting to build systems together. We – DIY Health Office - give them motivation in every meeting." (M03)

"I see that [management] is very good at networking. Staff data entry in the field always said that these people are very kind." (M02)

The role of IT workers in developing SIMUNDU was also significant. They helped develop the system and facilitated correct data entry operators whenever technical issues arose. IT workers also helped resolve inconsistencies in data records. Acknowledgment of staff efforts was also important to maintain motivation and buy-in.

"In the early days of SIMUNDU's development, the system was challenging to operate, as it wasn't as stable as it is now. I praise the enthusiasm and dedication of the users." (M01)

The **control** function - consisting of **quality** assurance management - was critical to avoid data duplication or missing entries and ultimately ensure data quality. This process was not regulated by specific Standard Operating Procedures but was addressed during training and monitored monthly. In addition, the DIY Health Office provided negative incentives to health facilities that were not submitting complete records and provided regular feedback from monitoring and evaluation exercises.

Specifically, 94.2%, 100%, and 100% of survey respondents in PHC, UPS, and DHO, respectively, reported their work had been subject to monitoring. More than half of the respondents in PHC and UPS facilities had been observed by supervisors while performing data entry at least once over the past year. At the PHC level, 48.3% of survey respondents had been subject to monitoring from the district/city office's team, and 45.7% received monitoring from DIY Health Office's staff. Conversely, 40% of respondents from UPS facilities were monitored by PHC's staff. Almost all survey respondents reported receiving feedback from the monitoring, mainly from the District/City and DIY Health Offices. Forty percent of respondents from UPS facilities reported receiving feedback from PHC. Immunization coordinators from the District/City Health Offices received feedback from the DIY Health Offices.

"In a [evaluation] meeting, DIY Health Office or District Health Office showed the progress of our data entry – correct or not, proper or not." (M02)

It is worth noting that DIY Province is quite a small geographic area. Because it consists of only five districts and one city, this province is relatively easy to monitor across all phases, from planning through monitoring and evaluation.

System performance

While SIMUNDU predominantly contains individual-level immunization records, it also serves as a source for aggregation and can synergize with other information systems. Notably, SIMUNDU can link to the DHIS2 and generate immunization-specific reports per the Ministry of Health's requirements. These reports are sent to the upper levels automatically if SIMUNDU is operated online or submitted via email if SIMUNDU is

operated offline. This functionality has had an essential role in ensuring the acceptability and adoption of the system.

Informants noted how transitioning from paper-based tools to an electronic system made data entry easier and reduced errors. SIMUNDU also facilitated the implementation of protocols for data storage and security. It enabled follow-up and defaulter tracking. Finally, integration with the DHIS2 meant reduced workload for the staff.

"We can track children who may have received vaccinations in different locations faster. For example, when the first dose of a vaccine is given in Bantul and the second one in Yogyakarta, the record can be linked within SIMUNDU" (M01).

"SIMUNDU makes detecting what data and vaccinations are missing easier since we enter data from the children's birth through the end of the immunization schedule. So, we will know where they miss any vaccine." (S03)

"The benefit of using SIMUNDU is first: we know the situation of immunizations more accurately….so our vaccine forecasting is more accurate …. and our budget, staff, facilities can be more effective and efficient in providing services." (S05)

"Colleagues from the mother and child health (KIA) program enter the data via the KIA "Sembada." So, this data will appear automatically in SIMUNDU because the two system are connected." (S01)

SIMUNDU is user-friendly and can be flexibly operated offline or online, allowing the responsible staff to maintain data entry irrespective of connectivity. 82.3%, 96%, and 100% of survey respondents from PHC, UPS, and DHO, respectively reported operating SIMUNDU online.

People's behavior

The interview showed that staff commitment was critical for the successful implementation of SIMUNDU, as indicated by their willingness to work overtime and bring home the data to enter into the system.

"I take it [the data] home too, for example, after immunization sessions– in my clinic, immunization runs four times per month, every week. So, when the session is finished, we can take the data home, [and] do the entry at home while relaxing." (S03)

The interviews confirmed this dedication, which spoke to a societal culture of helping others and responsibility and commitment to the team. This contributed to shaping an environment where people approach SIMUNDU as a shared responsibility and a collective endeavor. Informants also noted the high motivation of dedicated staff.

"That's all; we cannot judge by money [people's kindness, culture, and behavior]; explaining how good people are in Yogyakarta is essential. I was in another place before, and could not find people's kindness like in Yogyakarta - different characters." (M02)

"The second thing is that we need human resources concerned and love for data; otherwise, even though we have a good system, it will amount to nothing without good human resources. But good implementation will come more easily when people are concerned about data." (M04)

Resource: material, human and financial

Infrastructure and equipment emerged as critical factors in introducing and sustaining SIMUNDU implementation. Some desktops were explicitly allocated to the

immunization program, and some had to be shared with other staff. Other data entry officers reported using their laptop or smartphone (36.3% of survey respondents from PHC). In UPS facilities, 40.7% reported using office desktops; in the DHO, more than half of the respondents stated they used an office-supplied laptop. The majority of respondents – regardless of the type of facility - said their current device was sufficient to perform their work on SIMUNDU. Regarding connectivity, 64.6% of PHC survey respondents and 67.7% of UPS's reported operating SIMUNDU online, relying on the office's internet connection.

Management of financial resources was also crucial. According to the key informants, no special funds were allocated to SIMUNDU in the initial stages. Resources were leveraged through sharing activities – e.g., monitoring visits or transportation - with other programs, thus allowing cost efficiencies. Integration with other programs proved critical to ensuring sustainability.

"SIMUNDU's budget comes from the state budget called as Anggaran Pendapatan dan Belanja Negara (APBN). Every year the APBN allocates funding envelope for immunization to DIY and other provinces, where the budget is apportioned across the program [not explicitly written budget for SIMUNDU]." (M02)

Human resources are critical to the operation of SIMUNDU. According to interview, SIMUNDU data entry clerks must have patience, work carefully and not rush, be interested in data, be responsible, and have basic computer skills in word processing and spreadsheet software tools such as Microsoft Word and Excel, respectively. As shown by the survey, the large majority of SIMUNDU-operating staff was educated: at least 80% of data entry clerks in either PHC or UPS facilities have secondary education (>80%),

while at the managerial level (DHO), 75% of respondents have a Bachelor's degree (see Table 2). However, 19.4% and 9.1% of respondents from PHC and UPS facilities, have low computer literacy.

Various data entry clerks looked for strategies to resolve the obstacles they encountered when entering data to SIMUNDU. Based on the interviews, some clerks furthered their computer skills by taking private computer classes. Others learned from colleagues at their offices, or reached out for help to the district person in charge. To deal with the accumulation of data needing to be entered in SIMUNDU, staff would sometimes work at home after office hours, as their busy schedule at work did not allow time for data entry.

"If we found obstacles, we asked people in charge in PHC – asking for a solution or sharing by WhatsApp – or sometimes I asked the IT person in the DIY Health Office."

(S03)

Potential threats

As of today, SIMUNDU can be said to be a successful experience. However, some obstacles were encountered and addressed during implementation. Potential system sustaining include individual capacity, technical or system issues, and high workload. Staff computer literacy was identified as one of the main sustainability challenges. Internet connectivity was another obstacle, as not a good network equally supported all health facilities. The survey shows that 64.6% and 67.7% of PHC and UPS staff used office internet, while others had to rely on their home internet.

Further, incomplete and inconsistent records – such as differing child's date of birth or name spelling across relevant entries - make it challenging to consistently record

immunization information. These challenges have arisen during implementation and were promptly addressed. Yet, they had an impact on staff who was already juggling busy schedule in the office, causing delays in data entry. As shown by the survey, almost all respondents stated having other responsibilities besides operating SIMUNDU – notably 97.3%, 88%, and 100% of participants from PHC, UPS and district and city offices, respectively.

Opportunities

Informants appreciated SIMUNDU as an excellent system to manage immunization data. SIMUNDU has become necessary for program managers and policymakers; it allows them to monitor coverage and can help inform planning and programming. Currently, SIMUNDU is stable, thus is easier to manage than when it was in the development phase. It is also viable and no longer requires heavy reliance on the core workforce that started the system. The hopes expressed by data entry clerks in the interviews are that SIMUNDU is easier to operate and system errors are less frequent. Informants also stressed the need for refresher training to ensure knowledge and practice of the system is not lost.

"In my opinion, SIMUNDU is the best program in DIY, a collaboration between program managers and IT. It will continue to be implemented because it is a necessity. It has been stably used for more than five years, meaning this is needed." (M01)

"If I have the tool, in this case, SIMUNDU, when it is stable, whoever will be able to run it, I am sure that anyone can operate it. It means that it doesn't matter if we have people shifting (jobs)." (M01)

"In the future, if SIMUNDU is still used, other reports are not necessary. Now we have two different reports: SIMUNDU and stock card of vaccine – each stand-alone and need a separate report." (S05)

Based on the key informants' interviews, SIMUNDU is likely to be developed further / or expanded to other provinces. The DIY Health Office is open to supporting other provinces interested in introducing the system, for instance, through the lending staff for training and orientation. However, informants advised that a successful introduction requires a strong commitment from staff and management.

Discussion

Robust health information systems (HIS) are essential components of robust health systems (13). At the most basic level, immunization registries are systems that collect and report individual-level vaccine administration record data, thus facilitating individual follow-up of vaccination status. Registries also allow for the monitoring of vaccination coverage and enable analysis of AEFIs and surveillance data to inform the design of coverage interventions and outbreak investigations. When an electronic registry has interoperability with other electronic systems – such as in the case with SIMUNDU – it is considered an Immunization Information System (IIS) (14). This paper presents lessons learned from DIY's experience implementing an IIS.

DIY is the only province in Indonesia – out of thirty-four - that uses an IIS. This work has shed light on the strengths and underlying barriers of implementing an IIS in this context. The objective of this study was to draw lessons that inform sustainable scale-up in other provinces and possibly at the national level. This study highlighted individual capacity, technical or system issues, and high workload as the major barriers to

sustainability. Conversely, management, system performance, people's behavior, and available resources emerged as the main determinants of SIMUNDU's successful implementation - notably in improving acceptability, implementation costs, and adoption of this innovation (15).

Despite several obstacles encountered during the implementation of SIMUNDU, this study showed that this innovation was well accepted by key stakeholders. On the one hand, data entry clerks noted that the system is relatively user-friendly and allows to organize the data better and enhance its quality. On the other hand, managers noted the benefits this innovation brought about, namely in the potential for cohort data to support planning and monitoring and ultimately improve immunization coverage.

Effective management - across planning, organization, leadership, and control functions – is a crucial reason why SIMUNDU has been viable for over 5 years. Managers use their control to encourage the beliefs and actions of the staff with a dedicated and robust managerial process (16). SIMUNDU was born from the need for credible data to assist in carrying out DIY Health Office duties at the managerial and operational levels. At the managerial level, the disease prevention and control department and the IT department collaborated in designing a system that intended users readily accepted. Immunization officers and IT programmers played a central role from the early stages of development through implementation with effective coordination and communication. They were helped in this task with the full support of their respective superiors.

SIMUNDU is cost-effective in several ways. During the introductory period of its implementation, immunization programmers, IT officers, and other staff assisted in introducing SIMUNDU in all districts in the province. This was done by integrating some

of the activities across programs, thus building efficiency in terms of time and costs for both managers and staff. Sharing resources across programs was critical in the first years of building sustainability. Additionally, SIMUNDU maintenance does not require high costs because the DIY Health Office has developed the system and thus possesses in-house technical skills. The IT department has the capacity to monitor and improve processes and tailor them to user needs without much additional cost.

A good program without good leadership could fail in its implementation, and even if it was initially successful, it might not be sustainable (17). In the context of SIMUNDU, leadership and effective management support facilitated the program's adoption. The uptake of the new system was good and all health facilities providing immunization services have successfully transitioned to SIMUNDU. The strong network of the prominent persons in charge of SIMUNDU also facilitated the adoption. Good communication, care, and attention to staff concern positively affected staff performance. They felt that they were well-supported and treated kindly, and this helped them carry out their work joyfully. According to several informants, the DIY immunization program manager's leadership played an essential role in this effect.

The monitoring and evaluation mechanisms of SIMUNDU were also important. Preferred monitoring and evaluation activities include monthly reports and staff discussions during site monitoring visits. The immunization program manager suggested this approach to maintain data quality and ensure the system sustainability. These chosen mechanisms allow program managers to assess the actual practice in the field and the challenges faced to inform decisions about the follow-up actions to be taken. These processes supported the ongoing development of and learning from, SIMUNDU as a tool for data collection, analysis, and visualization, as well as the benefits for managers to

carry out monitoring and evaluation. The same sentiment was reflected in previous research undertaken in the India (18).

Human resources are a key determinant of the successful implementation of any HIS (19). People's behavior affects how the system works, develops, and survives (20),(21). In the case of SIMUNDU, implementation was facilitated by a culture of care, established networks, and a positive attitude towards data of both the program manager and IT team. From the staff's point of view, the local culture of helping each other and doing their job correctly and responsibly translated into staff carrying out their duties with enthusiasm and high commitment. Although facilities, funding and human resources were limited, the individuals involved were highly motivated and supportive.

Despite the many strengths of SIMUNDU, some obstacles may potentially challenge its sustainability in the long term. These obstacles can be divided into human variables and technical variables. From the human variables side, unequal capacity distribution at the operational level can result in differing levels of data quality across facilities and districts. Staff workload is another challenge need addressing, as their willingness to work overtime is not a sustainable strategy. Technical problems were another obstacle during the introduction of SIMUNDU, but qualified technicians/developers could solve these issues. During our research, we recognized the weakness of SIMUNDU that it had not used the person number as a unique code in data entry. This impacts SIMUNDU's inability to synchronize with other health programs that use a person's number as a unique code. However, this weakness can be seen as room for improvement for SIMUNDU shortly. Another thing that needs to be considered for other regions that will implement SIMUNDU that SIMUNDU is that implemented in the DIY province which consists of 5 districts/cities with relatively easy regional accessibility. For areas with more difficult

access, the commitment of the leadership and subordinates is the key to successful implementation.

Conclusion and recommendation

SIMUNDU is a promising innovation for the entire country, beyond DIY. There is agreement about the potential for scale-up of this IIS to other provinces. Experience of implementing this system in DIY over the past five years has shown that the benefits outweigh the challenges, and SIMUNDU has grown into a robust yet user-friendly system. Regular training to dedicated staff for strengthen their capacity as the system evolves and is updated, and a plan for anticipating and responding to staff turnover have proven critical strategies towards sustainability. SIMUNDU's success also rests on remarkable leadership, both in creating and enabling a supportive environment and pursuing integration with other programs to share limited resources.

This study's recommendations address three different stakeholders groups: the DIY Health Office, the national government, and researchers. First, to ensure continuity and sustainability and reduce the system's dependency on a particular person or party, SIMUNDU management and maintenance should be managed by people who have competency and interest in a good reporting system. Furthermore, a human resources plan should be developed in preparation for SIMUNDU roll-out in other provinces or at the national levels; this is necessary to avoid vacancies when DIY province staff are seconded to other areas for mentoring support. Second, the fact that SIMUNDU emerged from an actual need for immunization programme implementers and saw these at the front-line of its development and implementation, positively impacted its feasibility and viability. This suggests that the approach to scaling up SIMUNDU should be stepwise, considering each

region's specific characteristics and needs. To this effect, a readiness map and a timeline may be developed to roll out of SIMUNDU in a particular region. Third, further research is needed to assess the impact of SIMUNDU on immunization coverage. Based on our conversations with stakeholders, it would be particularly relevant to focus on a low-performing region and observe the impact over a 2 to the 3-year time window.

Study limitations

The empirical results reported herein should be considered in light of limitations. First, the results of the quantitative study must be considered concerning the limited sample size, particularly for UPS Health Facilities. However, considering the top-down immunization program and the characteristics of UPS, which will not be significantly different from each other, the results of this study are still valid and relevant to the existing. In qualitative research that aims to explore, caution is needed in interpreting the interview results. These results still a need in-depth studies with different approaches, such as focus group discussions to confirm the results.

Declarations

Ethics approval and consent to participate

This study was approved by the Ethical Review Board of Universitas Ahmad Dahlan, Yogyakarta, Indonesia (ethical approval code: 012005021). Before data collection began, consent to participate was obtained from research subjects (both survey and key informant interviews).

Adherence to national and international regulations

Not applicable

Consent for publication

Before data collection begins, an approval that data is taken for publication purposes is obtained from research subjects (both surveys and key informant interviews).

Availability of data and materials

The datasets generated and or analyzed for this study can be requested from the corresponding author.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

SS, TAW, RR, ASDN and MF designed the study. SS, TWS, SKW, SAM collected the data. SS and RR conducted data analysis. SS developed the paper with inputs and comments from MF on each draft. All authors agree with the manuscript’s results and conclusions.

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Authors' information:

The authors alone are responsible for the views expressed in this article. They do not necessarily represent the views, decisions, or policies of the institutions affiliated with them.

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BMC Health Services Research

Introduction and implementation of an immunization information system in Indonesia province of Daerah Istimewa Yogyakarta: lessons for scale-up

--Manuscript Draft--

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Corresponding Author:	Sulistyawati Sulistyawati, PhD Ahmad Dahlan University: Universitas Ahmad Dahlan Yogyakarta, Yogyakarta INDONESIA
Corresponding Author E-Mail:	sulistyawati.suyanto@ikm.uad.ac.id
Corresponding Author Secondary Information:	
Corresponding Author's Institution:	Ahmad Dahlan University: Universitas Ahmad Dahlan
Corresponding Author's Secondary Institution:	
First Author:	Sulistyawati Sulistyawati, PhD
First Author Secondary Information:	
Order of Authors:	Sulistyawati Sulistyawati, PhD

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Introduction and implementation of an immunization information system in Indonesia province of Daerah Istimewa Yogyakarta: lessons for scale-up

Sulistyawati Sulistyawati, MPH, PhD[1*]

Trisno Agung Wibowo, MPH[2]

Rokhmayanti Rokhmayanti, MPH[1]

Andri Setyo Dwi Nugroho, MPH[2]

Dr. Tri Wahyuni Sukesi, MPH[1]

Siti Kurnia Widi Hastuti, MPH[1]

Dr. Surahma Asti Mulasari, MPH[1]

Marta Feletto, PhD[3]

[1] Faculty of Public Health, Universitas Ahmad Dahlan, Yogyakarta, Indonesia

[2] Daerah Istimewa Yogyakarta (DIY) Health Office, Yogyakarta, Indonesia

[3] Alliance for Health Policy and Systems Research, World Health Organization, Geneva, Switzerland

*Corresponding author: sulistyawati.suyanto@ikm.uad.ac.id.

Kampus 3 - Jl. Prof Dr Soepomo, Janturan, Umbulharjo, Yogyakarta, Indonesia.

Abstract

Background: Immunization is ~~undeniably~~ critical to savinge children from infections. To increase vaccination coverage, valid and real-time data is needed. Accordingly, it is essential to have a good report system that serves as defaulter tracking to prevent children's immunization failure. The Daerah Istimewa Yogyakarta (DIY) H~~h~~ealth O~~o~~ffice introduced an electronic immunization registry and successfully implemented it for ~~more~~ over than five years. It is the only individual-based record system in Indonesia that has been sustainably operated for ~~such~~ a long time. Yet, no systematic assessment of this system has~~d~~ been conducted to date. This study examines the Sistem Informasi Imunisasi Terpadu (SIMUNDU) introduction and implementation process ~~in order~~ to draw lessons that could inform scalability and sustainability across the country.

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Results: Findings are presented according to three core themes that emerged from the data: system strengths, potential threats, and opportunities for scale-~~-~~up. Strengths -i.e. factors contributing to the success of SIMUNDU - include management, system performance, people's behavior, and resources. Potential threats to sustaining the system include individual capacity, technical or system issues, and high workload. Opportunities

– i.e promising factors that SIMUNDU can be operated sustainably – such as continuity, expectation and scale up possibility.

Conclusions: SIMUNDU is a promising innovation for ~~the entire country~~Indonesia, beyond DIY. There is agreement about the potential for scale-up of this IIS to other provinces. Experience of implementing this system in DIY over the past five years has shown that the benefits outweigh the challenges, and SIMUNDU has grown into a robust ~~and~~ yet user-friendly system.

Keywords: immunization, electronic immunization registry, immunization information system, interoperability, implementation research

Background

Neonatal and childhood vaccination is ~~an~~ essential ~~component of~~to infectious disease prevention and an absolute human right (1),(2). Vaccination has been proven to reduce the burden of infectious diseases globally (3). According to the WHO, in 2020, an estimated 23 million children under one year ~~of age~~ did not receive their essential vaccinations. Of these, 60% live in just ten countries, one of which is Indonesia (4). Indonesia is the fourth most populous country globally. It is composed of thousands of islands organized into 34 provinces. Various geographical and cultural factors influence population inequalities to access ~~to~~ health services (5). In 2001, the Indonesian government's decentralization policy was enacted. This was an excellent strategy to foster

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development by engaging regional resources (6). However, this strategy was not without consequence. One primary concern was the ~~fragmentation of the~~ Health Information System (HIS) fragmentation.

Indonesia's federal structure results in provinces and districts being relatively independent of the national Ministry of Health. This means that provincial and district-levels information systems ~~at the provincial and district levels~~ are locally regulated (7). For instance, *Pemantauan Wilayah Setempat* (PWS) is a management tool used to monitor coverage of specific health services in an administrative boundary. Depending on the service and region, it can be paper- or electronic-based. PWS-KIA is the monitoring system specific to maternal and child health (KIA), including immunization. PWS-KIA data are reported to the District or City Health Office, go to Province Health Office, and finally reported to the main level. Generally, the data are in ~~is in~~ Microsoft ~~excel~~ Excel formats; it will report via emails or various information systems, including Komdat, SiTT, SIHA, PISPK, and SIKDA Generik. PWS-KIA data feeds into ~~the~~ District Health Information System 2 (DHIS2) ~~in some provinces~~. Regional information systems have varying data quality, which reflects inequities in resources across regions. This adds to data integration challenges at the national level (7),(8) and affects strategic policymaking.

In ~~the context of~~ Indonesia’s federal system, Daerah Istimewa Yogyakarta (DIY) Province has the authority to regulate and use its budget within its four districts plus one city (Sleman, Gunungkidul, Bantul, Kulonprogo and Yogyakarta). This province is classified as a small province in terms of area size and the number of regions inside (9). However, this region can be ~~aforesaid to be~~considered a representation of Indonesia when viewed from the geographical, socio-economic and heterogeneous ~~of its~~ population. Regarding childhood vaccination, DIY is among the top ten performing provinces in the

country, with 97.7 % of children completing basic immunization coverage in 2019 (10). Immunization services are provided by Primary Health Centres or Puskesmas (PHC), as well as private clinics, hospitals, and midwives' practices (typically referred to as *Unit Pelayanan Swasta* or UPS).

An electronic immunization registry is a tool for recording individual children's immunization histories. In 2014, the DIY Health Office introduced an electronic immunization registry named SIMUNDU (*Sistem Informasi Imunisasi Terpadu*/ Integrated Immunization Information System). ~~An electronic immunization registry is a tool for recording individual children's immunization histories.~~ An electronic registry serves essential functions at all levels of the health system. At the district and higher levels, it allows for monitoring vaccination coverage by the vaccine, dose, cohort, and other variables – and can support microplanning and vaccine management. The service delivery level can facilitate individual follow-up of vaccination status and enable health workers to identify children due for vaccination and those who missed their vaccinations (defaulters).

SIMUNDU was designed to link with the PWS-KIA for immunization and interoperability with the DHIS2. While it predominantly contains individual-level immunization records, SIMUNDU also serves as a source for aggregation and can synergize with the *Pemantauan Wilayah Setempat* (PWS) reporting system. For this reason, it can be considered an Immunization Information System (IIS). This means that ~~data from~~ City and District levels feed into Provincial and National levels *(Personal communication with DIY immunization program officer).*

The original prototype was designed by the information and technology (IT) department of DIY Health Office to be operated offline. In DIY, three out of the four districts and the city introduced the system in 2015. The final district introduced it in 2017. At this stage, the point of data entry was the PHC only. By 2018, UPS facilities were also equipped with SIMUNDU and could enter data into the system. In 2019, the prototype was further developed to operate online. The online version was rolled out in 2020 (Figure 1). As of May 2021, 79.4% of all PHC and UPS facilities ~~were complying~~complied. This average rate masks, however, the fact that while all PHCs adopt SIMUNDU, it is more challenging to enforce its use in UPC facilities (Suyani 2020, oral communication, 2020, May 11).

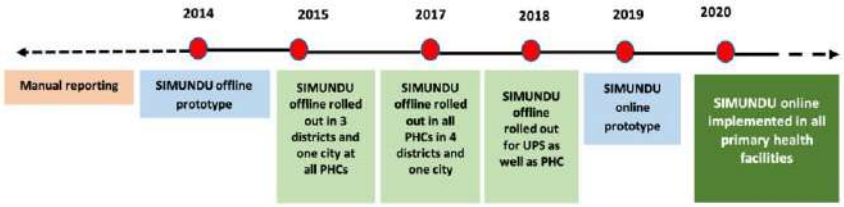

Figure 1. SIMUNDU's development and introduction

When a child receives a vaccination in a health facility, information on the child and the vaccination is entered in SIMUNDU as an individual child record. Each record includes a personal identifier, the child's socio-demographic characteristics (e.g., name, gender, date of birth, name of parents, address), the antigen administered, and the date and place of vaccination. SIMUNDU has been recently updated to allow the recording of vaccinations administered in schools (e.g., Human papillomavirus (HPV), Diphtheria Toxoid (DT), Tetanus-Diphtheria (TD), and Measles-Rubella (MR), though in the form

of aggregate data only. Furthermore, SIMUNDU has ~~being~~ been developed to record COVID-19 vaccinations in health facilities and those carried out in masse.

Monitoring is conducted ~~every~~ monthly to assess data completeness across health facilities, while an evaluation is conducted ~~every~~ yearly. These exercises have allowed the identification of several challenges related to implementing the system (e.g., workload, staff turnover, and rotation) and data quality (e.g., accuracy and timeliness). However, no systematic assessment of the system has been conducted to date. SIMUNDU is the first immunization information system ever introduced in Indonesia. Other districts and provinces have shown interest in rolling it out, and the Ministry of Health has acknowledged the innovation. The ~~objective of the~~is ~~was~~ work presented here aims ~~was~~ to examine SIMUNDU's introduction and implementation process to draw lessons that could inform scalability and sustainability across the country.

Methods

From May to October 2020, we examined the experience of introducing and implementing an immunization information system in the DIY province using an explanatory sequential mixed-method design, where each step informed the next (11). First, we ~~conducted a desk~~ reviewed of all relevant documentation available in the DIY H~~h~~ealth O~~o~~ffice – e.g., staff notes, meeting notes and monitoring notes – documenting SIMUNDU development and management processes. We also examined online documents, including health profiles and regulations on health reporting systems in Indonesia. This served as the initial data source ~~of data~~ and provided an overview of who was involved and how~~,~~ in developing and implementing SIMUNDU. This informed the survey design that we conducted as a second step. The survey targeted any staff responsible for entering data in SIMUNDU (i. e. data clerks) across all PHC and selected

UPS facilities and any staff responsible for managing the system at the district and city level (i.e., immunization coordinators). Sampling and recruitment strategies are outlined in Table 1.

Table 1. Survey participant

Level of the data entry and reporting system	Total number of facilities/ offices	Study population	Sampling strategy	Recruitment	Sample size
Primary Health Centre (PHC)	121	Data entry clerks	All facilities	Open invitation across all facilities	113
UPS - Central, General, Maternity and Pediatric Hospitals	65	Data entry clerks	Randomly selected 2 facilities per district/city (2*5=10)	Open invitation across selected facilities	8
UPS - Clinics	73	Data entry clerks	Randomly selected 2 facilities per district/city (2*5=10)	Open invitation across selected facilities	7
UPS - Midwives' Practices	271	Data entry clerks	Randomly selected 2 facilities per district/city (2*5=10)	Open invitation across selected facilities	10
District/City Health Office	5	Immunization coordinators	Total sampling	Open invitation	4*
			Total		**142**

*When the immunization coordinator had recently changed, the former was also invited.

All immunization coordinators in each district/city and data entry clerks from all primary health facilities (PHC) were invited to participate in this survey. For UPS facilities, we selected two clinics, two midwives' practices, and two hospitals per district/city and invited all of their staff to be involved in SIMUNDU data entry and management.

We developed and pre-tested an online survey in Bahasa Indonesia to inquire about SIMUNDU implementation, processes, and outcomes across PHC, UPS clinics, district or city and province offices. The questionnaire consisted of close-ended and Likert scale questions – ranging from 45 to 50 depending on the target type of facility and/or level of the health system – and enquired about respondents' socio-demographic characteristics as well as the process of implementing and managing SIMUNDU. Some questions provided an additional field for clarifying the reason for a particular answer choice ~~of answer~~.

All participants were invited to the DIY H~~h~~ealth O~~o~~ffice to complete~~fill out~~ the survey on their laptops, with their prior consent. A~~Having a~~ll participants in a room allowed researchers to monitor any missing or incomplete responses in real ~~-~~time and follow ~~-~~up with individual participants on-site to fill any gaps. We don't believe this may have introduced any significant bias as researchers would simply flag any missing responses and invite respondents to address those. Data were then exported ~~into~~ and analyzed in Microsoft Excel. An exploratory analysis of the survey data informed the topic areas that qualitative interviews ~~would delve~~explore into further.

Similarly, some informants were purposefully selected among survey participants to follow up on the range of perspectives that had emerged from the survey. Other informants had been identified at the desk review stage and chosen for their management functions. Selected informants were invited to the DIY Health Office for ~~the purpose of~~ the interview, and COVID-19 prevention protocol was observed. Every informant was informed about the study and asked to sign the informed consent. All invited informants agreed to participate. A total of nine 30-minute semi-structured interviews were conducted in Bahasa Indonesia language~~,~~ and recorded with prior consent from

participants. The interview team consisted of three researchers with the respective task of running the interview, observing and taking notes. A research assistant transcribed all interviews in Bahasa Indonesia language.

Thematic analysis was conducted using Quirkos qualitative tool following Braun and Clarke's approaches (12). Researchers familiarized themselves with the data, searching for initial codes and allowing themes to emerge. The principal investigator led the coding process, and led the research team in defining and naming the core themes emerging from the data, organizing and analyzing the data across the themes, and triangulating information from the desk review, the survey, and the interviews. This stage was also performed in Bahasa Indonesia. Data were translated to English only at sub-theme and core themes.

Results

Characteristic participant

a. Quantitative study

In total, 142 respondents participated in this study spread across five districts/ ~~or~~ cities in the DIY province. Most respondents came from Gunungkidul District, PHC, UPS, and DHO, 24.8%, 24%, and 25%, respectively. For all research units, the majority are women. At the UPS and DHO/CHO levels, most respondents were aged 41-45 years, i.e., 28.3% and 75%, respectively, while at the UPS level, the majority were aged 25-30 years (56.0%). For education level, PHC and UPS are dominated by Diploma 3 graduates, namely 86.7% and 80%, respectively, while in DHO/CHO, it is predominantly undergraduate graduates (75%) (Table 2)

Table 2. Characteristic respondents in three groups of respondents

Characteristic	PHC (n= 113) n (%)	UPS (n=25) n (%)	DHO/CHO (n= 4) n (%)
District/City			
Bantul	23 (20.4)	5 (20.0)	1 (25.0)
Gunungkidul	28 (24.8)	6 (24.0)	1 (25.0)
Yogyakarta	17 (15.0)	4 (16.0)	0 (0.0)
Kulonprogo	21 (18.6)	4 (16.0)	1 (25.0)
Sleman	24 (21.2)	6 (24.0)	1 (25.0)
Sex			
Male	3 (2.7)	0 (0.0)	2 (50.0)
Female	110 (97.3)	25 (100)	2 (50.0)
Age			
< 25	0 (0.0)	5 (20.0)	0 (0.0)
25-30	3 (2.7)	14 (56.0)	0 (0.0)
31-35	30 (26,5)	3 (12.0)	0 (0.0)
36-40	19 (16.8)	1 (4.0)	0 (0.0)
41-45	32 (28.3)	0 (0.0)	3 (75.0)
46-50	18 (15.9)	0 (0.0)	1 (25.0)
>50	11 (9.7)	2 (8.0)	0 (0.0)
Education			
Master	0 (0.0)	1 (4.0)	1 (25.0)
Bachelor	5 (4.4)	1 (4.0)	3 (75.0)
Diploma 4	9 (8.0)	2 (8.0)	0 (0.0)
Diploma 3	98 (86.7)	20 (80.0)	0 (0.0)
Senior high school	1 (0.9)	1 (4.0)	0 (0.0)

b. Qualitative study

Nine informants were recruited to provide the required information to explore ~~deeper into~~ the quantitative study results more deeply. They ~~hold roles~~serve as managers and staff at DHO/CHO, PHC, and UPS. Among the nine informants, 2 were men, and 7 were women. Three informants graduated ~~from~~ with master's, one bachelor's, and five diplomas graduates (Table 3).

Table 3. Informants' characteristics for the qualitative study

Sex	Age (years)	Education	Position	Subject group	Informant's code
Female	56	Magister	Head of disease prevention and control department at PHO level	Managerial	M 01
Male	57	Magister	The former of the disease prevention and control section at the PHO level	Managerial	M 02
Male	54	Bachelor	Immunization programmer at the PHO level	Managerial	M 03
Female	47	Magister	IT Person	Managerial	M 04

Female	34	Diploma	Data entry at the PHC level	Staff	S 01
Female	25	Diploma	Data entry at the UPS level	Staff	S 02
Female	31	Diploma	Data entry at the UPS level	Staff	S 03
Female	42	Diploma	Data entry at the PHC level	Staff	S 04
Female	24	Diploma	Data entry at the PHC level	Staff	S 05

c. Finding

Findings from the study are organized and presented across the three core themes that emerged from the qualitative analysis, notably system strengths, potential threats, and opportunities for scale-up. However~~Yet~~, data from ~~both the~~ qualitative and quantitative data fed into the analysis of these core themes~~,~~ to cross-validate the findings (Figure 2. Detailed findings from the survey are presented in Table Supplement 1.

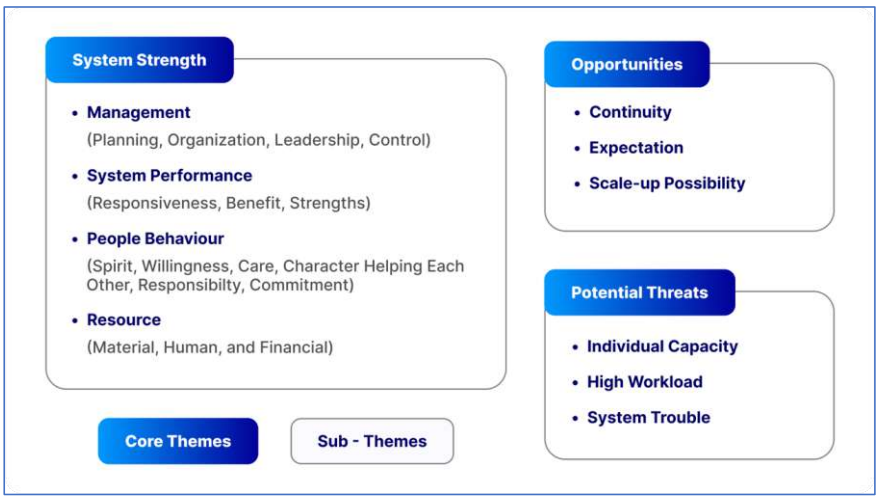

Figure 2. Strengths, potential threats, and opportunities for scale-up

System's Strengths

Factors contributing to the success of SIMUNDU include management, system performance, people's behavior, and resources.

Management

SIMUNDU arose due to concerns from the DIY ~~health~~ Health O~~o~~ffice immunization section around data quality, notably the need to address ~~issues related to~~ data inaccuracy, duplicate or missing data and lack of timely data, and the need for~~of~~ quality data to support follow-up and appropriate planning. The need for SIMUNDU arose from these challenges and needs.

"To our knowledge, [SIMUNDU development] started with a problem: estimates of the target population varied depending on the data source" (M02)

"Yes, I think [SIMUNDU management team] started to tire of managing a large volume of data with dubious validity. They need to know the situation in each district". (M04)

Effective management of SIMUNDU from development to implementation was highlighted as an essential determinant of its success across the critical functions of Planning, Organization~~ing~~, Leadership~~ing~~, and Control~~ling~~.

Careful **Planning** was ensured at each stage of SIMUNDU development and implementation. These stages included developing an initial business plan, providing training on and socialization to SIMUNDU, and developing a staff replacement plan to respond to turnover or retirement of staff in charge of operating the system or entering data. The parties involved in planning included the H~~h~~ead of the D~~d~~isease P~~p~~revention and C~~c~~ontrol D~~d~~epartment, IT personnel, and ~~immunization program staff~~ from the DIY ~~health~~ Health O~~o~~ffice immunization program staff.

Organizationing - the organization of SIMUNDU, is carried out at several levels. The top level is the DIY Hhealth Ooffice, the second level is the district/city health office, and the third level is health facilities (Figure 2). A third party was also involved in developing the system interface.

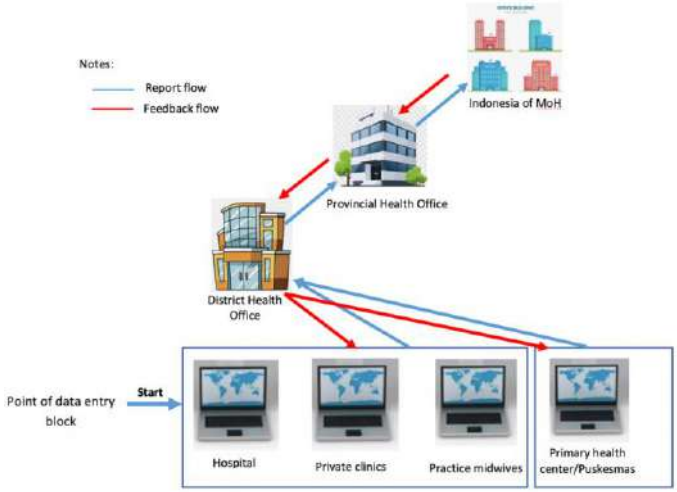

Figure 2. Visual organizing framework of SIMUNDU – DIY Province, Indonesia

At the beginning of SIMUNDU development, essential functions included database administrators, interface designers, and server administrators, and their interplay facilitated the system's smooth operation ~~of the system~~. Training specific to SIMUNDU was integrated with other training, typically immunization-related training. This enabled us to share of resources with other programs, thus ensuring viability. The training was delivered in the district/city health office: 87.6%, 72%, and 75% of survey respondents from PHC, UPS, and DHO/CHO, respectively had participated in in-house training. Training typically consisted of short sessions and included practice on the trainee's device ~~on how~~ to operate the system in both online and offline mode. Informants indicated that

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day-to-day operations were carried out autonomously by the staff~~,~~ through flexibly adjusting their work to protect the time to enter the data. ~~And t~~This seem~~eds~~ed~~ed~~ to work effectively.

Leader~~ship~~ship~~ing~~ - the success of SIMUNDU implementation is arguably related to strong leadership. Informants noted that managers played a crucial role in bridging the needs of the immunization program with the system design, closely monitoring the initial implementation process, and creating an enabling environment.

"I try to combine supporting and managing ~~the people involved~~ and monitoring ~~them~~the people imvolved. Currently, I monitor whether [SIMUNDU] can run optimally as our users are health facilities. I also monitor program development and the system's output." (M01)

"[SIMUNDU] was born from program managers, primary health centers, Districts, and DIY ~~health~~ Health O~~o~~ffices wanting to build systems together. We – DIY H~~h~~ealth O~~o~~ffice - give them motivation in every meeting." (M03)

"I see that [management] is very good at networking. Staff data entry in the field always said that these people are very kind." (M02)

The role of IT workers in developing SIMUNDU was also ~~reported to be~~ significant. They helped develop the system and facilitated ~~supported~~ correct data entry operators whenever ~~by assisting data entry operators whenever these encountered~~ technical issues arose. IT workers also ~~or~~ helped~~ing~~ resolve inconsistencies in ~~the~~ data records. Acknowledgment of staff efforts was also ~~an~~ important ~~lever~~ to maintain motivation and buy-in.

"In the early days of SIMUNDU's development, the system was challenging to operate, as it wasn't as stable as it is now. I praise the enthusiasm and dedication of the users." (M01)

The **control~~ling~~** function - consisting ~~in~~ of **quality** assurance management - was critical to avoid data duplication or missing entries~~,~~ and ultimately ensure data quality. This process was not regulated by specific Standard Operating Procedures but was addressed during training and monitored monthly. In addition, the DIY H~~h~~ealth O~~o~~ffice provided negative incentives to health facilities that were not submitting complete records and provided regular feedback from monitoring and evaluation exercises.

Specifically, 94.2%, 100%, and 100% of survey respondents in PHC, UPS, and DHO, respectively, reported their work had been subject to monitoring. More than half of the respondents in PHC and UPS facilities had been observed by supervisors while performing data entry at least once over the past year. At the PHC level, 48.3% of survey respondents had been subject to monitoring from the district/city office's team, and 45.7% received monitoring from DIY ~~health~~ Health O~~o~~ffice's staff. Conversely, 40% of respondents from UPS facilities were monitored by PHC's staff. Almost all survey respondents reported receiving feedback from the monitoring, mainly from the District/City and DIY H~~h~~ealth O~~o~~ffices. Forty percent of respondents from UPS facilities reported receiving feedback from PHC. Immunization coordinators from the District/City H~~h~~ealth O~~o~~ffices received feedback from the DIY H~~h~~ealth O~~o~~ffices.

"In a [evaluation] meeting, DIY ~~health~~ Health O~~o~~ffice or D~~d~~istrict H~~h~~ealth O~~o~~ffice showed the progress of our data entry – correct or not, proper or not." (M02)

It is worth noting that DIY Pprovince is quite a small geographic area. Because it consists of only five districts and one city, this province is relatively easy to monitor across all phases, from planning through monitoring and evaluation.

System performance

While SIMUNDU predominantly contains individual-level immunization records, it also serves as a source for aggregation and can synergize with other information systems. Notably, SIMUNDU can link to the DHIS2 and generate immunization-specific reports as per the Ministry of Health's requirements. These reports are sent to the upper levels automatically if SIMUNDU is operated online or submitted via email if SIMUNDU is operated offline. This functionality has had an essential role in ensuring the acceptability and adoption of the system.

Informants noted how transitioning from paper-based tools to an electronic system made data entry easier and reduced errors. SIMUNDUit also facilitated the implementation of protocols for data storage and security. It enabled follow-up and defaulter tracking. Finally, integration with the DHIS2 meant reduced workload for the staff.

"We can track do faster tracking of children who may have received vaccinations in different locations faster. For example, when the first dose of a vaccine is given in Bantul and the second one in Yogyakarta, the record can be linked within SIMUNDU" (M01).

"SIMUNDU makes it easier to detecting what data and vaccinations are missing easier since we enter data from the children's birth through the end of the immunization schedule. So, we will know where they miss any vaccine." (S03)

"The benefit of using SIMUNDU is first: we know the situation of immunizations more accurately….so our vaccine forecasting is more accurate …. and our budget, staff, facilities can be more effective and efficient in providing services." (S05)

"Colleagues from the mother and child health (KIA) program enter the data via the KIA "Sembada." So, this data will appear automatically in SIMUNDU because the two system are connected." (S01)

SIMUNDU is user-friendly and can be flexibly operated ~~either~~ offline or online, allowing the responsible staff to maintain data entry irrespective of connectivity. 82.3%, 96%, and 100% of survey respondents from PHC, UPS, and DHO, respectively reported ~~to~~ operating SIMUNDU online.

People's behavior

The interview showed that staff commitment was critical for the successful implementation of SIMUNDU, as indicated by their willingness to work overtime and bring home the data to enter into the system.

"I take it [the data] home too, for example, after immunization sessions– in my clinic, immunization runs four times per month, every week. So, when the session is finished, we can take the data home, [and] do the entry at home while relaxing." (S03)

The interviews confirmed this ~~This~~dedication ~~dedication was confirmed by the interviews~~, which spoke to a societal culture of helping others and responsibility and commitment to the team. This contributed to shaping ~~e~~ an environment where people approach SIMUNDU as a shared responsibility and a collective endeavor. Informants also noted the high motivation of dedicated staff.

"That's all; we cannot judge by money [~~[~~people's kindness, culture, and behavior]; ~~it's essential to~~ explaining how good people are in Yogyakarta is essential. I was in another place before, and ~~I~~ could not find people's kindness like in Yogyakarta - different characters." (M02)

"The second thing is that we need human resources concerned and love for data; otherwise, even though we have a good system, it will amount to nothing without good human resources. But good implementation will come more easily when people are concerned about data~~, good implementation will come more easily~~." (M04)

Resource: material, human and financial

Infrastructure and equipment emerged as critical factors ~~to~~ in introducing and sustaining SIMUNDU implementation. Some desktops were ~~specifically~~ explicitly allocated to the immunization program, and some had to be shared with other ~~programs'~~ staff. Other data entry officers reported using their ~~own~~ laptop or smartphone (36.3% of survey respondents from PHC). In UPS facilities, 40.7% reported using office desktops; ~~, and~~ in the DHO, more than half of the respondents stated they used an office-supplied laptop. The majority of respondents – regardless of the type of facility - said their current device was sufficient to perform their work on SIMUNDU. Regarding connectivity, 64.6% of PHC survey respondents and 67.7% of UPS's reported operating SIMUNDU online, relying on the office's internet connection.

Management of financial resources was also crucial. According to the key informants, no special funds were allocated to SIMUNDU in the initial stages. Resources were leveraged through sharing activities – e.g., ~~–~~monitoring visits or transportation - with other

programs, thus allowing cost efficiencies. Integration with other programs proved critical to ensuring sustainability.

"SIMUNDU's budget comes from the state budget called as Anggaran Pendapatan dan Belanja Negara (APBN). Every year the APBN allocates ~~a~~ funding envelope for immunization to DIY and other provinces, where the budget is apportioned across the program [not explicitly written budget for SIMUNDU]." (M02)

Human resources are critical to the operation of SIMUNDU. According to interview, SIMUNDU data entry clerks must have patience, work carefully and not rush, be interested in data, be responsible, and have basic computer skills in~~such as Ms~~ word processing and spreadsheet software tools such as Microsoft Word and ~~Ms e~~Excel, respectively. As shown by the survey, the large majority of SIMUNDU-operating staff was educated: at least 80% of data entry clerks in either PHC or UPS facilities have secondary education (>80%), while at the managerial level (DHO), 75% of respondents have a B~~b~~achelor's degree (see Table 2). However~~Yet~~, 19.4% and 9.1% of respondents from PHC and UPS facilities, ~~respectively~~ have low computer literacy.

Various data entry clerks looked for strategies to resolve the obstacles they encountered when entering data to SIMUNDU. Based on the interviews, some clerks furthered their computer skills by taking private computer classes. Others learned from ~~other~~ colleagues at their offices, or reached out for help to the district person in charge. To deal with the accumulation of data needing to be entered in SIMUNDU, staff would sometimes work at home after office hours, as their busy schedule at work did not allow time for data entry.

"If we found obstacles, we asked people in charge in PHC – asking for a solution or sharing by WhatsApp – or sometimes I asked the IT person in the DIY H~~h~~ealth ~~office~~Office." (S03)

Potential threats

As of today, SIMUNDU can be said to be a successful experience. However~~Yet~~, ~~a~~ ~~number~~some ~~of~~ obstacles were encountered and addressed during implementation. Potential system sustaining ~~threats to sustaining the system~~ include individual capacity, technical or system issues, and high workload. Staff computer literacy was identified as one of the main ~~challenges to~~ sustainability challenges. Internet connectivity was another obstacle, as not a good network ~~not all health facilities were~~ equally supported all health facilities~~by a good network~~. The survey shows that 64.6% and 67.7% of PHC and UPS staff used office internet, while others had to rely on their home internet.

Further, incomplete and inconsistent records – such as differing child's date of birth or name spelling across relevant entries - make it challenging to consistently record immunization information. These challenges have arisen during implementation~~,~~ and were promptly addressed. Yet, they had an impact on staff who was already juggling busy schedule in the office, causing delays in data entry. As shown by the survey, almost all respondents stated having other responsibilities besides operating SIMUNDU – notably 97.3%, 88%, and 100% of participants from PHC, UPS and district and city offices, respectively.

Opportunities

Informants appreciated SIMUNDU as an ~~good~~ excellent system ~~for~~ to manage immunization data. SIMUNDU has become necessary for program managers and

policymakers; ~~because~~ it allows them to monitor coverage and can help inform planning and programming. Currently, SIMUNDU is stable, thus is easier to manage than when it was in the development phase. It is also viable~~,~~ and no longer requires heavy reliance on the core workforce that started the system. The hopes expressed by data entry clerks in the interviews are that SIMUNDU is easier to operate~~,~~ and system errors are less frequent. Informants also stressed the need for refresher training to ensure knowledge and practice of the system ~~-~~is not lost.

"In my opinion, SIMUNDU is the best program in DIY~~-~~, ~~which is~~ a collaboration between program managers and IT. It will continue to be implemented because it is a necessity. It has been stably used for more than five years, meaning this is needed." (M01)

"If I have the tool, in this case, SIMUNDU, when it is stable, whoever will be able to run it, I am sure that anyone can operate it. It means that it doesn't matter if we have people shifting (jobs)." (M01)

"In the future, if SIMUNDU is still used, other reports are not necessary. Now we have two different reports: SIMUNDU and stock card of vaccine – each stand-alone and need a separate report." (S05)

Based on the key informants' interviews~~erskwkkwkw~~, SIMUNDU is likely to be developed further / or expanded to other provinces. The DIY H~~h~~ealth O~~o~~ffice is open to supporting other provinces interested in introducing the system, for instance, through the lending staff for training and orientation. However, informants advised that a successful introduction requires a strong commitment from ~~both~~ staff and management.

Discussion

Robust health information systems (HIS) are essential components of ~~strong~~ robust health systems (13). At the most basic level, immunization registries are systems that collect and report individual-level vaccine administration record data, thus facilitating individual follow-up of vaccination status. Registries also allow for the monitoring of vaccination coverage and ~~facilitate~~ enable analysis of AEFIs and surveillance data to inform the design of ~~–~~coverage interventions and outbreak investigations. When an electronic registry has interoperability with other electronic systems – such as in the case with SIMUNDU – it is considered an Immunization Information System (IIS) (14). This paper presents lessons learned from DIY's experience implementing an IIS.

DIY is the only province in Indonesia – out of thirty-four - that uses an IIS. This work has shed light on the strengths and underlying barriers of implementing an IIS in this context. The objective of this study was to draw lessons that inform sustainable scale-up in other provinces and possibly at the national level. This study highlighted individual capacity, technical or system issues, and high workload as the major ~~–~~barriers to sustainability. Conversely, ~~whereas~~ management, system performance, people's behavior, and available resources emerged as the main determinants of SIMUNDU's successful implementation ~~-~~, ~~–~~notably in improving acceptability, implementation costs, and adoption of this innovation (15).

Despite several obstacles encountered during the implementation of SIMUNDU, this study showed that this innovation was well accepted by key stakeholders ~~involved~~. On the one hand, data entry clerks noted that the system is ~~rather~~ relatively user-friendly and allows to ~~better~~ organize the data better and enhance its quality. On the other hand,

managers noted the benefits this innovation brought about, namely in ~~terms of~~ the potential for cohort data to support planning and monitoring and ultimately improve immunization coverage.

Effective management - across planning, organization~~ing~~, leadership~~,ing~~ and control~~ling~~ functions – is a crucial reason why SIMUNDU has been viable for over 5 years. Managers use their control to encourage the beliefs and actions of the staff ~~–~~with~~–~~ a dedicated and robust managerial process (16). SIMUNDU was born from the need for credible data to assist in carrying out DIY H~~h~~ealth O~~o~~ffice duties at the managerial and operational ~~-~~levels. At the managerial level, the disease prevention and control department and the IT department collaborated in designing a system that ~~was readily accepted by~~ intended users readily accepted. Immunization officers and IT programmers played a central role from the early stages of development through implementation with effective coordination and communication~~, and they~~ They were helped in this task ~~by~~ with the full support of their respective superiors.

SIMUNDU is cost-effective in several ways. During the introductory period of its implementation, immunization programmers, IT officers, and other staff assisted in introducing SIMUNDU in all districts in the province. This was done ~~through~~ by integrating some of the activities across programs, thus building efficiency~~ies~~ in terms of time and costs for both managers and staff. Sharing resources across programs was critical in the first years~~, for~~ of building sustainability. Additionally, SIMUNDU maintenance does not require high costs because the DIY Health Office ~~itself~~ has developed the system and thus possesses in-house technical skills. The IT department has the capacity to monitor and improve processes and tailor them to user needs without much additional cost.

A good program without good leadership could fail in its implementation, and even if it was initially successful, it might not be sustainable (17). In the context of SIMUNDU, ~~support from~~ leadership and effective management support facilitated the program's adoption. The ~~Uptake~~ uptake of the new system was good and all health facilities providing immunization services have successfully transitioned to SIMUNDU. The strong network of the ~~main~~ prominent persons in charge of SIMUNDU also facilitated the adoption. Good communication, care, and attention to staff concern~~s~~ positively affected staff performance. They felt that they were well ~~-~~supported and treated kindly, and this helped them carry out their work joyfully. According to several informants, the ~~leadership of the~~ DIY immunization program manager's leadership played an essential role ~~to~~ in this effect.

The monitoring and evaluation mechanisms of SIMUNDU were also important. Preferred monitoring and evaluation activities include monthly reports and staff ~~direct~~ discussions ~~with staff~~ during site monitoring visits. The immunization program manager suggested this approach to maintain data quality and ensure the system~~'s~~ sustainability. These chosen mechanisms allow program managers to assess the actual practice in the field and the challenges faced to inform decisions about the follow-up actions to be taken. These processes supported the ongoing development of ~~,~~ and learning from, SIMUNDU as a tool for data collection, analysis, and visualization, as well as the benefits for managers to carry out monitoring and evaluation. The same ~~statement~~ sentiment was ~~revealed~~ reflected ~~by~~ in previous research undertaken in the India ~~about the innovation of health management information systems for primary health care agrees that this can provide essential benefits~~ (18).

Human resources are a key determinant of the successful implementation of any HIS (19). People's behavior affects how the system works, develops, and survives (20),(21). In the case of SIMUNDU, implementation was facilitated by a culture of care, established networks, and a positive attitude towards data of both the program manager and IT team. From the staff's point of view, the local culture of helping each other and doing their job correctly and responsibly translated into staff carrying out their duties with enthusiasm and high commitment. Although facilities, funding and human resources were limited, the individuals involved were highly motivated and supportive.

Despite the many strengths of SIMUNDU, some obstacles may potentially challenge its sustainability in the long term. These obstacles can be divided into human variables and technical variables. From the human variables side, unequal capacity distribution ~~of capacity~~ at the operational level can result in differing levels of data quality across facilities and districts. Staff workload is another challenge need~~ing~~ addressing, as their willingness to work overtime is not a sustainable strategy. Technical problems were another obstacle during the introduction of SIMUNDU, but qualified technicians/developers ~~were able to~~could solve these issues~~System trouble was another obstacle during the introduction of SIMUNDU, but a qualified technician or developer solved it~~. During our research, we recognized the weakness of SIMUNDU that it had not used the person number as a unique code in data entry. This impacts SIMUNDU's inability to synchronize with other health programs that use a person's number as a unique code. However, this weakness can be seen as room for improvement for SIMUNDU shortly. Another thing that needs to be considered for other regions that will implement SIMUNDU that SIMUNDU is that implemented in the DIY province which consists of 5 districts/cities with relatively easy regional accessibility. For areas with more difficult

access, the commitment of the leadership and subordinates is the key to successful implementation.

Conclusion and recommendation

SIMUNDU is a promising innovation for the entire country, beyond DIY. There is agreement about the potential for scale-up of this IIS to other provinces. Experience of implementing this system in DIY over the past five years has shown that the benefits outweigh the challenges, and SIMUNDU has grown into a robust ~~and~~ yet user-friendly system. Regular training to dedicated staff ~~to~~ for strengthen their capacity as the system evolves and is updated, and a plan for anticipating and responding to staff turnover have proven critical strategies towards sustainability. SIMUNDU's success also rests on remarkable leadership, both in creating and enabling a supportive environment and ~~in~~ pursuing integration with other programs to share limited resources.

This study's ~~Recommendations~~ recommendations ~~stemming from this study~~ address three different ~~groups of~~ stakeholders groups: the DIY H~~h~~ealth O~~o~~ffice, the national government, and researchers. First, to ensure ~~-~~continuity and sustainability and reduce the system's dependency on ~~the~~ a particular person or party, SIMUNDU management and maintenance should be managed by people who have competency and interest in a good reporting system. Furthermore, a human resources plan should be developed in preparation for SIMUNDU roll-out in other provinces or at the national level~~s~~; this is necessary to avoid vacancies when DIY province staff are seconded to other areas for mentoring support. Second, the fact that SIMUNDU emerged from an actual need ~~o~~for immunization programme implementers~~,~~ and saw these at the front-line of its development and implementation, positively impacted its feasibility and viability. This

suggests that the approach to scaling up SIMUNDU should be stepwise, considering each region's specific characteristics and needs. To this effect, a readiness map and a timeline may be developed to roll ~~for the roll~~ out of SIMUNDU in a particular region. Third, further research is needed to assess the impact of SIMUNDU on immunization coverage. Based on our conversations with stakeholders, it would be particularly relevant to focus on a low-performing region and observe the impact over a 2 to the 3-year time window.

Study limitations

The empirical results reported herein should be considered in light of limitations. First, the results of ~~in~~ the quantitative study must be considered ~~with respect to~~concerning the limited sample size, particularly for UPS Health Facilities~~in the quantitative study, the result should be considered in the study sample size mainly for UPS health facility~~. However, considering the top-down immunization program and the characteristics of UPS, which will not be significantly different from each other, the results of this study are still valid and relevant to the existing. In qualitative research that aims to explore, caution is needed in interpreting the interview results. T~~From t~~hese results~~, there is~~ still a need ~~for~~ in-depth studies with different approaches, such as focus group discussions to confirm the results.

Declarations

Ethics approval and consent to participate

This study was approved by the Ethical Review Board of Universitas Ahmad Dahlan, Yogyakarta, Indonesia (ethical approval code: 012005021). Before data collection began, consent to participate was obtained from research subjects (both survey and key informant interviews).

Adherence to national and international regulations

Not applicable

Consent for publication

Before data collection begins, an approval that data is taken for publication purposes is obtained from research subjects (both surveys and key informant interviews).

Availability of data and materials

The datasets generated and or analyzed for this study can be requested from~~to~~ the corresponding author.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

SS, TAW, RR, ASDN and MF designed the study. SS, TWS, SKW, SAM collected the data. SS and RR conducted data analysis. SS developed the paper with inputs and comments from MF on each draft. All authors agree with the manuscript's results and conclusions.

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Authors' information:

The authors alone are responsible for the views expressed in this article. They do not necessarily represent the views, decisions, or policies of the institutions affiliated with them.

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Date: 15 Sep 2022
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BHSR-D-21-00992R3
Introduction and implementation of an immunization information system in Indonesia province of Daerah Istimewa Yogyakarta: lessons for scale-up
Sulistyawati Sulistyawati; Trisno Agung Wibowo; Rokhmayanti Rokhmayanti; Andri Setyo Dwi Nugroho; Tri Wahyuni Sukesi; Siti Kurnia Widi Hastuti; Surahma Asti Mulasari; Marta Feletto
BMC Health Services Research

Dear Dr Sulistyawati,

Your manuscript 'Introduction and implementation of an immunization information system in Indonesia province of Daerah Istimewa Yogyakarta: lessons for scale-up' (BHSR-D-21-00992R3) has been assessed by our reviewers. Based on these reports, and my own assessment as Editor, I am pleased to inform you that it is potentially acceptable for publication in BMC Health Services Research, once you have carried out some essential revisions suggested by our reviewers.

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Reviewer 2: Manuscript is much improved. A very few minor edits
Authors have organized into strengths, threats and opportunities. To be consistent with a SWOT analysis. Perhaps adding the weakness section to results. Otherwise, seems that authors are introducing new information into discussion for example obstacles that are not found in the results section. In the discussion section, the authors introduce human and technical variables, but this is the first mention of this.
Page 8, lines 13-14. It seems as if "to be" involved is not correct, because the authors wanted staff already involved in SIMUNDU data entry and management?

Page 9, paragraph 3, line 16, delete "into"
Another suggestion is to separate conclusion and recommendations with recommendations first, then conclusion.

Reviewer 3: Thank you for submitting this revised manuscript and the itemised response to review feedback. I am glad to see that you have addressed both major and minor issues raised previously.

You have provided reasonable responses to the major comments and the paper is more robust for it. The numerous small editorial changes have also improved readability of the paper. I am also satisfied that the figures are legible now. Some relatively small issues with the text remain, however this should be easily addressed with a further round of copy editing.

I believe this work is relevant to BMC HSR, and that it will advance the literature in its domain.

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Declarations
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Response to reviewer comment to paper entitled
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No	Reviewer's comment	Author 'response
1	Reviewer 2 Authors have organized into strengths, threats and opportunities. To be consistent with a SWOT analysis. Perhaps adding the weakness section to results.	Dear Reviewer 2, Thank you for reading our paper with your valuable input. We have added the weakness section to the result (page 21, line 7) and Figure 2 (page 12, line 2). Simultaneously, we have added weaknesses in the abstract.
	Otherwise, seems that authors are introducing new information into discussion for example obstacles that are not found in the results section.	In the result section, we put information about obstacles under the potential threats on page 20, line 15.
	In the discussion section, the authors introduce human and technical variables, but this is the first mention of this.	Human is written on page 18, line 20, in the Result section (Resource). While technical variable is mentioned in Result Section under potential threats (page 15, line 12, line 17)
	Page 8, lines 13-14. It seems as if "to be" involved is not correct, because the authors wanted staff already involved in SIMUNDU data entry and management?	Thank you for your detailed input. We changed "into" to "who"
	Page 9, paragraph 3, line 16, delete "into"	"Into" has been deleted Page 8, line 8
	Another suggestion is to separate conclusion and recommendations with recommendations first, then conclusion.	We have separated the conclusion and recommendation, Page 27-line 3
2	Reviewer 3 Thank you for submitting this revised manuscript and the itemised response to review feedback. I am glad to see that you have addressed both major and minor issues raised previously. You have provided reasonable responses to the major comments and the paper is more robust for it. The numerous small editorial changes have also improved readability of the paper. I am also satisfied that the figures are legible now. Some relatively small issues with the text remain, however this should be easily addressed with a further round of copy editing.	Dear reviewer 3 We thank you infinitely for providing feedback to this article so that it is worthy of consideration for publication in BMC HSR. I hope you are always healthy.

Introduction and implementation of an immunization information system in Indonesia province of Daerah Istimewa Yogyakarta: lessons for scale-up

Sulistyawati Sulistyawati, MPH, PhD[1*]

Trisno Agung Wibowo, MPH[2]

Rokhmayanti Rokhmayanti, MPH[1]

Andri Setyo Dwi Nugroho, MPH[2]

Dr. Tri Wahyuni Sukesi, MPH[1]

Siti Kurnia Widi Hastuti, MPH[1]

Dr. Surahma Asti Mulasari, MPH[1]

Marta Feletto, PhD[3]

[1] Faculty of Public Health, Universitas Ahmad Dahlan, Yogyakarta, Indonesia

[2] Daerah Istimewa Yogyakarta (DIY) Health Office, Yogyakarta, Indonesia

[3] Alliance for Health Policy and Systems Research, World Health Organization, Geneva, Switzerland

*Corresponding author: sulistyawati.suyanto@ikm.uad.ac.id.

Kampus 3 - Jl. Prof Dr Soepomo, Janturan, Umbulharjo, Yogyakarta, Indonesia.

Abstract

Background: Immunization is critical to saving children from infections. To increase vaccination coverage, valid and real-time data is needed. Accordingly, it is essential to have a good report system that serves as defaulter tracking to prevent children's immunization failure. The Daerah Istimewa Yogyakarta (DIY) Health Office introduced an electronic immunization registry and successfully implemented it for over than five years. It is the only individual-based record system in Indonesia that has been sustainably operated for a long time. Yet, no systematic assessment of this system has been conducted to date. This study examines the Sistem Informasi Imunisasi Terpadu (SIMUNDU) introduction and implementation process to draw lessons that could inform scalability and sustainability across the country.

Methods: This study used an explanatory sequential mixed-method design, which collected quantitative data from 142 participants and qualitative data from 9 participants. Entry data clerk in a health facility was systematically selected to participate in the survey. While in the key informant interview, the informant was selected based on the survey result. A descriptive and thematic approach was adopted to analyze the quantitative and qualitative data. Results from across the two approaches were integrated for comparison and contrast.

Results: Findings are presented according to three core themes that emerged from the data: system strengths, potential threats, weakness and opportunities for scale-up. Strengths -i.e. factors contributing to the success of SIMUNDU - include management, system performance, people's behavior, and resources. Potential threats to sustaining the system include individual capacity, technical or system issues, and high workload.

Opportunities – i.e promising factors that SIMUNDU can be operated sustainably – such as continuity, expectation and scale up possibility.

Conclusions: SIMUNDU is a promising innovation for Indonesia, beyond DIY. There is agreement about the potential for scale-up of this IIS to other provinces. Experience of implementing this system in DIY over the past five years has shown that the benefits outweigh the challenges, and SIMUNDU has grown into a robust yet user-friendly system.

Keywords: immunization, electronic immunization registry, immunization information system, interoperability, implementation research

Background

Neonatal and childhood vaccination is essential to infectious disease prevention and an absolute human right (1),(2). Vaccination has been proven to reduce the burden of infectious diseases globally (3). According to the WHO, in 2020, an estimated 23 million children under one year did not receive their essential vaccinations. Of these, 60% live in just ten countries, one of which is Indonesia (4). Indonesia is the fourth most populous country globally. It is composed of thousands of islands organized into 34 provinces. Various geographical and cultural factors influence population inequalities to access health services (5). In 2001, the Indonesian government's decentralization policy was enacted. This was an excellent strategy to foster development by engaging regional resources (6). However, this strategy was not without consequence. One primary concern was the Health Information System (HIS) fragmentation.

Indonesia's federal structure results in provinces and districts being relatively independent of the national Ministry of Health. This means that provincial and district-levels information systems are locally regulated (7). For instance, *Pemantauan Wilayah Setempat* (PWS) is a management tool used to monitor coverage of specific health services in an administrative boundary. Depending on the service and region, it can be paper- or electronic-based. PWS-KIA is the monitoring system specific to maternal and child health (KIA), including immunization. PWS-KIA data are reported to the District or City Health Office, go to Province Health Office, and finally reported to the main level. Generally, the data are in Microsoft Excel formats; it will report via emails or various information systems, including Komdat, SiTT, SIHA, PISPK, and SIKDA Generik. PWS-KIA data feeds into District Health Information System 2 (DHIS2). Regional information systems have varying data quality, which reflects inequities in resources across regions. This adds to data integration challenges at the national level (7),(8) and affects strategic policymaking.

In Indonesia's federal system, Daerah Istimewa Yogyakarta (DIY) Province has the authority to regulate and use its budget within its four districts plus one city (Sleman, Gunungkidul, Bantul, Kulonprogo and Yogyakarta). This province is classified as a small province in terms of area size and the number of regions inside (9). However, this region can be considered a representation of Indonesia when viewed from the geographical, socio-economic and heterogeneous population. Regarding childhood vaccination, DIY is among the top ten performing provinces in the country, with 97.7 % of children completing basic immunization coverage in 2019 (10). Immunization services are provided by Primary Health Centres or Puskesmas (PHC), as well as private clinics,

hospitals, and midwives' practices (typically referred to as *Unit Pelayanan Swasta* or UPS).

An electronic immunization registry is a tool for recording individual children's immunization histories. In 2014, the DIY Health Office introduced an electronic immunization registry named SIMUNDU (*Sistem Informasi Imunisasi Terpadu*/ Integrated Immunization Information System). An electronic registry serves essential functions at all levels of the health system. At the district and higher levels, it allows for monitoring vaccination coverage by the vaccine, dose, cohort, and other variables – and can support microplanning and vaccine management. The service delivery level can facilitate individual follow-up of vaccination status and enable health workers to identify children due for vaccination and those who missed their vaccinations (defaulters).

SIMUNDU was designed to link with the PWS-KIA for immunization and interoperability with the DHIS2. While it predominantly contains individual-level immunization records, SIMUNDU also serves as a source for aggregation and can synergize with the *Pemantauan Wilayah Setempat* (PWS) reporting system. For this reason, it can be considered an Immunization Information System (IIS). This means that City and District levels feed into Provincial and National levels *(Personal communication with DIY immunization program officer)*.

The original prototype was designed by the information and technology (IT) department of DIY Health Office to be operated offline. In DIY, three out of the four districts and the city introduced the system in 2015. The final district introduced it in 2017. At this stage, the point of data entry was the PHC only. By 2018, UPS facilities were also equipped with SIMUNDU and could enter data into the system. In 2019, the prototype was further

developed to operate online. The online version was rolled out in 2020 (Figure 1). As of May 2021, 79.4% of all PHC and UPS facilities complied. This average rate masks, however, the fact that while all PHCs adopt SIMUNDU, it is more challenging to enforce its use in UPC facilities (Suyani 2020, oral communication, 2020, May 11).

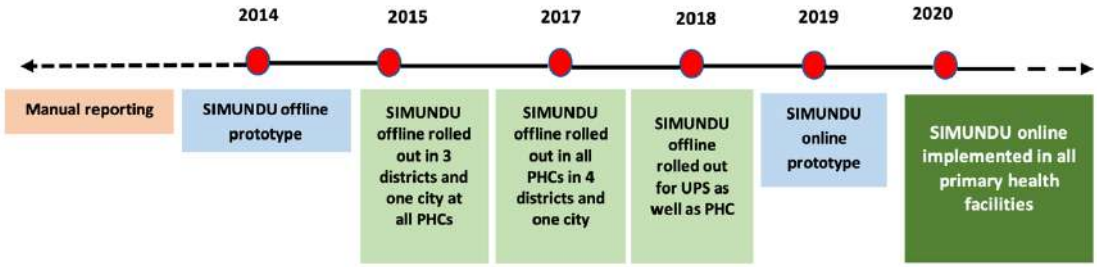

Figure 1. SIMUNDU's development and introduction

When a child receives a vaccination in a health facility, information on the child and the vaccination is entered in SIMUNDU as an individual child record. Each record includes a personal identifier, the child's socio-demographic characteristics (e.g., name, gender, date of birth, name of parents, address), the antigen administered, and the date and place of vaccination. SIMUNDU has been recently updated to allow the recording of vaccinations administered in schools (e.g., Human papillomavirus (HPV), Diphtheria Toxoid (DT), Tetanus-Diphtheria (TD), and Measles-Rubella (MR), though in the form of aggregate data only. Furthermore, SIMUNDU has been developed to record COVID-19 vaccinations in health facilities and those carried out in masse.

Monitoring is conducted monthly to assess data completeness across health facilities, while an evaluation is conducted yearly. These exercises have allowed the identification of several challenges related to implementing the system (e.g., workload, staff turnover, and rotation) and data quality (e.g., accuracy and timeliness). However, no systematic assessment of the system has been conducted to date. SIMUNDU is the first

immunization information system ever introduced in Indonesia. Other districts and provinces have shown interest in rolling it out, and the Ministry of Health has acknowledged the innovation. The work presented here aims to examine SIMUNDU's introduction and implementation process to draw lessons that could inform scalability and sustainability across the country.

Methods

From May to October 2020, we examined the experience of introducing and implementing an immunization information system in the DIY province using an explanatory sequential mixed-method design, where each step informed the next (11). First, we reviewed of all relevant documentation available in the DIY Health Office – e.g., staff notes, meeting notes and monitoring notes – documenting SIMUNDU development and management processes. We also examined online documents, including health profiles and regulations on health reporting systems in Indonesia. This served as the initial data source and provided an overview of who was involved and how in developing and implementing SIMUNDU. This informed the survey design that we conducted as a second step. The survey targeted any staff responsible for entering data in SIMUNDU (i. e. data clerks) across all PHC and selected UPS facilities and any staff responsible for managing the system at the district and city level (i. e., immunization coordinators). Sampling and recruitment strategies are outlined in Table 1.

Table 1. Survey participant

Level of the data entry and reporting system	Total number of facilities/ offices	Study population	Sampling strategy	Recruitment	Sample size
Primary Health Centre (PHC)	121	Data entry clerks	All facilities	Open invitation across all facilities	113
UPS - Central, General, Maternity and Pediatric Hospitals	65	Data entry clerks	Randomly selected 2 facilities per district/city (2*5=10)	Open invitation across selected facilities	8
UPS - Clinics	73	Data entry clerks	Randomly selected 2 facilities per district/city (2*5=10)	Open invitation across selected facilities	7
UPS - Midwives' Practices	271	Data entry clerks	Randomly selected 2 facilities per district/city (2*5=10)	Open invitation across selected facilities	10
District/City Health Office	5	Immunization coordinators	Total sampling	Open invitation	4*
			Total		**142**

*When the immunization coordinator had recently changed, the former was also invited.

All immunization coordinators in each district/city and data entry clerks from all primary health facilities (PHC) were invited to participate in this survey. For UPS facilities, we selected two clinics, two midwives' practices, and two hospitals per district/city and invited all of their staff who involved in SIMUNDU data entry and management.

We developed and pre-tested an online survey in Bahasa Indonesia to inquire about SIMUNDU implementation, processes, and outcomes across PHC, UPS clinics, district or city and province offices. The questionnaire consisted of close-ended and Likert scale questions – ranging from 45 to 50 depending on the target type of facility and/or level of the health system – and enquired about respondents' socio-demographic characteristics as well as the process of implementing and managing SIMUNDU. Some questions provided an additional field for clarifying the reason for a particular answer choice.

All participants were invited to the DIY Health Office to complete the survey on their laptops, with their prior consent. All participants in a room allowed researchers to monitor any missing or incomplete responses in real time and follow up with individual participants on-site to fill any gaps. We don't believe this may have introduced any significant bias as researchers would simply flag any missing responses and invite respondents to address those. Data were then exported and analyzed in Microsoft Excel. An exploratory analysis of the survey data informed the topic areas that qualitative interviews explore further.

Similarly, some informants were purposefully selected among survey participants to follow up on the range of perspectives that had emerged from the survey. Other informants had been identified at the desk review stage and chosen for their management functions. Selected informants were invited to the DIY Health Office for the interview, and COVID-19 prevention protocol was observed. Every informant was informed about the study and asked to sign the informed consent. All invited informants agreed to participate. A total of nine 30-minute semi-structured interviews were conducted in Bahasa Indonesia language and recorded with prior consent from participants. The interview team consisted of three researchers with the respective task of running the interview, observing and taking notes. A research assistant transcribed all interviews in Bahasa Indonesia language.

Thematic analysis was conducted using Quirkos qualitative tool following Braun and Clarke's approaches (12). Researchers familiarized themselves with the data, searching for initial codes and allowing themes to emerge. The principal investigator led the coding process, and led the research team in defining and naming the core themes emerging from the data, organizing and analyzing the data across the themes, and triangulating

information from the desk review, the survey, and the interviews. This stage was also performed in Bahasa Indonesia. Data were translated to English only at sub-theme and core themes.

Results

Characteristic participant

a. Quantitative study

In total, 142 respondents participated in this study spread across five districts/cities in the DIY province. Most respondents came from Gunungkidul District, PHC, UPS, and DHO, 24.8%, 24%, and 25%, respectively. For all research units, the majority are women. At the UPS and DHO/CHO levels, most respondents were aged 41-45 years, i.e., 28.3% and 75%, respectively, while at the UPS level, the majority were aged 25-30 years (56.0%). For education level, PHC and UPS are dominated by Diploma 3 graduates, namely 86.7% and 80%, respectively, while in DHO/CHO, it is predominantly undergraduate graduates (75%) (Table 2)

Table 2. Characteristic respondents in three groups of respondents

Characteristic	PHC (n= 113) n (%)	UPS (n=25) n (%)	DHO/CHO (n= 4) n (%)
District/City			
Bantul	23 (20.4)	5 (20.0)	1 (25.0)
Gunungkidul	28 (24.8)	6 (24.0)	1 (25.0)
Yogyakarta	17 (15.0)	4 (16.0)	0 (0.0)
Kulonprogo	21 (18.6)	4 (16.0)	1 (25.0)
Sleman	24 (21.2)	6 (24.0)	1 (25.0)
Sex			
Male	3 (2.7)	0 (0.0)	2 (50.0)
Female	110 (97.3)	25 (100)	2 (50.0)
Age			
< 25	0 (0.0)	5 (20.0)	0 (0.0)
25-30	3 (2.7)	14 (56.0)	0 (0.0)
31-35	30 (26,5)	3 (12.0)	0 (0.0)
36-40	19 (16.8)	1 (4.0)	0 (0.0)
41-45	32 (28.3)	0 (0.0)	3 (75.0)
46-50	18 (15.9)	0 (0.0)	1 (25.0)
>50	11 (9.7)	2 (8.0)	0 (0.0)

Education			
Master	0 (0.0)	1 (4.0)	1 (25.0)
Bachelor	5 (4.4)	1 (4.0)	3 (75.0)
Diploma 4	9 (8.0)	2 (8.0)	0 (0.0)
Diploma 3	98 (86.7)	20 (80.0)	0 (0.0)
Senior high school	1 (0.9)	1 (4.0)	0 (0.0)

b. Qualitative study

Nine informants were recruited to provide the required information to explore the quantitative study results more deeply. They serve as managers and staff at DHO/CHO, PHC, and UPS. Among the nine informants, 2 were men, and 7 were women. Three informants graduated with master's, one bachelor's, and five diplomas graduates (Table 3).

Table 3. Informants' characteristics for the qualitative study

Sex	**Age (years)**	**Education**	**Position**	**Subject group**	**Informant's code**
Female	56	Magister	Head of disease prevention and control department at PHO level	Managerial	M 01
Male	57	Magister	The former of the disease prevention and control section at the PHO level	Managerial	M 02
Male	54	Bachelor	Immunization programmer at the PHO level	Managerial	M 03
Female	47	Magister	IT Person	Managerial	M 04
Female	34	Diploma	Data entry at the PHC level	Staff	S 01
Female	25	Diploma	Data entry at the UPS level	Staff	S 02
Female	31	Diploma	Data entry at the UPS level	Staff	S 03
Female	42	Diploma	Data entry at the PHC level	Staff	S 04
Female	24	Diploma	Data entry at the PHC level	Staff	S 05

c. Finding

Findings from the study are organized and presented across the three core themes that emerged from the qualitative analysis, notably system strengths, potential threats, and opportunities for scale-up. However, data from qualitative and quantitative data fed into

the analysis of these core themes to cross-validate the findings (Figure 2. Detailed findings from the survey are presented in Table Supplement 1.

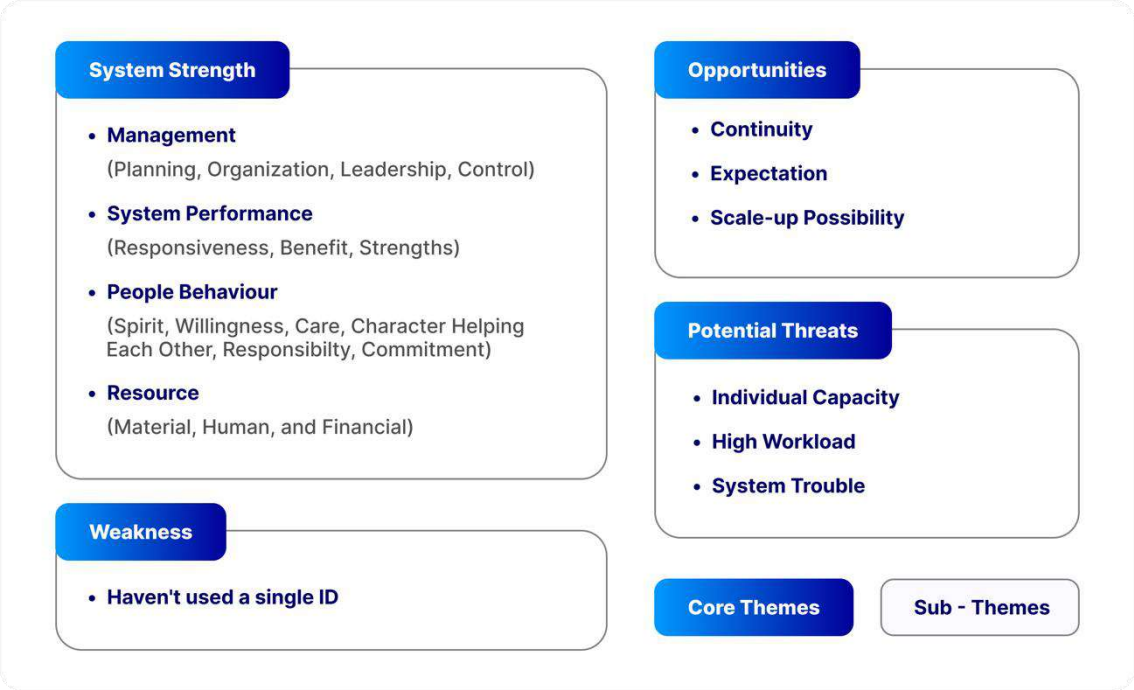

Figure 2. Strengths, potential threats, and opportunities for scale-up

System's Strengths

Factors contributing to the success of SIMUNDU include management, system performance, people's behavior, and resources.

Management

SIMUNDU arose due to concerns from the DIY Health Office immunization section around data quality, notably the need to address data inaccuracy, duplicate or missing data and lack of timely data, and the need for quality data to support follow-up and appropriate planning. The need for SIMUNDU arose from these challenges and needs.

"To our knowledge, [SIMUNDU development] started with a problem: estimates of the target population varied depending on the data source" (M02)

"Yes, I think [SIMUNDU management team] started to tire of managing a large volume of data with dubious validity. They need to know the situation in each district". (M04)

Effective management of SIMUNDU from development to implementation was highlighted as an essential determinant of its success across the critical functions of Planning, Organization, Leadership, and Control.

Careful **Planning** was ensured at each stage of SIMUNDU development and implementation. These stages included developing an initial business plan, providing training on and socialization to SIMUNDU, and developing a staff replacement plan to respond to turnover or retirement of staff in charge of operating the system or entering data. The parties involved in planning included the Head of the Disease Prevention and Control Department, IT personnel, and from the DIY Health Office immunization program staff.

Organization- the organization of SIMUNDU, is carried out at several levels. The top level is the DIY Health Office, the second level is the district/city health office, and the third level is health facilities (Figure 2). A third party was also involved in developing the system interface.

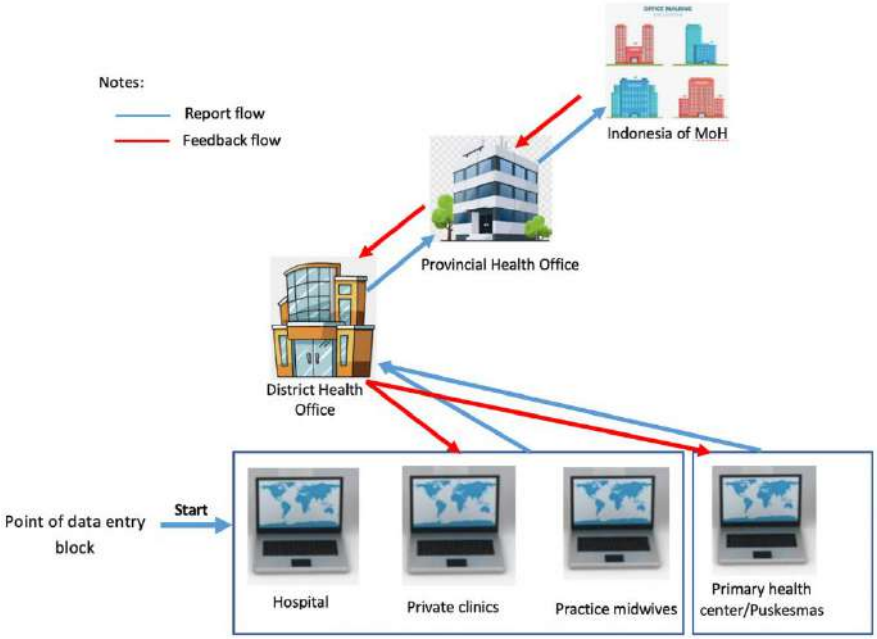

Figure 2. Visual organizing framework of SIMUNDU – DIY Province, Indonesia

At the beginning of SIMUNDU development, essential functions included database administrators, interface designers, and server administrators, and their interplay facilitated the system's smooth operation. Training specific to SIMUNDU was integrated with other training, typically immunization-related training. This enabled us to share of resources with other programs, thus ensuring viability. The training was delivered in the district/city health office: 87.6%, 72%, and 75% of survey respondents from PHC, UPS, and DHO/CHO, respectively had participated in in-house training. Training typically consisted of short sessions and included practice on the trainee's device to operate the system in both online and offline mode. Informants indicated that day-to-day operations were carried out autonomously by the staff through flexibly adjusting their work to protect the time to enter the data. This seemed to work effectively.

Leadership - the success of SIMUNDU implementation is arguably related to strong leadership. Informants noted that managers played a crucial role in bridging the needs of

the immunization program with the system design, closely monitoring the initial implementation process, and creating an enabling environment.

"I try to combine supporting and managing and monitoring the people imvolved. Currently, I monitor whether [SIMUNDU] can run optimally as our users are health facilities. I also monitor program development and the system's output." (M01)

"[SIMUNDU] was born from program managers, primary health centers, Districts, and DIY Health Offices wanting to build systems together. We – DIY Health Office - give them motivation in every meeting." (M03)

"I see that [management] is very good at networking. Staff data entry in the field always said that these people are very kind." (M02)

The role of IT workers in developing SIMUNDU was also significant. They helped develop the system and facilitated correct data entry operators whenever technical issues arose. IT workers also helped resolve inconsistencies in data records. Acknowledgment of staff efforts was also important to maintain motivation and buy-in.

"In the early days of SIMUNDU's development, the system was challenging to operate, as it wasn't as stable as it is now. I praise the enthusiasm and dedication of the users." (M01)

The **control** function - consisting of **quality** assurance management - was critical to avoid data duplication or missing entries and ultimately ensure data quality. This process was not regulated by specific Standard Operating Procedures but was addressed during training and monitored monthly. In addition, the DIY Health Office provided negative incentives to health facilities that were not submitting complete records and provided regular feedback from monitoring and evaluation exercises.

Specifically, 94.2%, 100%, and 100% of survey respondents in PHC, UPS, and DHO, respectively, reported their work had been subject to monitoring. More than half of the respondents in PHC and UPS facilities had been observed by supervisors while performing data entry at least once over the past year. At the PHC level, 48.3% of survey respondents had been subject to monitoring from the district/city office's team, and 45.7% received monitoring from DIY Health Office's staff. Conversely, 40% of respondents from UPS facilities were monitored by PHC's staff. Almost all survey respondents reported receiving feedback from the monitoring, mainly from the District/City and DIY Health Offices. Forty percent of respondents from UPS facilities reported receiving feedback from PHC. Immunization coordinators from the District/City Health Offices received feedback from the DIY Health Offices.

"In a [evaluation] meeting, DIY Health Office or District Health Office showed the progress of our data entry – correct or not, proper or not." (M02)

It is worth noting that DIY Province is quite a small geographic area. Because it consists of only five districts and one city, this province is relatively easy to monitor across all phases, from planning through monitoring and evaluation.

System performance

While SIMUNDU predominantly contains individual-level immunization records, it also serves as a source for aggregation and can synergize with other information systems. Notably, SIMUNDU can link to the DHIS2 and generate immunization-specific reports per the Ministry of Health's requirements. These reports are sent to the upper levels automatically if SIMUNDU is operated online or submitted via email if SIMUNDU is

operated offline. This functionality has had an essential role in ensuring the acceptability and adoption of the system.

Informants noted how transitioning from paper-based tools to an electronic system made data entry easier and reduced errors. SIMUNDU also facilitated the implementation of protocols for data storage and security. It enabled follow-up and defaulter tracking. Finally, integration with the DHIS2 meant reduced workload for the staff.

"We can track children who may have received vaccinations in different locations faster. For example, when the first dose of a vaccine is given in Bantul and the second one in Yogyakarta, the record can be linked within SIMUNDU" (M01).

"SIMUNDU makes detecting what data and vaccinations are missing easier since we enter data from the children's birth through the end of the immunization schedule. So, we will know where they miss any vaccine." (S03)

"The benefit of using SIMUNDU is first: we know the situation of immunizations more accurately….so our vaccine forecasting is more accurate …. and our budget, staff, facilities can be more effective and efficient in providing services." (S05)

"Colleagues from the mother and child health (KIA) program enter the data via the KIA "Sembada." So, this data will appear automatically in SIMUNDU because the two system are connected." (S01)

SIMUNDU is user-friendly and can be flexibly operated offline or online, allowing the responsible staff to maintain data entry irrespective of connectivity. 82.3%, 96%, and 100% of survey respondents from PHC, UPS, and DHO, respectively reported operating SIMUNDU online.

People's behavior

The interview showed that staff commitment was critical for the successful implementation of SIMUNDU, as indicated by their willingness to work overtime and bring home the data to enter into the system.

"I take it [the data] home too, for example, after immunization sessions– in my clinic, immunization runs four times per month, every week. So, when the session is finished, we can take the data home, [and] do the entry at home while relaxing." (S03)

The interviews confirmed this dedication, which spoke to a societal culture of helping others and responsibility and commitment to the team. This contributed to shaping an environment where people approach SIMUNDU as a shared responsibility and a collective endeavor. Informants also noted the high motivation of dedicated staff.

"That's all; we cannot judge by money [people's kindness, culture, and behavior]; explaining how good people are in Yogyakarta is essential. I was in another place before, and could not find people's kindness like in Yogyakarta - different characters." (M02)

"The second thing is that we need human resources concerned and love for data; otherwise, even though we have a good system, it will amount to nothing without good human resources. But good implementation will come more easily when people are concerned about data." (M04)

Resource: material, human and financial

Infrastructure and equipment emerged as critical factors in introducing and sustaining SIMUNDU implementation. Some desktops were explicitly allocated to the

immunization program, and some had to be shared with other staff. Other data entry officers reported using their laptop or smartphone (36.3% of survey respondents from PHC). In UPS facilities, 40.7% reported using office desktops; in the DHO, more than half of the respondents stated they used an office-supplied laptop. The majority of respondents – regardless of the type of facility - said their current device was sufficient to perform their work on SIMUNDU. Regarding connectivity, 64.6% of PHC survey respondents and 67.7% of UPS's reported operating SIMUNDU online, relying on the office's internet connection.

Management of financial resources was also crucial. According to the key informants, no special funds were allocated to SIMUNDU in the initial stages. Resources were leveraged through sharing activities – e.g., monitoring visits or transportation - with other programs, thus allowing cost efficiencies. Integration with other programs proved critical to ensuring sustainability.

"SIMUNDU's budget comes from the state budget called as Anggaran Pendapatan dan Belanja Negara (APBN). Every year the APBN allocates funding envelope for immunization to DIY and other provinces, where the budget is apportioned across the program [not explicitly written budget for SIMUNDU]." (M02)

Human resources are critical to the operation of SIMUNDU. According to interview, SIMUNDU data entry clerks must have patience, work carefully and not rush, be interested in data, be responsible, and have basic computer skills in word processing and spreadsheet software tools such as Microsoft Word and Excel, respectively. As shown by the survey, the large majority of SIMUNDU-operating staff was educated: at least 80% of data entry clerks in either PHC or UPS facilities have secondary education (>80%),

while at the managerial level (DHO), 75% of respondents have a Bachelor's degree (see Table 2). However, 19.4% and 9.1% of respondents from PHC and UPS facilities, have low computer literacy.

Various data entry clerks looked for strategies to resolve the obstacles they encountered when entering data to SIMUNDU. Based on the interviews, some clerks furthered their computer skills by taking private computer classes. Others learned from colleagues at their offices, or reached out for help to the district person in charge. To deal with the accumulation of data needing to be entered in SIMUNDU, staff would sometimes work at home after office hours, as their busy schedule at work did not allow time for data entry.

"If we found obstacles, we asked people in charge in PHC – asking for a solution or sharing by WhatsApp – or sometimes I asked the IT person in the DIY Health Office."

(S03)

Potential threats

As of today, SIMUNDU can be said to be a successful experience. However, some obstacles were encountered and addressed during implementation. Potential system sustaining include individual capacity, technical or system issues, and high workload. Staff computer literacy was identified as one of the main sustainability challenges. Internet connectivity was another obstacle, as not a good network equally supported all health facilities. The survey shows that 64.6% and 67.7% of PHC and UPS staff used office internet, while others had to rely on their home internet.

Further, incomplete and inconsistent records – such as differing child's date of birth or name spelling across relevant entries - make it challenging to consistently record

immunization information. These challenges have arisen during implementation and were promptly addressed. Yet, they had an impact on staff who was already juggling busy schedule in the office, causing delays in data entry. As shown by the survey, almost all respondents stated having other responsibilities besides operating SIMUNDU – notably 97.3%, 88%, and 100% of participants from PHC, UPS and district and city offices, respectively.

Weakness

The informant said that SIMUNDU assisted in their daily work, but they also reported that sometimes they needed more time to find the children's names on the next visit. It is because SIMUNDU data entry did not use a single national ID that could be valid anywhere. As a result, when a name input error occurs, the officer will need time to check with the name of the child's parents or the manual register.

"Sometimes, there was an incorrect name during the data entry; for example, Dita was written as Dieta. So, it is difficult for us to find them. If that happens, we must look back at the register or medical record data. " (S04)

"I experienced difficulty entering data on SIMUNDU when a new patient came from another health facility to us. It was challenging to find their record on SIMUNDU" (S05)

Opportunities

Informants appreciated SIMUNDU as an excellent system to manage immunization data. SIMUNDU has become necessary for program managers and policymakers; it allows them to monitor coverage and can help inform planning and programming. Currently, SIMUNDU is stable, thus is easier to manage than when it was in the development phase.

It is also viable and no longer requires heavy reliance on the core workforce that started the system. The hopes expressed by data entry clerks in the interviews are that SIMUNDU is easier to operate and system errors are less frequent. Informants also stressed the need for refresher training to ensure knowledge and practice of the system is not lost.

"In my opinion, SIMUNDU is the best program in DIY, a collaboration between program managers and IT. It will continue to be implemented because it is a necessity. It has been stably used for more than five years, meaning this is needed." (M01)

"If I have the tool, in this case, SIMUNDU, when it is stable, whoever will be able to run it, I am sure that anyone can operate it. It means that it doesn't matter if we have people shifting (jobs)." (M01)

"In the future, if SIMUNDU is still used, other reports are not necessary. Now we have two different reports: SIMUNDU and stock card of vaccine – each stand-alone and need a separate report." (S05)

Based on the key informants' interviews, SIMUNDU is likely to be developed further / or expanded to other provinces. The DIY Health Office is open to supporting other provinces interested in introducing the system, for instance, through the lending staff for training and orientation. However, informants advised that a successful introduction requires a strong commitment from staff and management.

Discussion

Robust health information systems (HIS) are essential components of robust health systems (13). At the most basic level, immunization registries are systems that collect and report individual-level vaccine administration record data, thus facilitating individual

follow-up of vaccination status. Registries also allow for the monitoring of vaccination coverage and enable analysis of AEFIs and surveillance data to inform the design of coverage interventions and outbreak investigations. When an electronic registry has interoperability with other electronic systems – such as in the case with SIMUNDU – it is considered an Immunization Information System (IIS) (14). This paper presents lessons learned from DIY's experience implementing an IIS.

DIY is the only province in Indonesia – out of thirty-four - that uses an IIS. This work has shed light on the strengths and underlying barriers of implementing an IIS in this context. The objective of this study was to draw lessons that inform sustainable scale-up in other provinces and possibly at the national level. This study highlighted individual capacity, technical or system issues, and high workload as the major barriers to sustainability. Conversely, management, system performance, people's behavior, and available resources emerged as the main determinants of SIMUNDU's successful implementation - notably in improving acceptability, implementation costs, and adoption of this innovation (15).

Despite several obstacles encountered during the implementation of SIMUNDU, this study showed that this innovation was well accepted by key stakeholders. On the one hand, data entry clerks noted that the system is relatively user-friendly and allows to organize the data better and enhance its quality. On the other hand, managers noted the benefits this innovation brought about, namely in the potential for cohort data to support planning and monitoring and ultimately improve immunization coverage.

Effective management - across planning, organization, leadership, and control functions – is a crucial reason why SIMUNDU has been viable for over 5 years. Managers use

their control to encourage the beliefs and actions of the staff with a dedicated and robust managerial process (16). SIMUNDU was born from the need for credible data to assist in carrying out DIY Health Office duties at the managerial and operational levels. At the managerial level, the disease prevention and control department and the IT department collaborated in designing a system that intended users readily accepted. Immunization officers and IT programmers played a central role from the early stages of development through implementation with effective coordination and communication. They were helped in this task with the full support of their respective superiors.

SIMUNDU is cost-effective in several ways. During the introductory period of its implementation, immunization programmers, IT officers, and other staff assisted in introducing SIMUNDU in all districts in the province. This was done by integrating some of the activities across programs, thus building efficiency in terms of time and costs for both managers and staff. Sharing resources across programs was critical in the first years of building sustainability. Additionally, SIMUNDU maintenance does not require high costs because the DIY Health Office has developed the system and thus possesses in-house technical skills. The IT department has the capacity to monitor and improve processes and tailor them to user needs without much additional cost.

A good program without good leadership could fail in its implementation, and even if it was initially successful, it might not be sustainable (17). In the context of SIMUNDU, leadership and effective management support facilitated the program's adoption. The uptake of the new system was good and all health facilities providing immunization services have successfully transitioned to SIMUNDU. The strong network of the prominent persons in charge of SIMUNDU also facilitated the adoption. Good communication, care, and attention to staff concern positively affected staff performance.

They felt that they were well-supported and treated kindly, and this helped them carry out their work joyfully. According to several informants, the DIY immunization program manager's leadership played an essential role in this effect.

The monitoring and evaluation mechanisms of SIMUNDU were also important. Preferred monitoring and evaluation activities include monthly reports and staff discussions during site monitoring visits. The immunization program manager suggested this approach to maintain data quality and ensure the system sustainability. These chosen mechanisms allow program managers to assess the actual practice in the field and the challenges faced to inform decisions about the follow-up actions to be taken. These processes supported the ongoing development of and learning from, SIMUNDU as a tool for data collection, analysis, and visualization, as well as the benefits for managers to carry out monitoring and evaluation. The same sentiment was reflected in previous research undertaken in the India (18).

Human resources are a key determinant of the successful implementation of any HIS (19). People's behavior affects how the system works, develops, and survives (20),(21). In the case of SIMUNDU, implementation was facilitated by a culture of care, established networks, and a positive attitude towards data of both the program manager and IT team. From the staff's point of view, the local culture of helping each other and doing their job correctly and responsibly translated into staff carrying out their duties with enthusiasm and high commitment. Although facilities, funding and human resources were limited, the individuals involved were highly motivated and supportive.

Despite the many strengths of SIMUNDU, some obstacles may potentially challenge its sustainability in the long term. These obstacles can be divided into human variables and

technical variables. From the human variables side, unequal capacity distribution at the operational level can result in differing levels of data quality across facilities and districts. Staff workload is another challenge need addressing, as their willingness to work overtime is not a sustainable strategy. Technical problems were another obstacle during the introduction of SIMUNDU, but qualified technicians/developers could solve these issues. During our research, we recognized the weakness of SIMUNDU that it had not used the person number as a unique (single) code (ID) in data entry. This impacts on the challenging on finding a person when the previous entry was inaccurate. The in absence SIMUNDU single ID also affect the SIMUNDU's inability to synchronize with other health programs that use a person's number as a unique code. However, this weakness can be seen as room for improvement for SIMUNDU shortly. Another thing that needs to be considered for other regions that will implement SIMUNDU that SIMUNDU is that implemented in the DIY province which consists of 5 districts/cities with relatively easy regional accessibility. For areas with more difficult access, the commitment of the leadership and subordinates is the key to successful implementation.

Conclusion

SIMUNDU is a promising innovation for the entire country, beyond DIY. There is agreement about the potential for scale-up of this IIS to other provinces. Experience of implementing this system in DIY over the past five years has shown that the benefits outweigh the challenges, and SIMUNDU has grown into a robust yet user-friendly system. Regular training to dedicated staff for strengthen their capacity as the system evolves and is updated, and a plan for anticipating and responding to staff turnover have proven critical strategies towards sustainability. SIMUNDU’s success also rests on

remarkable leadership, both in creating and enabling a supportive environment and pursuing integration with other programs to share limited resources.

Recommendation

This study's recommendations address three different stakeholders' groups: the DIY Health Office, the national government, and researchers. First, to ensure continuity and sustainability and reduce the system's dependency on a particular person or party, SIMUNDU management and maintenance should be managed by people who have competency and interest in a good reporting system. Furthermore, a human resources plan should be developed in preparation for SIMUNDU roll-out in other provinces or at the national levels; this is necessary to avoid vacancies when DIY province staff are seconded to other areas for mentoring support. Second, the fact that SIMUNDU emerged from an actual need for immunization programme implementers and saw these at the front-line of its development and implementation, positively impacted its feasibility and viability. This suggests that the approach to scaling up SIMUNDU should be stepwise, considering each region's specific characteristics and needs. To this effect, a readiness map and a timeline may be developed to roll out of SIMUNDU in a particular region. Third, further research is needed to assess the impact of SIMUNDU on immunization coverage. Based on our conversations with stakeholders, it would be particularly relevant to focus on a low-performing region and observe the impact over a 2 to the 3-year time window.

Study limitations

The empirical results reported herein should be considered in light of limitations. First, the results of the quantitative study must be considered concerning the limited sample size, particularly for UPS Health Facilities. However, considering the top-down

immunization program and the characteristics of UPS, which will not be significantly different from each other, the results of this study are still valid and relevant to the existing. In qualitative research that aims to explore, caution is needed in interpreting the interview results. These results still a need in-depth studies with different approaches, such as focus group discussions to confirm the results.

Declarations

Ethics approval and consent to participate

This study was approved by the Ethical Review Board of Universitas Ahmad Dahlan, Yogyakarta, Indonesia (ethical approval code: 012005021). Before data collection began, consent to participate was obtained from research subjects (both survey and key informant interviews).

Adherence to national and international regulations

Not applicable

Consent for publication

Before data collection begins, an approval that data is taken for publication purposes is obtained from research subjects (both surveys and key informant interviews).

Availability of data and materials

The datasets generated and or analyzed for this study can be requested from the corresponding author.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

SS, TAW, RR, ASDN and MF designed the study. SS, TWS, SKW, SAM collected the data. SS and RR conducted data analysis. SS developed the paper with inputs and comments from MF on each draft. All authors agree with the manuscript's results and conclusions.

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Authors' information:

The authors alone are responsible for the views expressed in this article. They do not necessarily represent the views, decisions, or policies of the institutions affiliated with them.

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BMC Health Services Research

Introduction and implementation of an immunization information system in Indonesia province of Daerah Istimewa Yogyakarta: lessons for scale-up

--Manuscript Draft--

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Abstract:	Background: Immunization is critical to saving children from infections. To increase vaccination coverage, valid and real-time data is needed. Accordingly, it is essential to have a good report system that serves as defaulter tracking to prevent children's immunization failure. The Daerah Istimewa Yogyakarta (DIY) Health Office introduced an electronic immunization registry and successfully implemented it for over than five years. It is the only individual-based record system in Indonesia that has been sustainably operated for a long time. Yet, no systematic assessment of this system has been conducted to date. This study examines the Sistem Informasi Imunisasi Terpadu (SIMUNDU) introduction and implementation process to draw lessons that could inform scalability and sustainability across the country. Methods: This study used an explanatory sequential mixed-method design, which collected quantitative data from 142 participants and qualitative data from 9 participants. Entry data clerk in a health facility was systematically selected to participate in the survey. While in the key informant interview, the informant was selected based on the survey result. A descriptive and thematic approach was adopted to analyze the quantitative and qualitative data. Results from across the two approaches were integrated for comparison and contrast. Results: Findings are presented according to three core themes that emerged from the data: system strengths, potential threats, and opportunities for scale-up. Strengths - i.e. factors contributing to the success of SIMUNDU - include management, system performance, people's behavior, and resources. Potential threats to sustaining the system include individual capacity, technical or system issues, and high workload. Opportunities – i.e promising factors that SIMUNDU can be operated sustainably – such as continuity, expectation and scale up possibility. Conclusions: SIMUNDU is a promising innovation for Indonesia, beyond DIY. There is agreement about the potential for scale-up of this IIS to other provinces. Experience of implementing this system in DIY over the past five years has shown that the benefits outweigh the challenges, and SIMUNDU has grown into a robust yet user-friendly system.
Corresponding Author:	Sulistyawati Sulistyawati, PhD Ahmad Dahlan University: Universitas Ahmad Dahlan Yogyakarta, Yogyakarta INDONESIA
Corresponding Author E-Mail:	sulistyawati.suyanto@ikm.uad.ac.id
Corresponding Author Secondary Information:	
Corresponding Author's Institution:	Ahmad Dahlan University: Universitas Ahmad Dahlan
Corresponding Author's Secondary Institution:	
First Author:	Sulistyawati Sulistyawati, PhD
First Author Secondary Information:	
Order of Authors:	Sulistyawati Sulistyawati, PhD

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Introduction and implementation of an immunization information system in Indonesia province of Daerah Istimewa Yogyakarta: lessons for scale-up

Sulistyawati Sulistyawati, MPH, PhD[1*]

Trisno Agung Wibowo, MPH[2]

Rokhmayanti Rokhmayanti, MPH[1]

Andri Setyo Dwi Nugroho, MPH[2]

Dr. Tri Wahyuni Sukesi, MPH[1]

Siti Kurnia Widi Hastuti, MPH[1]

Dr. Surahma Asti Mulasari, MPH[1]

Marta Feletto, PhD[3]

[1] Faculty of Public Health, Universitas Ahmad Dahlan, Yogyakarta, Indonesia

[2] Daerah Istimewa Yogyakarta (DIY) Health Office, Yogyakarta, Indonesia

[3] Alliance for Health Policy and Systems Research, World Health Organization, Geneva, Switzerland

*Corresponding author: sulistyawati.suyanto@ikm.uad.ac.id.

Kampus 3 - Jl. Prof Dr Soepomo, Janturan, Umbulharjo, Yogyakarta, Indonesia.

Abstract

Background: Immunization is critical to saving children from infections. To increase vaccination coverage, valid and real-time data is needed. Accordingly, it is essential to have a good report system that serves as defaulter tracking to prevent children's immunization failure. The Daerah Istimewa Yogyakarta (DIY) Health Office introduced an electronic immunization registry and successfully implemented it for over than five years. It is the only individual-based record system in Indonesia that has been sustainably operated for a long time. Yet, no systematic assessment of this system has been conducted to date. This study examines the Sistem Informasi Imunisasi Terpadu (SIMUNDU) introduction and implementation process to draw lessons that could inform scalability and sustainability across the country.

Methods: This study used an explanatory sequential mixed-method design, which collected quantitative data from 142 participants and qualitative data from 9 participants. Entry data clerk in a health facility was systematically selected to participate in the survey. While in the key informant interview, the informant was selected based on the survey result. A descriptive and thematic approach was adopted to analyze the quantitative and qualitative data. Results from across the two approaches were integrated for comparison and contrast.

Results: Findings are presented according to three core themes that emerged from the data: system strengths, potential threats, weakness ~~weakness~~ and opportunities for scale-up. Strengths -i.e. factors contributing to the success of SIMUNDU - include management, system performance, people's behavior, and resources. Potential threats to sustaining the system include individual capacity, technical or system issues, and high

workload. Opportunities – i.e promising factors that SIMUNDU can be operated sustainably – such as continuity, expectation and scale up possibility.

Conclusions: SIMUNDU is a promising innovation for Indonesia, beyond DIY. There is agreement about the potential for scale-up of this IIS to other provinces. Experience of implementing this system in DIY over the past five years has shown that the benefits outweigh the challenges, and SIMUNDU has grown into a robust yet user-friendly system.

Keywords: immunization, electronic immunization registry, immunization information system, interoperability, implementation research

Background

Neonatal and childhood vaccination is essential to infectious disease prevention and an absolute human right (1),(2). Vaccination has been proven to reduce the burden of infectious diseases globally (3). According to the WHO, in 2020, an estimated 23 million children under one year did not receive their essential vaccinations. Of these, 60% live in just ten countries, one of which is Indonesia (4). Indonesia is the fourth most populous country globally. It is composed of thousands of islands organized into 34 provinces. Various geographical and cultural factors influence population inequalities to access health services (5). In 2001, the Indonesian government's decentralization policy was enacted. This was an excellent strategy to foster development by engaging regional resources (6). However, this strategy was not without consequence. One primary concern was the Health Information System (HIS) fragmentation.

Indonesia's federal structure results in provinces and districts being relatively independent of the national Ministry of Health. This means that provincial and district-levels information systems are locally regulated (7). For instance, *Pemantauan Wilayah Setempat* (PWS) is a management tool used to monitor coverage of specific health services in an administrative boundary. Depending on the service and region, it can be paper- or electronic-based. PWS-KIA is the monitoring system specific to maternal and child health (KIA), including immunization. PWS-KIA data are reported to the District or City Health Office, go to Province Health Office, and finally reported to the main level. Generally, the data are in Microsoft Excel formats; it will report via emails or various information systems, including Komdat, SiTT, SIHA, PISPK, and SIKDA Generik. PWS-KIA data feeds into District Health Information System 2 (DHIS2). Regional information systems have varying data quality, which reflects inequities in resources across regions. This adds to data integration challenges at the national level (7),(8) and affects strategic policymaking.

In Indonesia's federal system, Daerah Istimewa Yogyakarta (DIY) Province has the authority to regulate and use its budget within its four districts plus one city (Sleman, Gunungkidul, Bantul, Kulonprogo and Yogyakarta). This province is classified as a small province in terms of area size and the number of regions inside (9). However, this region can be considered a representation of Indonesia when viewed from the geographical, socio-economic and heterogeneous population. Regarding childhood vaccination, DIY is among the top ten performing provinces in the country, with 97.7 % of children completing basic immunization coverage in 2019 (10). Immunization services are provided by Primary Health Centres or Puskesmas (PHC), as well as private clinics,

hospitals, and midwives' practices (typically referred to as *Unit Pelayanan Swasta* or UPS).

An electronic immunization registry is a tool for recording individual children's immunization histories. In 2014, the DIY Health Office introduced an electronic immunization registry named SIMUNDU (*Sistem Informasi Imunisasi Terpadu*/ Integrated Immunization Information System). An electronic registry serves essential functions at all levels of the health system. At the district and higher levels, it allows for monitoring vaccination coverage by the vaccine, dose, cohort, and other variables – and can support microplanning and vaccine management. The service delivery level can facilitate individual follow-up of vaccination status and enable health workers to identify children due for vaccination and those who missed their vaccinations (defaulters).

SIMUNDU was designed to link with the PWS-KIA for immunization and interoperability with the DHIS2. While it predominantly contains individual-level immunization records, SIMUNDU also serves as a source for aggregation and can synergize with the *Pemantauan Wilayah Setempat* (PWS) reporting system. For this reason, it can be considered an Immunization Information System (IIS). This means that City and District levels feed into Provincial and National levels *(Personal communication with DIY immunization program officer).*

The original prototype was designed by the information and technology (IT) department of DIY Health Office to be operated offline. In DIY, three out of the four districts and the city introduced the system in 2015. The final district introduced it in 2017. At this stage, the point of data entry was the PHC only. By 2018, UPS facilities were also equipped with SIMUNDU and could enter data into the system. In 2019, the prototype was further

developed to operate online. The online version was rolled out in 2020 (Figure 1). As of May 2021, 79.4% of all PHC and UPS facilities complied. This average rate masks, however, the fact that while all PHCs adopt SIMUNDU, it is more challenging to enforce its use in UPC facilities (Suyani 2020, oral communication, 2020, May 11).

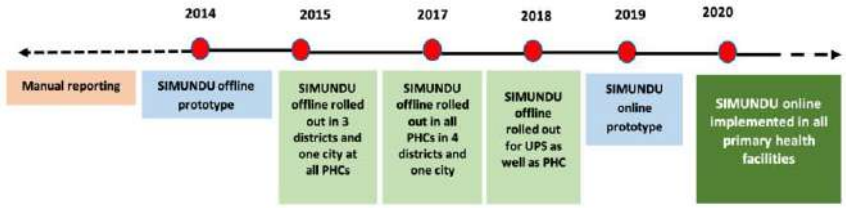

Figure 1. SIMUNDU's development and introduction

When a child receives a vaccination in a health facility, information on the child and the vaccination is entered in SIMUNDU as an individual child record. Each record includes a personal identifier, the child's socio-demographic characteristics (e.g., name, gender, date of birth, name of parents, address), the antigen administered, and the date and place of vaccination. SIMUNDU has been recently updated to allow the recording of vaccinations administered in schools (e.g., Human papillomavirus (HPV), Diphtheria Toxoid (DT), Tetanus-Diphtheria (TD), and Measles-Rubella (MR), though in the form of aggregate data only. Furthermore, SIMUNDU has been developed to record COVID-19 vaccinations in health facilities and those carried out in masse.

Monitoring is conducted monthly to assess data completeness across health facilities, while an evaluation is conducted yearly. These exercises have allowed the identification of several challenges related to implementing the system (e.g., workload, staff turnover, and rotation) and data quality (e.g., accuracy and timeliness). However, no systematic assessment of the system has been conducted to date. SIMUNDU is the first

immunization information system ever introduced in Indonesia. Other districts and provinces have shown interest in rolling it out, and the Ministry of Health has acknowledged the innovation. The work presented here aims to examine SIMUNDU's introduction and implementation process to draw lessons that could inform scalability and sustainability across the country.

Methods

From May to October 2020, we examined the experience of introducing and implementing an immunization information system in the DIY province using an explanatory sequential mixed-method design, where each step informed the next (11). First, we reviewed of all relevant documentation available in the DIY Health Office – e.g., staff notes, meeting notes and monitoring notes – documenting SIMUNDU development and management processes. We also examined online documents, including health profiles and regulations on health reporting systems in Indonesia. This served as the initial data source and provided an overview of who was involved and how in developing and implementing SIMUNDU. This informed the survey design that we conducted as a second step. The survey targeted any staff responsible for entering data in SIMUNDU (i. e. data clerks) across all PHC and selected UPS facilities and any staff responsible for managing the system at the district and city level (i. e., immunization coordinators). Sampling and recruitment strategies are outlined in Table 1.

Table 1. Survey participant

Level of the data entry and reporting system	Total number of facilities/ offices	Study population	Sampling strategy	Recruitment	Sample size
Primary Health Centre (PHC)	121	Data entry clerks	All facilities	Open invitation across all facilities	113
UPS - Central, General, Maternity and Pediatric Hospitals	65	Data entry clerks	Randomly selected 2 facilities per district/city (2*5=10)	Open invitation across selected facilities	8
UPS - Clinics	73	Data entry clerks	Randomly selected 2 facilities per district/city (2*5=10)	Open invitation across selected facilities	7
UPS - Midwives' Practices	271	Data entry clerks	Randomly selected 2 facilities per district/city (2*5=10)	Open invitation across selected facilities	10
District/City Health Office	5	Immunization coordinators	Total sampling	Open invitation	4*
			Total		**142**

*When the immunization coordinator had recently changed, the former was also invited.

All immunization coordinators in each district/city and data entry clerks from all primary health facilities (PHC) were invited to participate in this survey. For UPS facilities, we selected two clinics, two midwives' practices, and two hospitals per district/city and invited all of their staff who ~~who~~ involved in SIMUNDU data entry and management.

We developed and pre-tested an online survey in Bahasa Indonesia to inquire about SIMUNDU implementation, processes, and outcomes across PHC, UPS clinics, district or city and province offices. The questionnaire consisted of close-ended and Likert scale questions – ranging from 45 to 50 depending on the target type of facility and/or level of the health system – and enquired about respondents' socio-demographic characteristics as well as the process of implementing and managing SIMUNDU. Some questions provided an additional field for clarifying the reason for a particular answer choice.

All participants were invited to the DIY Health Office to complete the survey on their laptops, with their prior consent. All participants in a room allowed researchers to monitor any missing or incomplete responses in real time and follow up with individual participants on-site to fill any gaps. We don't believe this may have introduced any significant bias as researchers would simply flag any missing responses and invite respondents to address those. Data were then exported and analyzed in Microsoft Excel. An exploratory analysis of the survey data informed the topic areas that qualitative interviews explore further.

Similarly, some informants were purposefully selected among survey participants to follow up on the range of perspectives that had emerged from the survey. Other informants had been identified at the desk review stage and chosen for their management functions. Selected informants were invited to the DIY Health Office for the interview, and COVID-19 prevention protocol was observed. Every informant was informed about the study and asked to sign the informed consent. All invited informants agreed to participate. A total of nine 30-minute semi-structured interviews were conducted in Bahasa Indonesia language and recorded with prior consent from participants. The interview team consisted of three researchers with the respective task of running the interview, observing and taking notes. A research assistant transcribed all interviews in Bahasa Indonesia language.

Thematic analysis was conducted using Quirkos qualitative tool following Braun and Clarke's approaches (12). Researchers familiarized themselves with the data, searching for initial codes and allowing themes to emerge. The principal investigator led the coding process, and led the research team in defining and naming the core themes emerging from the data, organizing and analyzing the data across the themes, and triangulating

information from the desk review, the survey, and the interviews. This stage was also performed in Bahasa Indonesia. Data were translated to English only at sub-theme and core themes.

Results

Characteristic participant

a. Quantitative study

In total, 142 respondents participated in this study spread across five districts/cities in the DIY province. Most respondents came from Gunungkidul District, PHC, UPS, and DHO, 24.8%, 24%, and 25%, respectively. For all research units, the majority are women. At the UPS and DHO/CHO levels, most respondents were aged 41-45 years, i.e., 28.3% and 75%, respectively, while at the UPS level, the majority were aged 25-30 years (56.0%). For education level, PHC and UPS are dominated by Diploma 3 graduates, namely 86.7% and 80%, respectively, while in DHO/CHO, it is predominantly undergraduate graduates (75%) (Table 2)

Table 2. Characteristic respondents in three groups of respondents

Characteristic	PHC (n= 113) n (%)	UPS (n=25) n (%)	DHO/CHO (n= 4) n (%)
District/City			
Bantul	23 (20.4)	5 (20.0)	1 (25.0)
Gunungkidul	28 (24.8)	6 (24.0)	1 (25.0)
Yogyakarta	17 (15.0)	4 (16.0)	0 (0.0)
Kulonprogo	21 (18.6)	4 (16.0)	1 (25.0)
Sleman	24 (21.2)	6 (24.0)	1 (25.0)
Sex			
Male	3 (2.7)	0 (0.0)	2 (50.0)
Female	110 (97.3)	25 (100)	2 (50.0)
Age			
< 25	0 (0.0)	5 (20.0)	0 (0.0)
25-30	3 (2.7)	14 (56.0)	0 (0.0)
31-35	30 (26,5)	3 (12.0)	0 (0.0)
36-40	19 (16.8)	1 (4.0)	0 (0.0)
41-45	32 (28.3)	0 (0.0)	3 (75.0)
46-50	18 (15.9)	0 (0.0)	1 (25.0)
>50	11 (9.7)	2 (8.0)	0 (0.0)

Education			
Master	0 (0.0)	1 (4.0)	1 (25.0)
Bachelor	5 (4.4)	1 (4.0)	3 (75.0)
Diploma 4	9 (8.0)	2 (8.0)	0 (0.0)
Diploma 3	98 (86.7)	20 (80.0)	0 (0.0)
Senior high school	1 (0.9)	1 (4.0)	0 (0.0)

b. Qualitative study

Nine informants were recruited to provide the required information to explore the quantitative study results more deeply. They serve as managers and staff at DHO/CHO, PHC, and UPS. Among the nine informants, 2 were men, and 7 were women. Three informants graduated with master's, one bachelor's, and five diplomas graduates (Table 3).

Table 3. Informants' characteristics for the qualitative study

Sex	Age (years)	Education	Position	Subject group	Informant's code
Female	56	Magister	Head of disease prevention and control department at PHO level	Managerial	M 01
Male	57	Magister	The former of the disease prevention and control section at the PHO level	Managerial	M 02
Male	54	Bachelor	Immunization programmer at the PHO level	Managerial	M 03
Female	47	Magister	IT Person	Managerial	M 04
Female	34	Diploma	Data entry at the PHC level	Staff	S 01
Female	25	Diploma	Data entry at the UPS level	Staff	S 02
Female	31	Diploma	Data entry at the UPS level	Staff	S 03
Female	42	Diploma	Data entry at the PHC level	Staff	S 04
Female	24	Diploma	Data entry at the PHC level	Staff	S 05

c. Finding

Findings from the study are organized and presented across the three core themes that emerged from the qualitative analysis, notably system strengths, potential threats, and opportunities for scale-up. However, data from qualitative and quantitative data fed into

the analysis of these core themes to cross-validate the findings (Figure 2. Detailed findings from the survey are presented in Table Supplement 1.

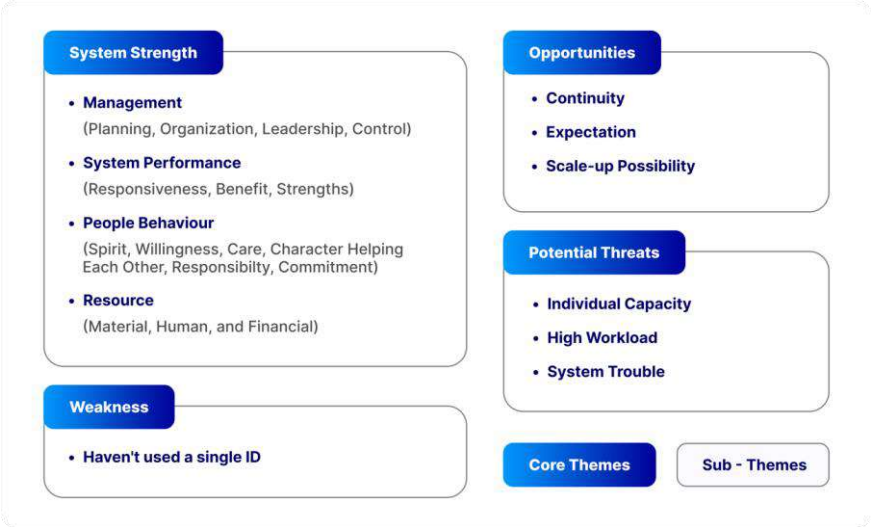

Figure 2. Strengths, potential threats, and opportunities for scale-up

System's Strengths

Factors contributing to the success of SIMUNDU include management, system performance, people's behavior, and resources.

Management

SIMUNDU arose due to concerns from the DIY Health Office immunization section around data quality, notably the need to address data inaccuracy, duplicate or missing data and lack of timely data, and the need for quality data to support follow-up and appropriate planning. The need for SIMUNDU arose from these challenges and needs.

"To our knowledge, [SIMUNDU development] started with a problem: estimates of the target population varied depending on the data source" (M02)

"Yes, I think [SIMUNDU management team] started to tire of managing a large volume of data with dubious validity. They need to know the situation in each district". (M04)

Effective management of SIMUNDU from development to implementation was highlighted as an essential determinant of its success across the critical functions of Planning, Organization, Leadership, and Control.

Careful **Planning** was ensured at each stage of SIMUNDU development and implementation. These stages included developing an initial business plan, providing training on and socialization to SIMUNDU, and developing a staff replacement plan to respond to turnover or retirement of staff in charge of operating the system or entering data. The parties involved in planning included the Head of the Disease Prevention and Control Department, IT personnel, and from the DIY Health Office immunization program staff.

Organization- the organization of SIMUNDU, is carried out at several levels. The top level is the DIY Health Office, the second level is the district/city health office, and the third level is health facilities (Figure 2). A third party was also involved in developing the system interface.

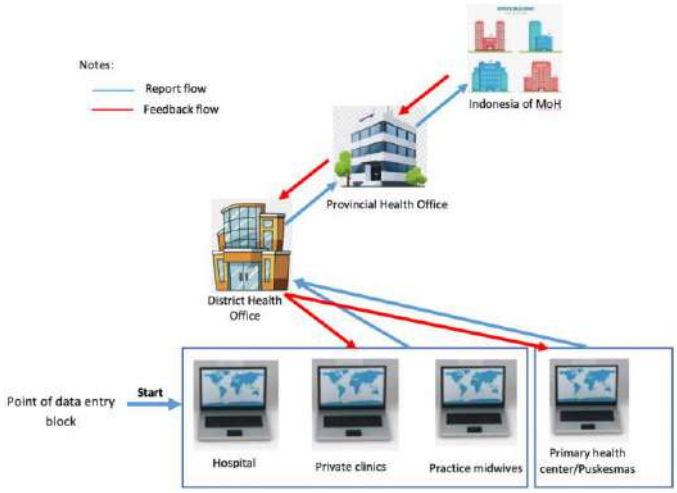

Figure 2. Visual organizing framework of SIMUNDU – DIY Province, Indonesia

At the beginning of SIMUNDU development, essential functions included database administrators, interface designers, and server administrators, and their interplay facilitated the system's smooth operation. Training specific to SIMUNDU was integrated with other training, typically immunization-related training. This enabled us to share of resources with other programs, thus ensuring viability. The training was delivered in the district/city health office: 87.6%, 72%, and 75% of survey respondents from PHC, UPS, and DHO/CHO, respectively had participated in in-house training. Training typically consisted of short sessions and included practice on the trainee's device to operate the system in both online and offline mode. Informants indicated that day-to-day operations were carried out autonomously by the staff through flexibly adjusting their work to protect the time to enter the data. This seemed to work effectively.

Leadership - the success of SIMUNDU implementation is arguably related to strong leadership. Informants noted that managers played a crucial role in bridging the needs of

the immunization program with the system design, closely monitoring the initial implementation process, and creating an enabling environment.

"I try to combine supporting and managing and monitoring the people imvolved. Currently, I monitor whether [SIMUNDU] can run optimally as our users are health facilities. I also monitor program development and the system's output." (M01)

"[SIMUNDU] was born from program managers, primary health centers, Districts, and DIY Health Offices wanting to build systems together. We – DIY Health Office - give them motivation in every meeting." (M03)

"I see that [management] is very good at networking. Staff data entry in the field always said that these people are very kind." (M02)

The role of IT workers in developing SIMUNDU was also significant. They helped develop the system and facilitated correct data entry operators whenever technical issues arose. IT workers also helped resolve inconsistencies in data records. Acknowledgment of staff efforts was also important to maintain motivation and buy-in.

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"In the early days of SIMUNDU's development, the system was challenging to operate, as it wasn't as stable as it is now. I praise the enthusiasm and dedication of the users." (M01)

The **control** function - consisting of **quality** assurance management - was critical to avoid data duplication or missing entries and ultimately ensure data quality. This process was not regulated by specific Standard Operating Procedures but was addressed during training and monitored monthly. In addition, the DIY Health Office provided negative incentives to health facilities that were not submitting complete records and provided regular feedback from monitoring and evaluation exercises.

Specifically, 94.2%, 100%, and 100% of survey respondents in PHC, UPS, and DHO, respectively, reported their work had been subject to monitoring. More than half of the respondents in PHC and UPS facilities had been observed by supervisors while performing data entry at least once over the past year. At the PHC level, 48.3% of survey respondents had been subject to monitoring from the district/city office's team, and 45.7% received monitoring from DIY Health Office's staff. Conversely, 40% of respondents from UPS facilities were monitored by PHC's staff. Almost all survey respondents reported receiving feedback from the monitoring, mainly from the District/City and DIY Health Offices. Forty percent of respondents from UPS facilities reported receiving feedback from PHC. Immunization coordinators from the District/City Health Offices received feedback from the DIY Health Offices.

"In a [evaluation] meeting, DIY Health Office or District Health Office showed the progress of our data entry – correct or not, proper or not." (M02)

It is worth noting that DIY Province is quite a small geographic area. Because it consists of only five districts and one city, this province is relatively easy to monitor across all phases, from planning through monitoring and evaluation.

System performance

While SIMUNDU predominantly contains individual-level immunization records, it also serves as a source for aggregation and can synergize with other information systems. Notably, SIMUNDU can link to the DHIS2 and generate immunization-specific reports per the Ministry of Health's requirements. These reports are sent to the upper levels automatically if SIMUNDU is operated online or submitted via email if SIMUNDU is

operated offline. This functionality has had an essential role in ensuring the acceptability and adoption of the system.

Informants noted how transitioning from paper-based tools to an electronic system made data entry easier and reduced errors. SIMUNDU also facilitated the implementation of protocols for data storage and security. It enabled follow-up and defaulter tracking. Finally, integration with the DHIS2 meant reduced workload for the staff.

"We can track children who may have received vaccinations in different locations faster. For example, when the first dose of a vaccine is given in Bantul and the second one in Yogyakarta, the record can be linked within SIMUNDU" (M01).

"SIMUNDU makes detecting what data and vaccinations are missing easier since we enter data from the children's birth through the end of the immunization schedule. So, we will know where they miss any vaccine." (S03)

"The benefit of using SIMUNDU is first: we know the situation of immunizations more accurately….so our vaccine forecasting is more accurate …. and our budget, staff, facilities can be more effective and efficient in providing services." (S05)

"Colleagues from the mother and child health (KIA) program enter the data via the KIA "Sembada." So, this data will appear automatically in SIMUNDU because the two system are connected." (S01)

SIMUNDU is user-friendly and can be flexibly operated offline or online, allowing the responsible staff to maintain data entry irrespective of connectivity. 82.3%, 96%, and 100% of survey respondents from PHC, UPS, and DHO, respectively reported operating SIMUNDU online.

People's behavior

The interview showed that staff commitment was critical for the successful implementation of SIMUNDU, as indicated by their willingness to work overtime and bring home the data to enter into the system.

"I take it [the data] home too, for example, after immunization sessions– in my clinic, immunization runs four times per month, every week. So, when the session is finished, we can take the data home, [and] do the entry at home while relaxing." (S03)

The interviews confirmed this dedication, which spoke to a societal culture of helping others and responsibility and commitment to the team. This contributed to shaping an environment where people approach SIMUNDU as a shared responsibility and a collective endeavor. Informants also noted the high motivation of dedicated staff.

"That's all; we cannot judge by money [people's kindness, culture, and behavior]; explaining how good people are in Yogyakarta is essential. I was in another place before, and could not find people's kindness like in Yogyakarta - different characters." (M02)

"The second thing is that we need human resources concerned and love for data; otherwise, even though we have a good system, it will amount to nothing without good human resources. But good implementation will come more easily when people are concerned about data." (M04)

Resource: material, human and financial

Infrastructure and equipment emerged as critical factors in introducing and sustaining SIMUNDU implementation. Some desktops were explicitly allocated to the

immunization program, and some had to be shared with other staff. Other data entry officers reported using their laptop or smartphone (36.3% of survey respondents from PHC). In UPS facilities, 40.7% reported using office desktops; in the DHO, more than half of the respondents stated they used an office-supplied laptop. The majority of respondents – regardless of the type of facility - said their current device was sufficient to perform their work on SIMUNDU. Regarding connectivity, 64.6% of PHC survey respondents and 67.7% of UPS's reported operating SIMUNDU online, relying on the office's internet connection.

Management of financial resources was also crucial. According to the key informants, no special funds were allocated to SIMUNDU in the initial stages. Resources were leveraged through sharing activities – e.g., monitoring visits or transportation - with other programs, thus allowing cost efficiencies. Integration with other programs proved critical to ensuring sustainability.

"SIMUNDU's budget comes from the state budget called as Anggaran Pendapatan dan Belanja Negara (APBN). Every year the APBN allocates funding envelope for immunization to DIY and other provinces, where the budget is apportioned across the program [not explicitly written budget for SIMUNDU]." (M02)

Human resources are critical to the operation of SIMUNDU. According to interview, SIMUNDU data entry clerks must have patience, work carefully and not rush, be interested in data, be responsible, and have basic computer skills in word processing and spreadsheet software tools such as Microsoft Word and Excel, respectively. As shown by the survey, the large majority of SIMUNDU-operating staff was educated: at least 80% of data entry clerks in either PHC or UPS facilities have secondary education (>80%),

while at the managerial level (DHO), 75% of respondents have a Bachelor's degree (see Table 2). However, 19.4% and 9.1% of respondents from PHC and UPS facilities, have low computer literacy.

Various data entry clerks looked for strategies to resolve the obstacles they encountered when entering data to SIMUNDU. Based on the interviews, some clerks furthered their computer skills by taking private computer classes. Others learned from colleagues at their offices, or reached out for help to the district person in charge. To deal with the accumulation of data needing to be entered in SIMUNDU, staff would sometimes work at home after office hours, as their busy schedule at work did not allow time for data entry.

"If we found obstacles, we asked people in charge in PHC – asking for a solution or sharing by WhatsApp – or sometimes I asked the IT person in the DIY Health Office." *(S03)*

Potential threats

As of today, SIMUNDU can be said to be a successful experience. However, some obstacles were encountered and addressed during implementation. Potential system sustaining include individual capacity, technical or system issues, and high workload. Staff computer literacy was identified as one of the main sustainability challenges. Internet connectivity was another obstacle, as not a good network equally supported all health facilities. The survey shows that 64.6% and 67.7% of PHC and UPS staff used office internet, while others had to rely on their home internet.

Further, incomplete and inconsistent records – such as differing child's date of birth or name spelling across relevant entries - make it challenging to consistently record

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immunization information. These challenges have arisen during implementation and were promptly addressed. Yet, they had an impact on staff who was already juggling busy schedule in the office, causing delays in data entry. As shown by the survey, almost all respondents stated having other responsibilities besides operating SIMUNDU – notably 97.3%, 88%, and 100% of participants from PHC, UPS and district and city offices, respectively.

Weakness

The informant said that SIMUNDU assisted in their daily work, but they also reported that sometimes they needed more time to find the children's names on the next visit. It is because SIMUNDU data entry did not use a single national ID that could be valid anywhere. As a result, when a name input error occurs, the officer will need time to check with the name of the child's parents or the manual register.

"Sometimes, there was an incorrect name during the data entry; for example, Dita was written as Dieta. So, it is difficult for us to find them. If that happens, we must look back at the register or medical record data. " (S04)

"I experienced difficulty entering data on SIMUNDU when a new patient came from another health facility to us. It was challenging to find their record on SIMUNDU" (S05)

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Opportunities

Informants appreciated SIMUNDU as an excellent system to manage immunization data. SIMUNDU has become necessary for program managers and policymakers; it allows them to monitor coverage and can help inform planning and programming. Currently, SIMUNDU is stable, thus is easier to manage than when it was in the development phase.

It is also viable and no longer requires heavy reliance on the core workforce that started the system. The hopes expressed by data entry clerks in the interviews are that SIMUNDU is easier to operate and system errors are less frequent. Informants also stressed the need for refresher training to ensure knowledge and practice of the system is not lost.

"In my opinion, SIMUNDU is the best program in DIY, a collaboration between program managers and IT. It will continue to be implemented because it is a necessity. It has been stably used for more than five years, meaning this is needed." (M01)

"If I have the tool, in this case, SIMUNDU, when it is stable, whoever will be able to run it, I am sure that anyone can operate it. It means that it doesn't matter if we have people shifting (jobs)." (M01)

"In the future, if SIMUNDU is still used, other reports are not necessary. Now we have two different reports: SIMUNDU and stock card of vaccine – each stand-alone and need a separate report." (S05)

Based on the key informants' interviews, SIMUNDU is likely to be developed further / or expanded to other provinces. The DIY Health Office is open to supporting other provinces interested in introducing the system, for instance, through the lending staff for training and orientation. However, informants advised that a successful introduction requires a strong commitment from staff and management.

Discussion

Robust health information systems (HIS) are essential components of robust health systems (13). At the most basic level, immunization registries are systems that collect and report individual-level vaccine administration record data, thus facilitating individual

follow-up of vaccination status. Registries also allow for the monitoring of vaccination coverage and enable analysis of AEFIs and surveillance data to inform the design of coverage interventions and outbreak investigations. When an electronic registry has interoperability with other electronic systems – such as in the case with SIMUNDU – it is considered an Immunization Information System (IIS) (14). This paper presents lessons learned from DIY's experience implementing an IIS.

DIY is the only province in Indonesia – out of thirty-four - that uses an IIS. This work has shed light on the strengths and underlying barriers of implementing an IIS in this context. The objective of this study was to draw lessons that inform sustainable scale-up in other provinces and possibly at the national level. This study highlighted individual capacity, technical or system issues, and high workload as the major barriers to sustainability. Conversely, management, system performance, people's behavior, and available resources emerged as the main determinants of SIMUNDU's successful implementation - notably in improving acceptability, implementation costs, and adoption of this innovation (15).

Despite several obstacles encountered during the implementation of SIMUNDU, this study showed that this innovation was well accepted by key stakeholders. On the one hand, data entry clerks noted that the system is relatively user-friendly and allows to organize the data better and enhance its quality. On the other hand, managers noted the benefits this innovation brought about, namely in the potential for cohort data to support planning and monitoring and ultimately improve immunization coverage.

Effective management - across planning, organization, leadership, and control functions – is a crucial reason why SIMUNDU has been viable for over 5 years. Managers use

their control to encourage the beliefs and actions of the staff with a dedicated and robust managerial process (16). SIMUNDU was born from the need for credible data to assist in carrying out DIY Health Office duties at the managerial and operational levels. At the managerial level, the disease prevention and control department and the IT department collaborated in designing a system that intended users readily accepted. Immunization officers and IT programmers played a central role from the early stages of development through implementation with effective coordination and communication. They were helped in this task with the full support of their respective superiors.

SIMUNDU is cost-effective in several ways. During the introductory period of its implementation, immunization programmers, IT officers, and other staff assisted in introducing SIMUNDU in all districts in the province. This was done by integrating some of the activities across programs, thus building efficiency in terms of time and costs for both managers and staff. Sharing resources across programs was critical in the first years of building sustainability. Additionally, SIMUNDU maintenance does not require high costs because the DIY Health Office has developed the system and thus possesses in-house technical skills. The IT department has the capacity to monitor and improve processes and tailor them to user needs without much additional cost.

A good program without good leadership could fail in its implementation, and even if it was initially successful, it might not be sustainable (17). In the context of SIMUNDU, leadership and effective management support facilitated the program's adoption. The uptake of the new system was good and all health facilities providing immunization services have successfully transitioned to SIMUNDU. The strong network of the prominent persons in charge of SIMUNDU also facilitated the adoption. Good communication, care, and attention to staff concern positively affected staff performance.

They felt that they were well-supported and treated kindly, and this helped them carry out their work joyfully. According to several informants, the DIY immunization program manager's leadership played an essential role in this effect.

The monitoring and evaluation mechanisms of SIMUNDU were also important. Preferred monitoring and evaluation activities include monthly reports and staff discussions during site monitoring visits. The immunization program manager suggested this approach to maintain data quality and ensure the system sustainability. These chosen mechanisms allow program managers to assess the actual practice in the field and the challenges faced to inform decisions about the follow-up actions to be taken. These processes supported the ongoing development of and learning from, SIMUNDU as a tool for data collection, analysis, and visualization, as well as the benefits for managers to carry out monitoring and evaluation. The same sentiment was reflected in previous research undertaken in the India (18).

Human resources are a key determinant of the successful implementation of any HIS (19). People's behavior affects how the system works, develops, and survives (20),(21). In the case of SIMUNDU, implementation was facilitated by a culture of care, established networks, and a positive attitude towards data of both the program manager and IT team. From the staff's point of view, the local culture of helping each other and doing their job correctly and responsibly translated into staff carrying out their duties with enthusiasm and high commitment. Although facilities, funding and human resources were limited, the individuals involved were highly motivated and supportive.

Despite the many strengths of SIMUNDU, some obstacles may potentially challenge its sustainability in the long term. These obstacles can be divided into human variables and

technical variables. From the human variables side, unequal capacity distribution at the operational level can result in differing levels of data quality across facilities and districts. Staff workload is another challenge need addressing, as their willingness to work overtime is not a sustainable strategy. Technical problems were another obstacle during the introduction of SIMUNDU, but qualified technicians/developers could solve these issues. During our research, we recognized the weakness of SIMUNDU that it had not used the person number as a unique (single) code (ID) in data entry. This impacts on the challenging on finding a person when the previous entry was inaccurate. The in absence SIMUNDU single ID also affect the SIMUNDU's inability to synchronize with other health programs that use a person's number as a unique code. However, this weakness can be seen as room for improvement for SIMUNDU shortly. Another thing that needs to be considered for other regions that will implement SIMUNDU that SIMUNDU is that implemented in the DIY province which consists of 5 districts/cities with relatively easy regional accessibility. For areas with more difficult access, the commitment of the leadership and subordinates is the key to successful implementation.

Conclusion ~~and recommendation~~

SIMUNDU is a promising innovation for the entire country, beyond DIY. There is agreement about the potential for scale-up of this IIS to other provinces. Experience of implementing this system in DIY over the past five years has shown that the benefits outweigh the challenges, and SIMUNDU has grown into a robust yet user-friendly system. Regular training to dedicated staff for strengthen their capacity as the system evolves and is updated, and a plan for anticipating and responding to staff turnover have proven critical strategies towards sustainability. SIMUNDU’s success also rests on

remarkable leadership, both in creating and enabling a supportive environment and pursuing integration with other programs to share limited resources.

Recommendation

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This study's recommendations address three different stakeholders' groups: the DIY Health Office, the national government, and researchers. First, to ensure continuity and sustainability and reduce the system's dependency on a particular person or party, SIMUNDU management and maintenance should be managed by people who have competency and interest in a good reporting system. Furthermore, a human resources plan should be developed in preparation for SIMUNDU roll-out in other provinces or at the national levels; this is necessary to avoid vacancies when DIY province staff are seconded to other areas for mentoring support. Second, the fact that SIMUNDU emerged from an actual need for immunization programme implementers and saw these at the front-line of its development and implementation, positively impacted its feasibility and viability. This suggests that the approach to scaling up SIMUNDU should be stepwise, considering each region's specific characteristics and needs. To this effect, a readiness map and a timeline may be developed to roll out of SIMUNDU in a particular region. Third, further research is needed to assess the impact of SIMUNDU on immunization coverage. Based on our conversations with stakeholders, it would be particularly relevant to focus on a low-performing region and observe the impact over a 2 to the 3-year time window.

Study limitations

The empirical results reported herein should be considered in light of limitations. First, the results of the quantitative study must be considered concerning the limited sample size, particularly for UPS Health Facilities. However, considering the top-down

immunization program and the characteristics of UPS, which will not be significantly different from each other, the results of this study are still valid and relevant to the existing. In qualitative research that aims to explore, caution is needed in interpreting the interview results. These results still a need in-depth studies with different approaches, such as focus group discussions to confirm the results.

Declarations

Ethics approval and consent to participate

This study was approved by the Ethical Review Board of Universitas Ahmad Dahlan, Yogyakarta, Indonesia (ethical approval code: 012005021). Before data collection began, consent to participate was obtained from research subjects (both survey and key informant interviews).

Adherence to national and international regulations

Not applicable

Consent for publication

Before data collection begins, an approval that data is taken for publication purposes is obtained from research subjects (both surveys and key informant interviews).

Availability of data and materials

The datasets generated and or analyzed for this study can be requested from the corresponding author.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

SS, TAW, RR, ASDN and MF designed the study. SS, TWS, SKW, SAM collected the data. SS and RR conducted data analysis. SS developed the paper with inputs and comments from MF on each draft. All authors agree with the manuscript's results and conclusions.

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Authors' information:

The authors alone are responsible for the views expressed in this article. They do not necessarily represent the views, decisions, or policies of the institutions affiliated with them.

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Sulistyawati Sulistyawati; Trisno Agung Wibowo; Rokhmayanti Rokhmayanti; Andri Setyo Dwi Nugroho; Tri Wahyuni Sukesi; Siti Kurnia Widi Hastuti; Surahma Asti Mulasari; Marta Feletto
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Introduction and implementation of an immunization information system in the Indonesian province of Daerah Istimewa Yogyakarta: lessons for scaling-up

Abstract

Background: Immunization is critical to saving children from infections. To increase vaccination coverage, valid and real-time data are needed. Accordingly, it is essential to have a good report system that serves as defaulter tracking to prevent children's immunization failure. The Daerah Istimewa Yogyakarta (DIY) Health Office introduced an electronic immunization registry and successfully implemented it for more than five years. It is the only individual-based record system in Indonesia that has been sustainably operated for a long time. Yet, no systematic assessment of this system has been conducted to date. This study examines the Sistem Informasi Imunisasi Terpadu (SIMUNDU) introduction and implementation process with a view to extracting lessons that could inform scalability and sustainability across the country.

Methods: This study used an explanatory sequential mixed-method design, which collected quantitative data from 142 participants and qualitative data from nine participants. The data entry clerk at a health facility was systematically selected to participate in the survey, while in the key informant interview, the informant was selected based on the survey result. A descriptive and thematic approach was adopted to analyze the quantitative and qualitative data. Results from across the two approaches were integrated for comparison and contrast.

Results: Findings are presented according to three core themes that emerged from the data: system strengths, potential threats, weakness and opportunities for scaling-up. Strengths, i.e., factors contributing to the success of SIMUNDU, include management,

system performance, people's behavior, and resources. Potential threats to sustaining the system include individual capacity, technical or system issues, and high workload. Opportunities – i.e., a promising factor that influences the SIMUNDU ability to operate sustainably – such as continuity, expectation, and the possibility of scaling up.

Conclusions: SIMUNDU is a promising innovation for Indonesia, beyond DIY. There is agreement about the potential for scaling up this IIS to other provinces. The experience of implementing this system in DIY over the past five years has shown that the benefits outweigh the challenges, and SIMUNDU has grown into a robust yet user-friendly system.

Keywords: immunization, electronic immunization registry, immunization information system, interoperability, implementation research

Background

Neonatal and childhood vaccination is essential for infectious disease prevention and an absolute human right (1),(2). Vaccination has been proven to reduce the burden of infectious diseases globally (3). According to the WHO, in 2020, an estimated 23 million children under the age of one year did not receive their essential vaccinations. Of these, 60% live in just ten countries, one of which is Indonesia (4). Indonesia is the fourth most populous country globally. It is composed of thousands of islands organized into 34 provinces. Various geographical and cultural factors influence population inequalities in accessing health services (5). In 2001, the Indonesian government's decentralization policy was enacted. This was an excellent strategy for fostering development by engaging regional resources (6). However, this strategy was not without consequence. One primary concern was the health information system (HIS) fragmentation.

Indonesia's federal structure results in provinces and districts being relatively independent of the national Ministry of Health. This means that provincial- and district-level information systems are locally regulated (7). For instance, *Pemantauan Wilayah Setempat* (PWS) is a management tool used to monitor the coverage of specific health services within an administrative boundary. Depending on the service and region, it can be paper- or electronic-based. PWS-KIA is the monitoring system specific to maternal and child health (KIA), including immunization. PWS-KIA data are reported to the District or City Health Office, go to the Province Health Office, and are finally reported to the main level. Generally, the data are in Microsoft Excel formats; they will be reported via emails or various information systems, including Komdat Kesmas, SITT, SIHA, PISPK, and SIKDA Generik. PWS-KIA data feed into District Health Information System 2 (DHIS2). Regional information systems have varying data quality, which reflects inequities in resources across regions. This adds to data integration challenges at the national level (7),(8) and affects strategic policymaking.

In Indonesia’s federal system, Daerah Istimewa Yogyakarta (DIY) province has the authority to regulate and use its budget within its four districts plus one city (Sleman, Gunungkidul, Bantul, Kulonprogo, and Yogyakarta). This province is classified as a small province in terms of area size and the number of regions inside (9). However, this region can be considered a representation of Indonesia when viewed from the geographical, socioeconomic, and heterogeneous population perspective. With regard to childhood vaccination, DIY is among the top ten performing provinces in the country, with 97.7% of children completing basic immunization coverage in 2019 (10). Immunization services are provided by primary health centers or Puskesmas (PHC), as

well as private clinics, hospitals, and midwives' practices (typically referred to as *Unit Pelayanan Swasta* or UPS).

An electronic immunization registry is a tool for recording individual children's immunization histories. In 2014, the DIY Health Office introduced an electronic immunization registry named SIMUNDU (*Sistem Informasi Imunisasi Terpadu*/ Integrated Immunization Information System). An electronic registry provides essential functions at all levels of the health system. At the district and higher levels, it allows for monitoring vaccination coverage by vaccine, dose, cohort, and other variables – and can support microplanning and vaccine management. The service delivery level can facilitate individual follow-up of vaccination status and enable health workers to identify children due for vaccination and those who have missed their vaccinations (defaulters).

SIMUNDU was designed to link with PWS-KIA for immunization and interoperability with the DHIS2. While it predominantly contains individual-level immunization records, SIMUNDU also serves as a source for aggregation and can synergize with the *Pemantauan Wilayah Setempat* (PWS) reporting system. For this reason, it can be considered an immunization information system (IIS). This means that city and district levels feed into provincial and national levels *(Personal communication with DIY immunization program officer)*.

The original prototype was designed by the information and technology (IT) department of the DIY Health Office to be operated offline. In DIY, three out of the four districts and the city introduced the system in 2015. The final district introduced it in 2017. At this stage, the point of data entry was the PHC only. By 2018, UPS facilities were also equipped with SIMUNDU and could enter data into the system. In 2019, the prototype

was further developed to operate online. The online version was rolled out in 2020 (Figure 1). As of May 2021, 79.4% of all PHC and UPS facilities complied. This average rate masks, however, the fact that while all PHCs adopt SIMUNDU, it is more challenging to enforce its use in UPC facilities (Suyani 2020, oral communication, 2020, May 11).

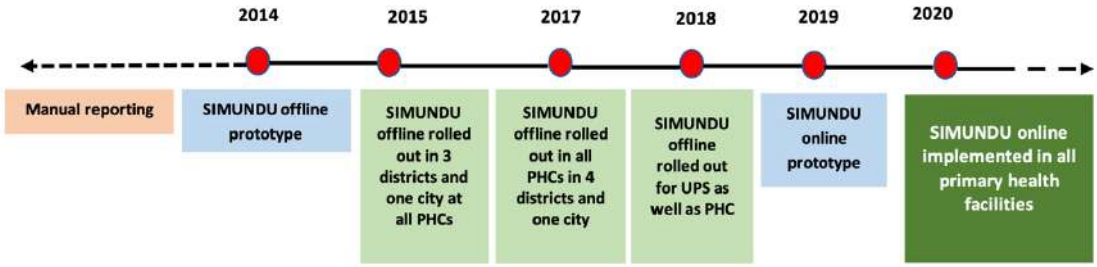

Figure 1. SIMUNDU's development and introduction

When a child receives a vaccination in a health facility, information on the child and the vaccination is entered in SIMUNDU as an individual child record. Each record includes a personal identifier, the child's sociodemographic characteristics (e.g., name, gender, date of birth, name of parents, address), the antigen administered, and the date and place of vaccination. SIMUNDU has been recently updated to allow the recording of vaccinations administered in schools (e.g., human papillomavirus (HPV), diphtheria toxoid (DT), tetanus-diphtheria (TD), and measles-rubella (MR)), albeit in the form of aggregate data only. Furthermore, SIMUNDU has been developed to record COVID-19 vaccinations in health facilities and those carried out en masse.

Monitoring is conducted monthly to assess data completeness across health facilities, while an evaluation is conducted yearly. These exercises have allowed the identification of several challenges related to implementing the system (e.g., workload, staff turnover, and rotation) and data quality (e.g., accuracy and timeliness). However, no systematic assessment of the system has been conducted to date. SIMUNDU is the first

immunization information system ever introduced in Indonesia. Other districts and provinces have shown interest in rolling it out, and the Ministry of Health has acknowledged the innovation. The work presented here aims to examine SIMUNDU's introduction and implementation process with a view to extracting lessons that could inform scalability and sustainability across the country.

Methods

From May to October 2020, we examined the experience of introducing and implementing an immunization information system in DIY province using an explanatory sequential mixed-method design, where each step informed the next (11). First, we reviewed all relevant documentation available in the DIY Health Office – e.g., staff notes, meeting notes, and monitoring notes – documenting SIMUNDU development and management processes. We also examined online documents, including health profiles and regulations on health-reporting systems in Indonesia. This served as the initial data source and provided an overview of who was involved and how in developing and implementing SIMUNDU. This informed the survey design that we conducted as a second step. The survey targeted any staff responsible for entering data in SIMUNDU (i.e., data clerks) across all PHC and selected UPS facilities and any staff responsible for managing the system at the district and city level (i.e., immunization coordinators). Sampling and recruitment strategies are outlined in Table 1.

Table 1. Survey participants

Level of the data entry and reporting system	Total number of facilities/ offices	Study population	Sampling strategy	Recruitment	Sample size
Primary Health Center (PHC)	121	Data entry clerks	All facilities	Open invitation across all facilities	113
UPS – Central, General, Maternity, and Pediatric Hospitals	65	Data entry clerks	Randomly selected 2 facilities per district/city (2*5=10)	Open invitation across selected facilities	8
UPS – Clinics	73	Data entry clerks	Randomly selected 2 facilities per district/city (2*5=10)	Open invitation across selected facilities	7
UPS – Midwives' Practices	271	Data entry clerks	Randomly selected 2 facilities per district/city (2*5=10)	Open invitation across selected facilities	10
District/City Health Office	5	Immunization coordinators	Total sampling	Open invitation	4*
			Total		**142**

*When the immunization coordinator recently changed, the former was also invited.

All immunization coordinators in each district/city and data entry clerks from all primary health facilities (PHCs) were invited to participate in this survey. For UPS facilities, we selected two clinics, two midwives' practices, and two hospitals per district/city and invited all of their staff who were involved in SIMUNDU data entry and management.

We developed and pretested an online survey in Bahasa Indonesia to inquire about SIMUNDU implementation, processes, and outcomes across PHC, UPS clinics, and district or city and province offices. The questionnaire consisted of closed-ended and Likert scale questions – ranging from 45 to 50 depending on the target type of facility and/or level of the health system – and enquired about respondents' sociodemographic characteristics as well as the process of implementing and managing SIMUNDU. Some

questions provided an additional field for clarifying the reason for a particular answer choice.

All participants were invited to the DIY Health Office to complete the survey on their laptops, with their prior consent. All participants in a room allowed researchers to monitor any missing or incomplete responses in real time and follow up with individual participants on-site to fill any gaps. We don't believe this may have introduced any significant bias as researchers would simply flag any missing responses and invite respondents to address those. Data were then exported and analyzed in Microsoft Excel. The topic areas for the qualitative interview were informed by an exploratory analysis of the survey data.

Similarly, some informants were purposefully selected among survey participants to follow up on the range of perspectives that had emerged from the survey. Other informants had been identified at the desk review stage and chosen for their management functions. Selected informants were invited to the DIY Health Office for the interview, and COVID-19 prevention protocols were observed. Every informant was informed about the study and asked to sign the informed consent. All invited informants agreed to participate. A total of nine 30-minute semi-structured interviews were conducted in the Bahasa Indonesia language and recorded with prior consent from participants. The interview team consisted of three researchers with the respective tasks of running the interview, observing, and taking notes. A research assistant transcribed all interviews into Bahasa Indonesia.

Thematic analysis was conducted using the Quirkos qualitative tool following Braun and Clarke's approaches (12). Researchers familiarized themselves with the data, searching

for initial codes and allowing themes to emerge. The principal investigator led the coding process, and led the research team too in defining and naming the core themes emerging from the data, organizing and analyzing the data across the themes, and triangulating information from the desk review, the survey, and the interviews. This stage was also performed in Bahasa Indonesia. Data were translated into English only at subtheme and core themes levels'.

Results

Participant characteristics

a. Quantitative study

In total, 142 respondents participated in this study spread across five districts/cities in DIY province. Among them, Gunungkidul has a higher proportion of respondents than the other district, with 24.8%, 24%, and 25% for PHC, UPS, and DHO, respectively. For all research units, the majority were women. At the UPS and DHO/CHO levels, most respondents were aged 41–45 years, i.e., 28.3% and 75%, respectively, while at the UPS level, the majority were aged 25–30 years (56.0%). In terms of education level, PHC and UPS are dominated by Diploma 3 graduates, namely 86.7% and 80%, respectively, while in DHO/CHO, there are predominantly undergraduate graduates (75%) (Table 2)

Table 2. Characteristic respondents in three groups of respondents

Characteristic	PHC (n=113) n (%)	UPS (n=25) n (%)	DHO/CHO (n=4) n (%)
District/City			
Bantul	23 (20.4)	5 (20.0)	1 (25.0)
Gunungkidul	28 (24.8)	6 (24.0)	1 (25.0)
Yogyakarta	17 (15.0)	4 (16.0)	0 (0.0)
Kulonprogo	21 (18.6)	4 (16.0)	1 (25.0)
Sleman	24 (21.2)	6 (24.0)	1 (25.0)
Sex			
Male	3 (2.7)	0 (0.0)	2 (50.0)
Female	110 (97.3)	25 (100)	2 (50.0)

Age			
< 25	0 (0.0)	5 (20.0)	0 (0.0)
25–30	3 (2.7)	14 (56.0)	0 (0.0)
31–35	30 (26,5)	3 (12.0)	0 (0.0)
36–40	19 (16.8)	1 (4.0)	0 (0.0)
41–45	32 (28.3)	0 (0.0)	3 (75.0)
46–50	18 (15.9)	0 (0.0)	1 (25.0)
>50	11 (9.7)	2 (8.0)	0 (0.0)
Education			
Master	0 (0.0)	1 (4.0)	1 (25.0)
Bachelor	5 (4.4)	1 (4.0)	3 (75.0)
Diploma 4	9 (8.0)	2 (8.0)	0 (0.0)
Diploma 3	98 (86.7)	20 (80.0)	0 (0.0)
Senior high school	1 (0.9)	1 (4.0)	0 (0.0)

b. Qualitative study

Nine informants were recruited to provide the required information to explore the quantitative study results more deeply. They serve as managers and staff at DHO/CHO, PHC, and UPS. Among the nine informants, two were men and seven were women. Three informants graduated with a master's, one with a bachelor's, and there were five graduates with diplomas (Table 3).

Table 3. Informants' characteristics for the qualitative study

Sex	Age (years)	Education	Position	Subject group	Informant's code
Female	56	Master's	Head of disease prevention and control department at PHO level	Managerial	M 01
Male	57	Master's	The former head of the disease prevention and control section at the PHO level	Managerial	M 02
Male	54	Bachelor's	Immunization programmer at the PHO level	Managerial	M 03
Female	47	Master's	IT person	Managerial	M 04
Female	34	Diploma	Data entry at the PHC level	Staff	S 01
Female	25	Diploma	Data entry at the UPS level	Staff	S 02
Female	31	Diploma	Data entry at the UPS level	Staff	S 03
Female	42	Diploma	Data entry at the PHC level	Staff	S 04
Female	24	Diploma	Data entry at the PHC level	Staff	S 05

c. Findings

Findings from the study are organized and presented across the three core themes that emerged from the qualitative analysis, notably system strengths, potential threats, and opportunities for scale-up. However, data from qualitative and quantitative data fed into the analysis of these core themes to cross-validate the findings (Figure 2. Detailed findings from the survey are presented in Table Supplement 1.

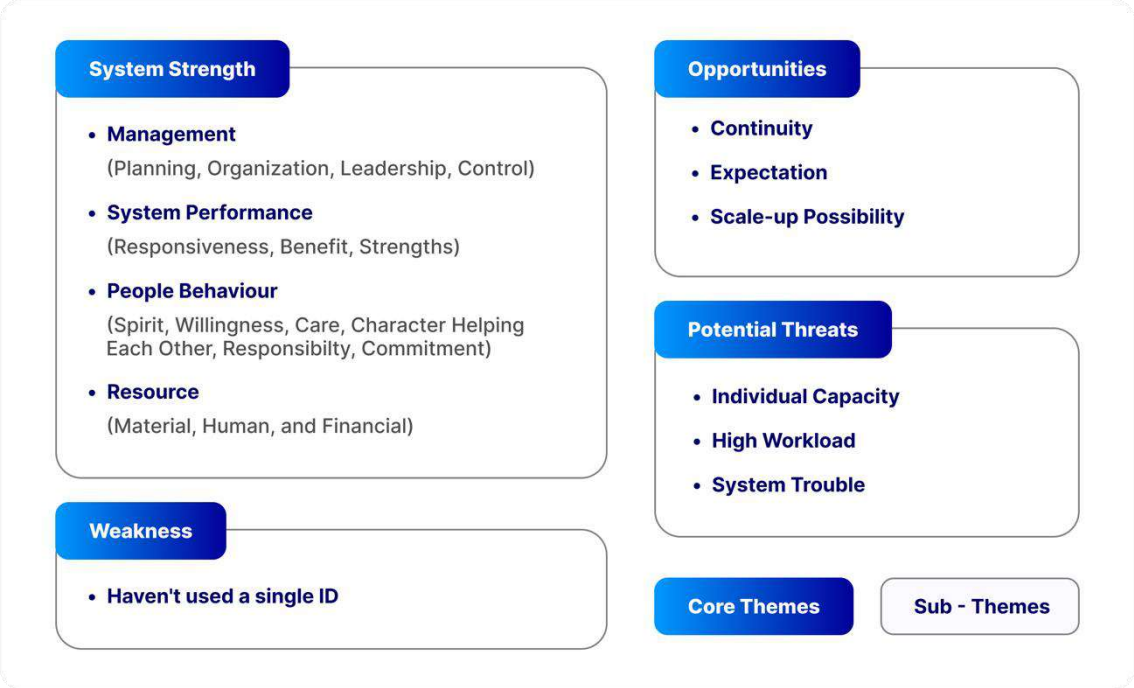

Figure 2. Strengths, potential threats, and opportunities for scale-up

System's Strengths

Factors contributing to the success of SIMUNDU include management, system performance, people's behavior, and resources.

Management

SIMUNDU arose due to concerns from the DIY Health Office immunization section around data quality, notably the need to address data inaccuracy, duplicate or missing

data and a lack of timely data, and the need for quality data to support follow-up and appropriate planning. The need for SIMUNDU arose from these challenges and needs.

"To our knowledge, [SIMUNDU development] started with a problem: estimates of the target population varied depending on the data source." (M02)

"Yes, I think [SIMUNDU management team] started to tire of managing a large volume of data with dubious validity. They need to know the situation in each district." (M04)

Effective management of SIMUNDU from development to implementation was highlighted as an essential determinant of its success across the critical functions of planning, organization, leadership, and control.

Careful **planning** was ensured at each stage of the development and implementation of SIMUNDU. These stages included developing an initial business plan, providing training on and socialization to SIMUNDU, and developing a staff replacement plan to respond to turnover or retirement of staff in charge of operating the system or entering data. The parties involved in planning included the Head of the Disease Prevention and Control Department, IT personnel, and, from the DIY Health Office, immunization program staff.

Organization – the organization of SIMUNDU is carried out at several levels. The top level is the DIY Health Office, the second level is the district/city health office, and the third level is health facilities (Figure 2). A third party was also involved in developing the system interface.

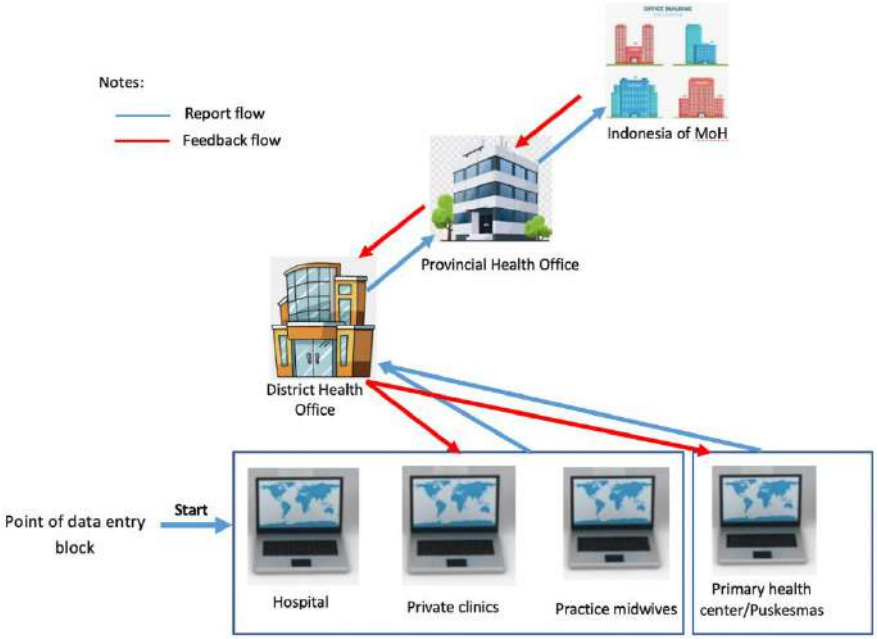

Figure 3. Visual organizing framework of SIMUNDU – DIY province, Indonesia

At the beginning of the development of SIMUNDU, essential functions included database administrators, interface designers, and server administrators, and their interplay facilitated the system's smooth operation. Training specific to SIMUNDU was integrated with other training, typically immunization-related training. This enabled us to share resources with other programs, thus ensuring viability. The training was delivered in the district/city health office: 87.6%, 72%, and 75% of survey respondents from PHC, UPS, and DHO/CHO, respectively, participated in in-house training. Training typically consisted of short sessions and included practice on the trainee's device in operating the system in both online and offline mode. Informants indicated that day-to-day operations were carried out autonomously by the staff through flexibly adjusting their work to protect the time to enter the data. This seemed to work effectively.

Leadership – the success of SIMUNDU implementation is arguably related to strong leadership. Informants noted that managers played a crucial role in bridging the needs of

the immunization program with the system design, closely monitoring the initial implementation process, and creating an enabling environment.

"I try to combine supporting and managing and monitoring the people involved. Currently, I monitor whether [SIMUNDU] can run optimally as our users are health facilities. I also monitor program development and the system's output." (M01)

"[SIMUNDU] was born from program managers, primary health centers, districts, and DIY health offices wanting to build systems together. We – DIY Health Office – give them motivation in every meeting." (M03)

"I see that [management] is very good at networking. Staff data entries in the field always indicated that these people are very kind." (M02)

The role of IT workers in developing SIMUNDU was also significant. They helped develop the system and facilitated correct data entry operators whenever technical issues arose. IT workers also helped resolve inconsistencies in data records. Acknowledgment of staff efforts was also important to maintain motivation and buy-in.

"In the early days of SIMUNDU's development, the system was challenging to operate, as it wasn't as stable as it is now. I praise the enthusiasm and dedication of the users." (M01)

The **control** function – consisting of **quality** assurance management – was critical to avoid data duplication or missing entries and ultimately ensure data quality. This process was not regulated by specific standard operating procedures but was addressed during training and monitored monthly. In addition, the DIY Health Office provided negative incentives to health facilities that were not submitting complete records and provided regular feedback from monitoring and evaluation exercises.

Specifically, 94.2%, 100%, and 100% of survey respondents in PHC, UPS, and DHO, respectively, reported that their work had been subject to monitoring. More than half of the respondents in PHC and UPS facilities had been observed by supervisors while performing data entry at least once over the past year. At the PHC level, 48.3% of survey respondents had been subject to monitoring from the district/city office's team, and 45.7% received monitoring from DIY Health Office staff. Conversely, 40% of respondents from UPS facilities were monitored by PHC staff. Almost all survey respondents reported receiving feedback from the monitoring, mainly from the district/city and DIY health offices. Forty percent of respondents from UPS facilities reported receiving feedback from PHC. Immunization coordinators from the district/city health offices received feedback from the DIY health offices.

"In a [evaluation] meeting, the DIY Health Office or District Health Office showed the progress of our data entry – correct or not, proper or not." (M02)

It is worth noting that DIY province is quite a small geographic area. Because it consists of only five districts and one city, this province is relatively easy to monitor across all phases, from planning through monitoring and evaluation.

System performance

While SIMUNDU predominantly contains individual-level immunization records, it also serves as a source for aggregation and can synergize with other information systems. Notably, SIMUNDU can link to the DHIS2 and generate immunization-specific reports as per the Ministry of Health's requirements. These reports are sent to the upper levels automatically if SIMUNDU is operated online or submitted via email if SIMUNDU is

operated offline. This functionality has had an essential role in ensuring the acceptability and adoption of the system.

Informants noted how transitioning from paper-based tools to an electronic system made data entry easier and reduced errors. SIMUNDU also facilitated the implementation of protocols for data storage and security. It enabled follow-up and defaulter tracking. Finally, integration with the DHIS2 meant reduced workload for the staff.

"We can track children who may have received vaccinations in different locations faster. For example, when the first dose of a vaccine is given in Bantul and the second one in Yogyakarta, the record can be linked within SIMUNDU." (M01)

"SIMUNDU makes detecting what data and vaccinations are missing easier since we enter data from the children's birth through the end of the immunization schedule. So, we will know where they miss any vaccine." (S03)

"The benefit of using SIMUNDU is first: we know the situation of immunizations more accurately….so our vaccine forecasting is more accurate …. and our budget, staff, facilities can be more effective and efficient in providing services." (S05)

"Colleagues from the mother and child health (KIA) program enter the data via the KIA "Sembada." So, these data will appear automatically in SIMUNDU because the two systems are connected." (S01)

SIMUNDU is user-friendly and can be flexibly operated offline or online, allowing the responsible staff to maintain data entry irrespective of connectivity; 82.3%, 96%, and 100% of survey respondents from PHC, UPS, and DHO, respectively, reported operating SIMUNDU online.

People's behavior

The interview showed that staff commitment was critical for the successful implementation of SIMUNDU, as indicated by their willingness to work overtime and bring home the data to enter into the system.

"I take it [the data] home too, for example, after immunization sessions – in my clinic, immunization runs four times per month, every week. So, when the session is finished, we can take the data home, [and] do the entry at home while relaxing." (S03)

The interviews confirmed this dedication, which spoke to a societal culture of helping others and responsibility and commitment to the team. This contributed to shaping an environment where people approach SIMUNDU as a shared responsibility and a collective endeavor. Informants also noted the high motivation of dedicated staff.

"That's all; we cannot judge by money [people's kindness, culture, and behavior]; explaining how good people are in Yogyakarta is essential. I was in another place before, and could not find people's kindness like in Yogyakarta – different characters." (M02)

"The second thing is that we need human resources that are concerned about, and have a love for, data; otherwise, even if we have a good system, it will amount to nothing without good human resources. But good implementation will come more easily when people are concerned about data." (M04)

Resources: material, human, and financial

Infrastructure and equipment emerged as critical factors in introducing and sustaining SIMUNDU implementation. Some desktops were explicitly allocated to the

immunization program, and some had to be shared with other staff. Other data entry officers reported using their laptop or smartphone (36.3% of survey respondents from PHC). In UPS facilities, 40.7% reported using office desktops; in the DHO, more than half of the respondents said they used an office-supplied laptop. The majority of respondents – regardless of the type of facility – said their current device was sufficient to perform their work on SIMUNDU. In terms of connectivity, 64.6% of PHC survey respondents and 67.7% of UPS's reported operating SIMUNDU online, relying on the office's Internet connection.

Management of financial resources was also crucial. According to the key informants, no special funds were allocated to SIMUNDU in the initial stages. Resources were leveraged through sharing activities – e.g., monitoring visits or transportation – with other programs, thus allowing cost efficiencies. Integration with other programs proved critical to ensuring sustainability.

"SIMUNDU's budget comes from the state budget known as Anggaran Pendapatan dan Belanja Negara (APBN). Every year the APBN allocates funding envelopes for immunization to DIY and other provinces, where the budget is apportioned across the program [not an explicitly written budget for SIMUNDU]." (M02)

Human resources are critical to the operation of SIMUNDU. According to the interviews, SIMUNDU data entry clerks must have patience, work carefully and not rush, be interested in data, be responsible, and have basic computer skills in word processing and spreadsheet software tools such as Microsoft Word and Excel, respectively. As shown by the survey, the large majority of SIMUNDU-operating staff were educated: At least 80% of data entry clerks in both PHC and UPS facilities have secondary education (> 80%),

while at the managerial level (DHO), 75% of respondents have a bachelor's degree (see Table 2). However, 19.4% and 9.1% of respondents from PHC and UPS facilities have low computer literacy.

Various data entry clerks looked for strategies to resolve the obstacles they encountered when entering data into SIMUNDU. Based on the interviews, some clerks furthered their computer skills by taking private computer classes. Others learned from colleagues in their offices, or reached out for help to the district person in charge. To deal with the accumulation of data needing to be entered in SIMUNDU, staff would sometimes work at home after office hours, as their busy schedule at work did not allow time for data entry.

"If we found obstacles, we asked people in charge in PHC – asking for a solution or sharing by WhatsApp – or sometimes I asked the IT person in the DIY Health Office."

(S03)

Potential threats

As of today, SIMUNDU can be said to be a successful experience. However, some obstacles were encountered and addressed during implementation. Potential system sustaining includes individual capacity, technical or system issues, and high workload. Staff computer literacy was identified as one of the main sustainability challenges. Internet connectivity was another obstacle, as a good network did not support all health facilities. The survey shows that 64.6% and 67.7% of PHC and UPS staff, respectively, used the office Internet, while others had to rely on their home Internet.

Further incomplete and inconsistent records – such as a different child's date of birth or name spelling across relevant entries – make it challenging to consistently record

immunization information. These challenges have arisen during implementation and were promptly addressed. Yet, they had an impact on staff who were already juggling busy schedules in the office, causing delays in data entry. As shown by the survey, almost all respondents said they had other responsibilities besides operating SIMUNDU – notably 97.3%, 88%, and 100% of participants from PHC, UPS and district and city offices, respectively.

Weakness

The informant said that SIMUNDU assisted in their daily work, but they also reported that sometimes they needed more time to find the children's names on the next visit. This is because SIMUNDU data entry did not use a single national ID that could be valid anywhere. As a result, when a name input error occurs, the officer will need time to check the name with the child's parents or the manual register.

"Sometimes, there was an incorrect name during the data entry; for example, Dita was written as Dieta. So, it is difficult for us to find them. If that happens, we must look back at the register or medical record data." (S04)

"I experienced difficulty entering data in SIMUNDU when a new patient came from another health facility to us. It was challenging to find their record on SIMUNDU." (S05)

Opportunities

Informants appreciated SIMUNDU as an excellent system to manage immunization data. SIMUNDU has become necessary for program managers and policymakers; it allows them to monitor coverage and can help inform planning and programming. Currently, SIMUNDU is stable, thus it is easier to manage than when it was in the development

phase. It is also viable and no longer requires heavy reliance on the core workforce that started the system. The hopes expressed by data entry clerks in the interviews are that SIMUNDU is easier to operate and system errors are less frequent. Informants also stressed the need for refresher training to ensure that knowledge and practice of the system is not lost.

"In my opinion, SIMUNDU is the best program in DIY, a collaboration between program managers and IT. It will continue to be implemented because it is a necessity. It has been stably used for more than five years, meaning this is needed." (M01)

"If I have the tool, in this case SIMUNDU, when it is stable, whoever will be able to run it, I am sure that anyone can operate it. It means that it doesn't matter if we have people shifting [jobs]." (M01)

"In the future, if SIMUNDU is still used, other reports are not necessary. Now we have two different reports: SIMUNDU and stock card of vaccine – each stands alone and needs a separate report." (S05)

Based on the key informants' interviews, SIMUNDU is likely to be developed further or expanded to other provinces. The DIY Health Office is open to supporting other provinces interested in introducing the system – for instance, through the lending staff for training and orientation. However, informants advised that a successful introduction requires a strong commitment from staff and management.

Discussion

Robust health information systems (HIS) are essential components of robust health systems (13). At the most basic level, immunization registries are systems that collect and

report individual-level vaccine administration record data, thus facilitating individual follow-up of vaccination status. Registries also allow for the monitoring of vaccination coverage and enable analysis of AEFIs and surveillance data to inform the design of coverage interventions and outbreak investigations. When an electronic registry has interoperability with other electronic systems – such as in the case of SIMUNDU – it is considered an immunization information system (IIS) (14). This paper presents lessons learned from DIY's experience of implementing an IIS.

DIY is the only province in Indonesia – out of 34 – that uses an IIS. This work has shed light on the strengths of, and underlying barriers to, implementing an IIS in this context. The objective of this study was to draw lessons that inform sustainable scale-up in other provinces and possibly at the national level. This study highlighted individual capacity, technical or system issues, and high workload as the major barriers to sustainability. Conversely, management, system performance, people's behavior, and available resources emerged as the main determinants of SIMUNDU's successful implementation – notably in improving acceptability, implementation costs, and adoption of this innovation (15).

Despite several obstacles encountered during the implementation of SIMUNDU, this study showed that this innovation was well accepted by key stakeholders. On the one hand, data entry clerks noted that the system is relatively user-friendly and makes it possible to organize the data better and enhance its quality. On the other hand, managers noted the benefits this innovation brought about, namely in the potential for cohort data to support planning and monitoring and ultimately improve immunization coverage.

Effective management – across planning, organization, leadership, and control functions – is a crucial reason why SIMUNDU has been viable for over five years. Managers use their control to encourage the beliefs and actions of the staff with a dedicated and robust managerial process (16). SIMUNDU was born from the need for credible data to assist in carrying out DIY Health Office duties at the managerial and operational levels. At the managerial level, the disease prevention and control department and the IT department collaborated in designing a system that intended users readily accepted. Immunization officers and IT programmers played a central role from the early stages of development through implementation with effective coordination and communication. They were helped in this task, with the full support of their respective superiors.

SIMUNDU is cost-effective in several ways. During the introductory period of its implementation, immunization programmers, IT officers, and other staff assisted in introducing SIMUNDU in all districts in the province. This was done by integrating some of the activities across programs, thus building efficiency in terms of time and costs for both managers and staff. Sharing resources across programs was critical in the first years of building sustainability. Additionally, maintaining SIMUNDU does not incur high costs because the DIY Health Office has developed the system and thus possesses in-house technical skills. The IT department has the capacity to monitor and improve processes and tailor them to user needs without much additional cost.

A good program without good leadership could fail in its implementation, and even if it was initially successful, it might not be sustainable (17). In the context of SIMUNDU, leadership and effective management support facilitated the program's adoption. The uptake of the new system was good and all health facilities providing immunization services have successfully transitioned to SIMUNDU. The strong network of the

prominent persons in charge of SIMUNDU also facilitated the adoption. Good communication, care, and attention to staff concern positively affected staff performance. They felt that they were well supported and treated kindly, and this helped them carry out their work joyfully. According to several informants, the DIY immunization program manager's leadership played an essential role in this effect.

The monitoring and evaluation mechanisms of SIMUNDU were also important. Preferred monitoring and evaluation activities include monthly reports and staff discussions during site monitoring visits. The immunization program manager suggested this approach to maintain data quality and ensure the system's sustainability. These chosen mechanisms allow program managers to assess the actual practice in the field and the challenges faced to inform decisions about the follow-up actions to be taken. These processes supported the ongoing development of, and learning from, SIMUNDU as a tool for data collection, analysis, and visualization, as well as the benefits for managers in carrying out monitoring and evaluation. The same sentiment was reflected in previous research undertaken in India (18).

Human resources are a key determinant of the successful implementation of any HIS (19). People's behavior affects how the system works, develops, and survives (20),(21). In the case of SIMUNDU, implementation was facilitated by a culture of care, established networks, and a positive attitude towards data on the part of both the program manager and the IT team. From the staff's point of view, the local culture of helping each other and doing their job correctly and responsibly translated into staff carrying out their duties with enthusiasm and great commitment. Although facilities, funding, and human resources were limited, the individuals involved were highly motivated and supportive.

Despite the many strengths of SIMUNDU, some obstacles may potentially challenge its sustainability in the long term. These obstacles can be divided into human variables and technical variables. In terms of human variables, unequal capacity distribution at the operational level can result in differing levels of data quality across facilities and districts. Staff workload is another challenge that needs addressing, as their willingness to work overtime is not a sustainable strategy. Technical problems were another obstacle during the introduction of SIMUNDU, but qualified technicians/developers could solve these issues. During our research, we recognized the weakness of SIMUNDU that it had not used the person number as a unique (single) code (ID) in data entry. This impacts on the challenge of finding a person when the previous entry was inaccurate. The in absence SIMUNDU single ID also affects SIMUNDU's inability to synchronize with other health programs that use a person's number as a unique code. However, this weakness can be seen as room for improvement for SIMUNDU shortly. Another thing that needs to be considered for other regions that will implement SIMUNDU that SIMUNDU is that implemented in DIY province, which consists of five districts/cities with relatively easy regional accessibility. For areas with more difficult access, the commitment of the leadership and subordinates is the key to successful implementation.

Conclusion

SIMUNDU is a promising innovation for the entire country, beyond DIY. There is agreement about the potential for scale-up of this IIS to other provinces. Experience of implementing this system in DIY over the past five years has shown that the benefits outweigh the challenges, and SIMUNDU has grown into a robust yet user-friendly system. Regular training for dedicated staff to strengthen their capacity as the system evolves and is updated, and a plan for anticipating and responding to staff turnover, have

proven critical strategies towards sustainability. SIMUNDU's success also rests on remarkable leadership, both in creating and enabling a supportive environment and pursuing integration with other programs to share limited resources.

Recommendations

This study's recommendations address three different stakeholder groups: the DIY Health Office, the national government, and researchers. First, to ensure continuity and sustainability and reduce the system's dependency on a particular person or party, SIMUNDU management and maintenance should be managed by people who have competency and interest in a good reporting system. Furthermore, a human resources plan should be developed in preparation for SIMUNDU rollout in other provinces or at the national level; this is necessary to avoid vacancies when DIY province staff are seconded to other areas for mentoring support. Second, the fact that SIMUNDU emerged from an actual need for immunization program implementers and saw these at the front line of its development and implementation positively impacted its feasibility and viability. This suggests that the approach to scaling up SIMUNDU should be stepwise, taking into consideration each region's specific characteristics and needs. To this effect, a readiness map and a timeline may be developed to roll out SIMUNDU in a particular region. Third, further research is needed to assess the impact of SIMUNDU on immunization coverage. Based on our conversations with stakeholders, it would be particularly relevant to focus on a low-performing region and observe the impact over a two- to three-year time window.

Study limitations

The empirical results reported herein should be considered in light of limitations. First, the results of the quantitative study must be considered in view of the limited sample size, particularly for UPS health facilities. However, given the top-down immunization program and the characteristics of UPS, which will not be significantly different from each other, the results of this study are still valid and relevant to the existing. In qualitative research that aims to explore, caution is needed in interpreting the interview results. There is still a need for in-depth studies with different approaches, such as focus group discussions, to confirm the results.

Abbreviations

AEFI	: Adverse Events Following Immunization
APBN	: Anggaran Pendapatan dan Belanja Negara (State Budget)
CHO	: City Health Office
COVID-19	: Coronavirus Disease 2019
DHIS2	: District Health Information System 2
DHO	: District Health Office
DIY	: Daerah Istimewa Yogyakarta (Special Region of Yogyakarta)
DT	: Diphtheria Toxoid
HIS	: Health Information System
HPV	: Human papillomavirus
ID	: Identity
IIS	: Immunization Information System
IT	: Information Technology

KIA : Kesehatan Ibu dan Anak (Maternal and Child Health)

KOMDAT KESMAS : Komunikasi Data Kesehatan Masyarakat (Public Health Data Communication)

MR : Measles-Rubella

PHC : Primary Health Centers

PHO : Provincial Health Office

PISPK : Program Indonesia Sehat dengan Pendekatan Keluarga (Healthy Indonesia Program with Family Approach)

PWS : Pemantauan Wilayah Setempat (Local Area Monitoring)

SIHA : HIV AIDS Information System

SIKDA : Regional Health Information System

SIMUNDU : Integrated Immunization Information System

SITT : Integrated Tuberculosis Information System

TD : Tetanus-Diphtheria

UPS : Unit Pelayanan Swasta (Private Service Unit)

Declarations

Ethics approval and consent to participate

This study was approved by the Ethical Review Board of Universitas Ahmad Dahlan, Yogyakarta, Indonesia (ethical approval code: 012005021). Written informed consent was obtained from the participants before data collection started.

Adherence to national and international regulations

Not applicable

Consent for publication

Not applicable

Availability of data and materials

The data sets generated and/or analyzed for this study can be requested from the corresponding author.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

SS, TAW, RR, ASDN, and MF designed the study. SS, TWS, SKW, and SAM collected the data. SS and RR conducted data analysis. SS developed the paper with inputs and comments from MF on each draft. All authors agree with the manuscript’s results and conclusions.

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Authors' note:

The authors alone are responsible for the views expressed in this article. They do not necessarily represent the views, decisions, or policies of the institutions affiliated with them.

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sulistyawati suyanto <sulistyawati.suyanto@ikm.uad.ac.id>

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Introduction and implementation of an immunization information system in the Indonesia province of Daerah Istimewa Yogyakarta: lessons for scaling-up
Sulistyawati Sulistyawati; Trisno Agung Wibowo; Rokhmayanti Rokhmayanti; Andri Setyo Dwi Nugroho; Tri Wahyuni Sukesi; Siti Kurnia Widi Hastuti; Surahma Asti Mulasari; Marta Feletto
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Sulistyawati, MPH., Ph.D.
Department of Public Health, Universitas Ahmad Dahlan, Indonesia
+62-8170402693 | sulistyawati.suyanto@ikm.uad.ac.id

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Introduction and implementation of an immunization information system in the Indonesian province of Daerah Istimewa Yogyakarta: lessons for scaling-up

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Sulistyawati Sulistyawati ✉

Email : sulistyawati.suyanto@ikm.uad.ac.id

Affiliationids : Aff1, Correspondingaffiliationid : Aff1

Trisno Agung Wibowo Affiliationids : Aff2

Rokhmayanti Rokhmayanti Affiliationids : Aff1

Andri Setyo Dwi Nugroho Affiliationids : Aff2

Tri Wahyuni Sukesi Affiliationids : Aff1

Siti Kurnia Widi Hastuti Affiliationids : Aff1

Surahma Asti Mulasari Affiliationids : Aff1

Marta Feletto Affiliationids : Aff3

Aff1 Faculty of Public Health, Universitas Ahmad Dahlan, Kampus 3 - Jl. Prof Dr Soepomo, Janturan, Umbulharjo, Yogyakarta, Indonesia

Aff2 Daerah Istimewa Yogyakarta (DIY) Health Office, Yogyakarta, Indonesia

Aff3 Alliance for Health Policy and Systems Research, World Health Organization, Geneva, Switzerland

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Abstract

Background

Immunization AQ1 is critical to saving children from infections. To increase vaccination coverage, valid and real-time data are needed. Accordingly, it is essential to have a good report system that serves as defaulter tracking to prevent children's immunization failure. The Daerah Istimewa Yogyakarta (DIY) Health Office introduced an electronic immunization registry and successfully implemented it for more than five years. It is the only individual-based record system in Indonesia that has been sustainably operated for a long time. Yet, no systematic assessment of this system has been conducted to date. This study examines the Sistem Informasi Imunisasi Terpadu (SIMUNDU) introduction and implementation process with a view to extracting lessons that could inform scalability and sustainability across the country.

Methods

This study AQ2 used an explanatory sequential mixed-method design, which collected quantitative data from 142 participants and qualitative data from nine participants. The data entry clerk at a health facility was systematically selected to participate in the survey, while in the key informant interview, the informant was selected based on the survey result. A descriptive and thematic approach was adopted to analyze the quantitative and qualitative data. Results from across the two approaches were integrated for comparison and contrast.

Results

Findings are presented according to three core themes that emerged from the data: system strengths, potential threats, weakness and opportunities for scaling-up. Strengths, i.e., factors contributing to the success of SIMUNDU, include management, system performance, people's behavior, and resources. Potential threats to sustaining the system include individual capacity, technical or system issues, and high workload. Opportunities – i.e., a promising factor that influences the SIMUNDU ability to operate sustainably – such as continuity, expectation, and the possibility of scaling up.

Conclusions

SIMUNDU is a promising innovation for Indonesia, beyond DIY. There is agreement about the potential for scaling up this IIS to other provinces. The experience of implementing this system in DIY over the past five years has shown that the benefits outweigh the challenges, and SIMUNDU has grown into a robust yet user-friendly system.

Keywords

Immunization
Electronic immunization registry
Immunization information system
Interoperability
Implementation research

Abbreviations

AEFI Adverse Events Following Immunization
APBN Anggaran Pendapatan dan Belanja Negara (State Budget)
CHO City Health Office
COVID-19 Coronavirus Disease 2019
DHIS2 District Health Information System 2
DHO District Health Office
DIY Daerah Istimewa Yogyakarta (Special Region of Yogyakarta)
DT Diphtheria Toxoid
HIS Health Information System
HPV Human papillomavirus
ID Identity
IIS Immunization Information System
IT Information Technology
KIA Kesehatan Ibu dan Anak (Maternal and Child Health)
KOMDAT KESMAS Komunikasi Data Kesehatan Masyarakat (Public Health Data Communication)
MR Measles-Rubella
PHC Primary Health Centers
PHO Provincial Health Office
PISPK Program Indonesia Sehat dengan Pendekatan Keluarga (Healthy Indonesia Program with Family Approach)
PWS Pemantauan Wilayah Setempat (Local Area Monitoring)
SIHA HIV AIDS Information System

SIKDA Regional Health Information System
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TD Tetanus-Diphtheria
UPS Unit Pelayanan Swasta (Private Service Unit)

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12913-022-08910-6.

Background

Neonatal AQ3 and childhood vaccination is essential for infectious disease prevention and an absolute human right [1, 2]. Vaccination has been proven to reduce the burden of infectious diseases globally [3]. According to the WHO, in 2020, an estimated 23 million children under the age of one year did not receive their essential vaccinations. Of these, 60% live in just ten countries, one of which is Indonesia [4]. Indonesia is the fourth most populous country globally. It is composed of thousands of islands organized into 34 provinces. Various geographical and cultural factors influence population inequalities in accessing health services [5]. In 2001, the Indonesian government's decentralization policy was enacted. This was an excellent strategy for fostering development by engaging regional resources [6]. However, this strategy was not without consequence. One primary concern was the health information system (HIS) fragmentation.

Indonesia's federal structure results in provinces and districts being relatively independent of the national Ministry of Health. This means that provincial- and district-level information systems are locally regulated [7]. For instance, *Pemantauan Wilayah Setempat* (PWS) is a management tool used to monitor the coverage of specific health services within an administrative boundary. Depending on the service and region, it can be paper- or electronic-based. PWS-KIA is the monitoring system specific to maternal and child health (KIA), including immunization. PWS-KIA data are reported to the District or City Health Office, go to the Province Health Office, and are finally reported to the main level. Generally, the data are in Microsoft Excel formats; they will be reported via emails or various information systems, including Komdat Kesmas, SITT, SIHA, PISPK, and SIKDA Generik. PWS-KIA data feed into District Health Information System 2 (DHIS2). Regional information systems have varying data quality, which reflects inequities in resources across regions. This adds to data integration challenges at the national level [7, 8] and affects strategic policymaking.

In Indonesia’s federal system, Daerah Istimewa Yogyakarta (DIY) province has the authority to regulate and use its budget within its four districts plus one city (Sleman, Gunungkidul, Bantul, Kulonprogo, and Yogyakarta). This province is classified as a small province in terms of area size and the number of regions inside [9]. However, this region can be considered a representation of Indonesia when viewed from the geographical, socioeconomic, and heterogeneous population perspective. With regard to childhood vaccination, DIY is among the top ten performing provinces in the country, with 97.7% of children completing basic immunization coverage in 2019 [10]. Immunization services are provided by primary health centers or Puskesmas (PHC), as well as private clinics, hospitals, and midwives' practices (typically referred to as *Unit Pelayanan Swasta* or UPS).

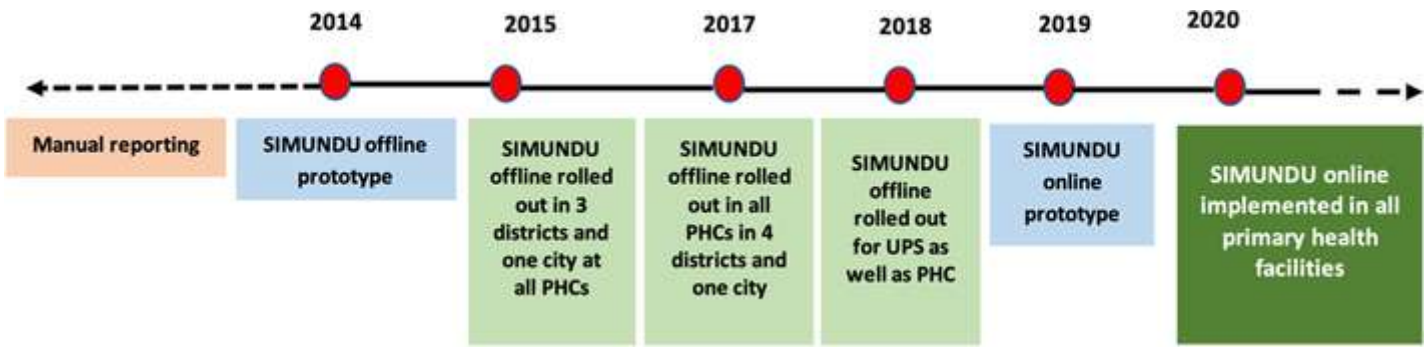
An electronic immunization registry is a tool for recording individual children’s immunization histories. In 2014, the DIY Health Office introduced an electronic immunization registry named SIMUNDU (*Sistem Informasi Imunisasi Terpadu*/ Integrated Immunization Information System). An electronic registry provides essential functions at all levels of the health system. At the district and higher levels, it allows for monitoring vaccination coverage by vaccine, dose, cohort, and other variables – and can support microplanning and vaccine management. The service delivery level can facilitate individual follow-up of vaccination status and enable health workers to identify children due for vaccination and those who have missed their vaccinations (defaulters).

SIMUNDU was designed to link with PWS-KIA for immunization and interoperability with the DHIS2. While it predominantly contains individual-level immunization records, SIMUNDU also serves as a source for aggregation and can synergize with the *Pemantauan Wilayah Setempat* (PWS) reporting system. For this reason, it can be considered an immunization information system (IIS). This means that city and district levels feed into provincial and national levels *(Personal communication with DIY immunization program officer)*.

The original prototype was designed by the information and technology (IT) department of the DIY Health Office to be operated offline. In DIY, three out of the four districts and the city introduced the system in 2015. The final district introduced it in 2017. At this stage, the point of data entry was the PHC only. By 2018, UPS facilities were also equipped with SIMUNDU and could enter data into the system. In 2019, the prototype was further developed to operate online. The online version was rolled out in 2020 (Fig. 1). As of May 2021, 79.4% of all PHC and UPS facilities complied. This average rate masks, however, the fact that while all PHCs adopt SIMUNDU, it is more challenging to enforce its use in UPC facilities (Suyani 2020, oral communication, AQ4 2020, May 11).

Fig. 1

SIMUNDU’s development and introduction



When a child receives a vaccination in a health facility, information on the child and the vaccination is entered in SIMUNDU as an individual child record. Each record includes a personal identifier, the child's sociodemographic characteristics (e.g., name, gender, date of birth, name of parents, address), the antigen administered, and the date and place of vaccination. SIMUNDU has been recently updated to allow the recording of vaccinations administered in schools (e.g., human papillomavirus (HPV), diphtheria toxoid (DT), tetanus-diphtheria (TD), and measles-rubella (MR)), albeit in the form of aggregate data only. Furthermore, SIMUNDU has been developed to record COVID-19 vaccinations in health facilities and those carried out en masse.

Monitoring is conducted monthly to assess data completeness across health facilities, while an evaluation is conducted yearly. These exercises have allowed the identification of several challenges related to implementing the system (e.g., workload, staff turnover, and rotation) and data quality (e.g., accuracy and timeliness). However, no systematic assessment of the system has been conducted to date. SIMUNDU is the first immunization information system ever introduced in Indonesia. Other districts and provinces have shown interest in rolling it out, and the Ministry of Health has acknowledged the innovation. The work presented here aims to examine SIMUNDU's introduction and implementation process with a view to extracting lessons that could inform scalability and sustainability across the country.

Methods

From May to October 2020, we examined the experience of introducing and implementing an immunization information system in DIY province using an explanatory sequential mixed-method design, where each step informed the next [11]. First, we reviewed all relevant documentation available in the DIY Health Office – e.g., staff notes, meeting notes, and monitoring notes – documenting SIMUNDU development and management processes. We also examined online documents, including health profiles and regulations on health-reporting systems in Indonesia. This served as the initial data source and provided an overview of who was involved and how in developing and implementing SIMUNDU. This informed the survey design that we conducted as a second step. The survey targeted any staff responsible for entering data in SIMUNDU (i.e., data clerks) across all PHC and selected UPS facilities and any staff responsible for managing the system at the district and city level (i.e., immunization coordinators). Sampling and recruitment **AQ5** strategies are outlined in Table 1.

Table 1

Survey participants

Level of the data entry and reporting system	Total number of facilities/ offices	Study population	Sampling strategy	Recruitment	Sample size
Primary Health Center (PHC)	121	Data entry clerks	All facilities	Open invitation across all facilities	113
UPS – Central, General, Maternity, and Pediatric Hospitals	65	Data entry clerks	Randomly selected 2 facilities per district/city (2*5 = 10)	Open invitation across selected facilities	8
UPS – Clinics	73	Data entry clerks	Randomly selected 2 facilities per district/city (2*5 = 10)	Open invitation across selected facilities	7
UPS – Midwives' Practices	271	Data entry clerks	Randomly selected 2 facilities per district/city (2*5 = 10)	Open invitation across selected facilities	10
District/City Health Office	5	Immunization coordinators	Total sampling	Open invitation	4*
Total					**142**

*When the immunization coordinator recently changed, the former was also invited

All immunization coordinators in each district/city and data entry clerks from all primary health facilities (PHCs) were invited to participate in this survey. For UPS facilities, we selected two clinics, two midwives' practices, and two hospitals per district/city and invited all of their staff who were involved in SIMUNDU data entry and management.

We developed and pretested an online survey in Bahasa Indonesia to inquire about SIMUNDU implementation, processes, and outcomes across PHC, UPS clinics, and district or city and province offices. The questionnaire consisted of closed-ended and Likert scale questions – ranging from 45 to 50 depending on the target type of facility and/or level of the health system – and enquired about respondents' sociodemographic characteristics as well as the process of implementing and managing SIMUNDU. Some questions provided an additional field for clarifying the reason for a particular answer choice.

All participants were invited to the DIY Health Office to complete the survey on their laptops, with their prior consent. All participants in a room allowed researchers to monitor any missing or incomplete responses in real time and follow up with individual participants on-site to fill any gaps. We don't believe this may have introduced any significant bias as researchers would simply flag any missing responses and invite respondents to address those. Data were then exported and analyzed in Microsoft Excel. The topic areas for the qualitative interview were informed by an exploratory analysis of the survey data.

Similarly, some informants were purposefully selected among survey participants to follow up on the range of perspectives that had emerged from the survey. Other informants had been identified at the desk review stage and chosen for their management functions. Selected informants were invited to the DIY Health Office for the interview, and COVID-19 prevention protocols were observed. Every informant was informed about the study and asked to sign the informed consent. All invited informants agreed to participate. A total of nine 30-min semi-structured interviews were conducted in the Bahasa Indonesia language and recorded with prior consent from participants. The interview team consisted of three researchers with the respective tasks of running the interview, observing, and taking notes. A research assistant transcribed all interviews into Bahasa Indonesia.

Thematic analysis was conducted using the Quirkos qualitative tool following Braun and Clarke's approaches [12]. Researchers familiarized themselves with the data, searching for initial codes and allowing themes to emerge. The principal investigator led the coding process, and led the research team too in defining and naming the core themes emerging from the data, organizing and analyzing the data across the themes, and triangulating information from the desk review, the survey, and the interviews. This stage was also performed in Bahasa Indonesia. Data were translated into English only at subtheme and core themes levels'.

Results

Participant characteristics

Quantitative study

In total, 142 respondents participated in this study spread across five districts/cities in DIY province. Among them, Gunungkidul has a higher proportion of respondents than the other district, with 24.8%, 24%, and 25% for PHC, UPS, and DHO, respectively. For all research units, the majority were women. At the UPS and DHO/CHO levels, most respondents were aged 41–45 years, i.e., 28.3% and 75%, respectively, while at the UPS level, the majority were aged 25–30 years (56.0%). In terms of education level, PHC and UPS are dominated by Diploma 3 graduates, namely 86.7% and 80%, respectively, while in DHO/CHO, there are predominantly undergraduate graduates (75%) (Table 2).

Table 2

Characteristic ~~respondents~~participants in three groups of respondents

Characteristic	PHC (*n* = 113) n (%)	UPS (*n* = 25) n (%)	DHO/CHO (*n* = 4) n (%)
District/City			
Bantul	23 (20.4)	5 (20.0)	1 (25.0)
Gunungkidul	28 (24.8)	6 (24.0)	1 (25.0)
Yogyakarta	17 (15.0)	4 (16.0)	0 (0.0)
Kulonprogo	21 (18.6)	4 (16.0)	1 (25.0)
Sleman	24 (21.2)	6 (24.0)	1 (25.0)
Sex			
Male	3333(2.7)	0 (0.0)	2 (50.0)
Female	110 (97.3)	25 (100)	2 (50.0)
Age			
< 25	0 (0.0)	5 (20.0)	0 (0.0)
25–30	3 (2.7)	14 (56.0)	0 (0.0)
31–35	30 (26,5)	3 (12.0)	0 (0.0)
36–40	19 (16.8)	1 (4.0)	0 (0.0)
41–45	32 (28.3)	0 (0.0)	3 (75.0)
46–50	18 (15.9)	0 (0.0)	1 (25.0)
> 50	11 (9.7)	2 (8.0)	0 (0.0)
Education			
Master	0 (0.0)	1 (4.0)	1 (25.0)
Bachelor	5 (4.4)	1 (4.0)	3 (75.0)
Diploma 4	9 (8.0)	2 (8.0)	0 (0.0)
Diploma 3	98 (86.7)	20 (80.0)	0 (0.0)
Senior high school	1 (0.9)	1 (4.0)	0 (0.0)

Qualitative study

Nine informants were recruited to provide the required information to explore the quantitative study results more deeply. They serve as managers and staff at DHO/CHO, PHC, and UPS. Among the nine informants, two were men and seven were women. Three informants graduated with a master's, one with a bachelor's, and there were five graduates with diplomas (Table 3).

Table 3

Informants' characteristics for the qualitative study

Sex	Age (years)	Education	Position	Subject group	Informant's code
Female	56	Master's	Head of disease prevention and control department at PHO level	Managerial	M 01
Male	57	Master's	The former head of the disease prevention and control section at the PHO level	Managerial	M 02

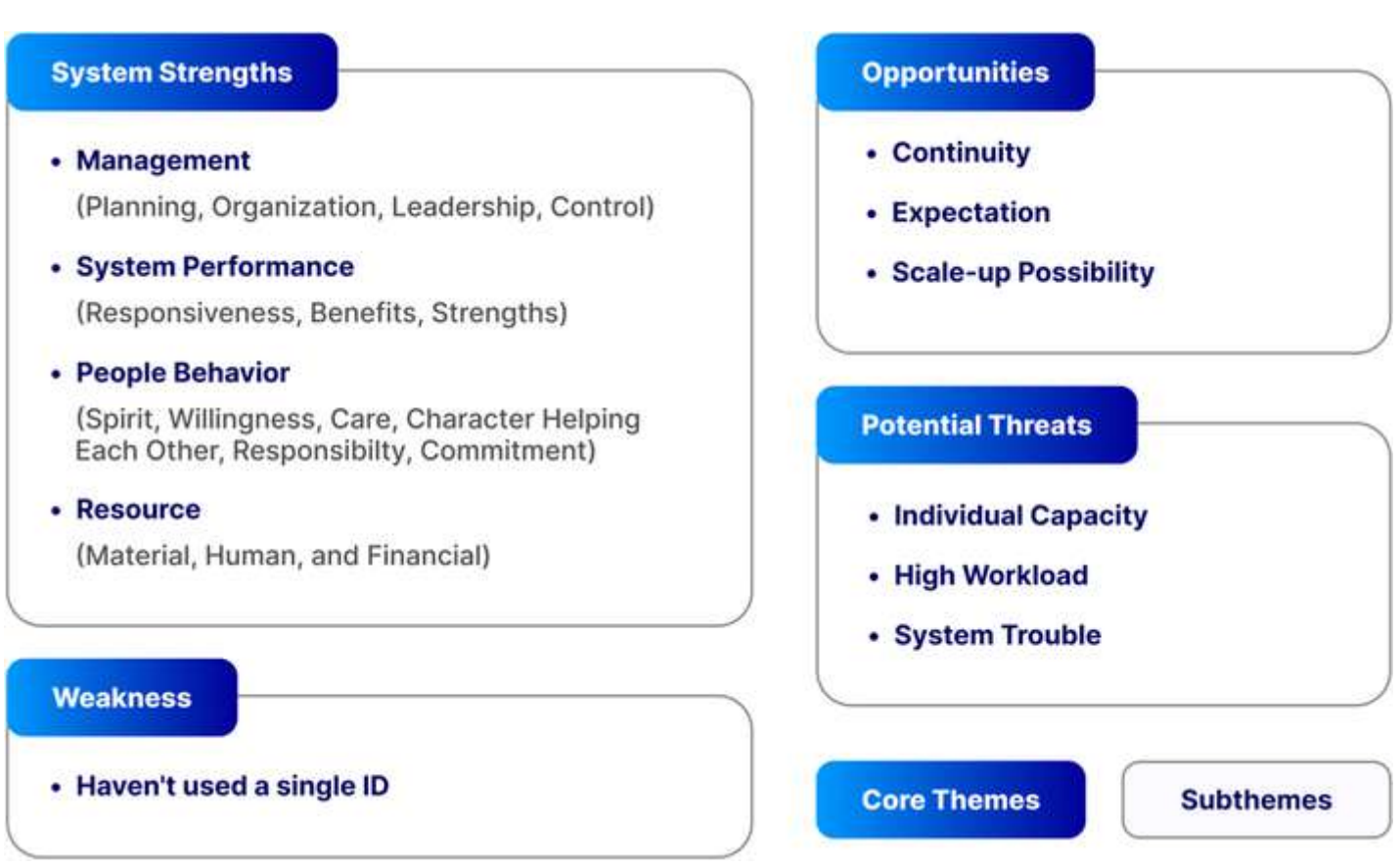
Sex	Age (years)	Education	Position	Subject group	Informant's code
Male	54	Bachelor's	Immunization programmer (coordinator) at the PHO level	Managerial	M 03
Female	47	Master's	IT person	Managerial	M 04
Female	34	Diploma	Data entry at the PHC level	Staff	S 01
Female	25	Diploma	Data entry at the UPS level	Staff	S 02
Female	31	Diploma	Data entry at the UPS level	Staff	S 03
Female	42	Diploma	Data entry at the PHC level	Staff	S 04
Female	24	Diploma	Data entry at the PHC level	Staff	S 05

Findings

Findings from the study are organized and presented across the three core themes that emerged from the qualitative analysis, notably system strengths, potential threats, and opportunities for scale-up. However, data from qualitative and quantitative data fed into the analysis of these core themes to cross-validate the findings (Fig. 2. Detailed findings from the survey are presented in Table Supplement 1.

Fig. 2

Strengths, potential threats, and opportunities for scaling-up



System's strengths

Factors contributing to the success of SIMUNDU include management, system performance, people's behavior, and resources.

Management

SIMUNDU arose due to concerns from the DIY Health Office immunization section around data quality, notably the need to address data inaccuracy, duplicate or missing data and a lack of timely data, and the need for quality data to support follow-up and appropriate planning. The need for SIMUNDU arose from these challenges and needs.

> "To our knowledge, [SIMUNDU development] started with a problem: estimates of the target population varied depending on the data source." (M02)

> "Yes, I think [SIMUNDU management team] started to tire of managing a large volume of data with dubious validity. They need to know the situation in each district." (M04)

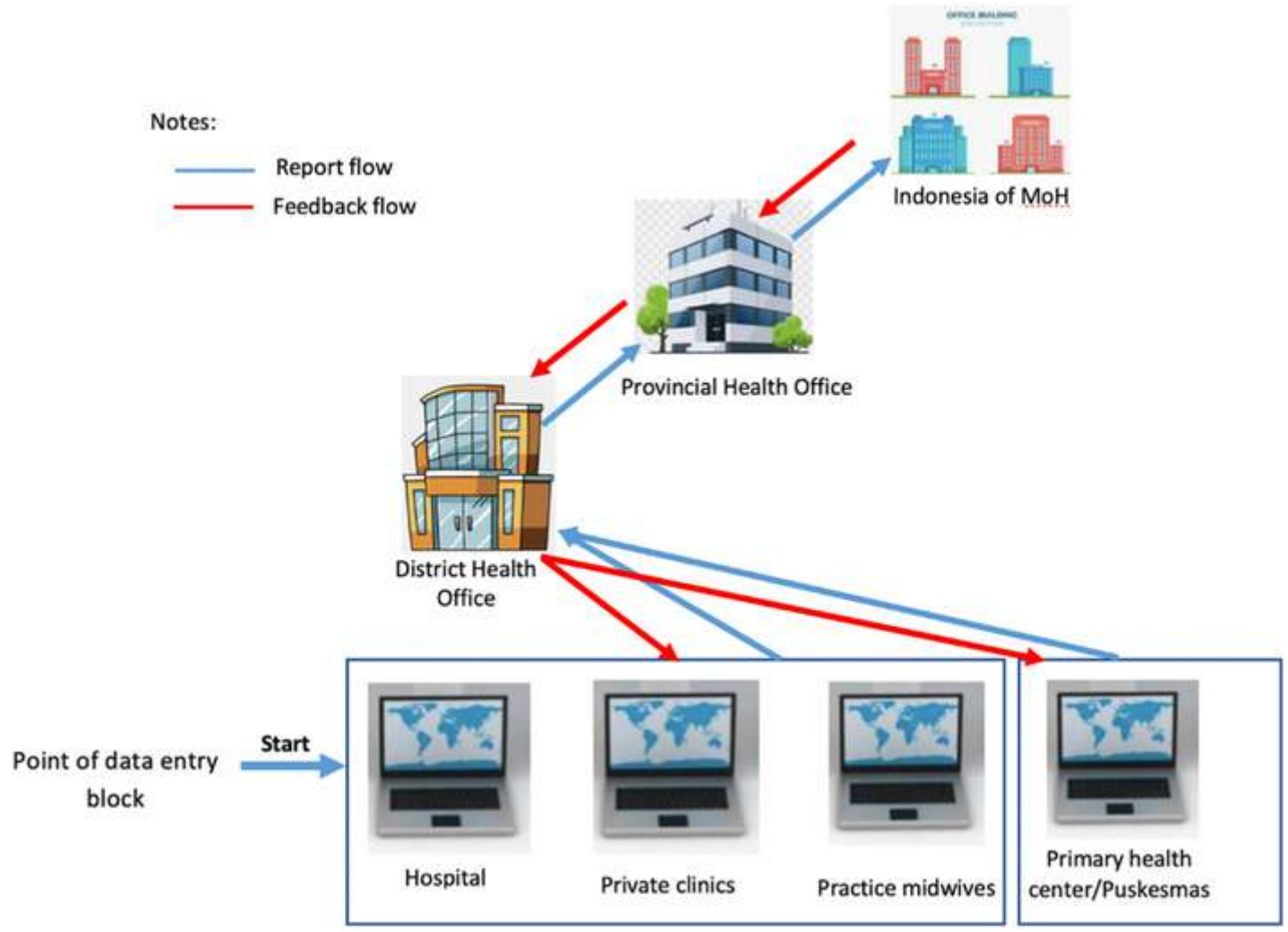
Effective management of SIMUNDU from development to implementation was highlighted as an essential determinant of its success across the critical functions of planning, organization, leadership, and control.

Careful planning was ensured at each stage of the development and implementation of SIMUNDU. These stages included developing an initial business plan, providing training on and socialization to SIMUNDU, and developing a staff replacement plan to respond to turnover or retirement of staff in charge of operating the system or entering data. The parties involved in planning included the Head of the Disease Prevention and Control Department, IT personnel, and, from the DIY Health Office, immunization program staff.

Organization – the organization of SIMUNDU is carried out at several levels. The top level is the DIY Health Office, the second level is the district/city health office, and the third level is health facilities (Fig. 3). A third party was also involved in developing the system interface.

Fig. 3

Visual organizing framework of SIMUNDU – DIY province, Indonesia



At the beginning of the development of SIMUNDU, essential functions included database administrators, interface designers, and server administrators, and their interplay facilitated the system's smooth operation. Training specific to SIMUNDU was integrated with other training, typically immunization-related. This enabled us to share resources with other programs, thus ensuring viability. The training was delivered in the district/city health office: 87.6%, 72%, and 75% of survey respondents from PHC, UPS, and DHO/CHO, respectively, participated in in-house training. Training typically consisted of short sessions and included practice on the trainee's device in operating the system in both online and offline mode. Informants indicated that day-to-day operations were carried out autonomously by the staff through flexibly adjusting their work to protect the time to enter the data. This seemed to work effectively.

Leadership – the success of SIMUNDU implementation is arguably related to strong leadership. Informants noted that managers played a crucial role in bridging the needs of the immunization program with the system design, closely monitoring the initial implementation process, and creating an enabling environment.

> "I try to combine supporting and managing and monitoring the people involved. Currently, I monitor whether [SIMUNDU] can run optimally as our users are health facilities. I also monitor program development and the system's output." (M01).
>
> "[SIMUNDU] was born from program managers, primary health centers, districts, and DIY health offices wanting to build systems together. We – DIY Health Office – give them motivation in every meeting." (M03).
>
> "I see that [management] is very good at networking. Staff data entries in the field always indicated that these people are very kind." (M02)

The role of IT workers in developing SIMUNDU was also significant. They helped develop the system and facilitated correct entries by entry clerk whenever technical issues arose. IT workers also helped resolve inconsistencies in data records. Acknowledgment of staff efforts was also important to maintain motivation and buy-in.

> "In the early days of SIMUNDU's development, the system was challenging to operate, as it wasn't as stable as it is now. I praise the enthusiasm and dedication of the users." (M01)

The control function – consisting of quality assurance management – was critical to avoid data duplication or missing entries and ultimately ensure data quality. This process was not regulated by specific standard operating procedures but was addressed during training and monitored monthly. In addition, the DIY Health Office provided negative incentives to health facilities that were not submitting complete records and provided regular feedback from monitoring and evaluation exercises.

Specifically, 94.2%, 100%, and 100% of survey respondents in PHC, UPS, and DHO, respectively, reported that their work had been subject to monitoring. More than half of the respondents in PHC and UPS facilities had been observed by supervisors while performing data entry at least once over the past year. At the PHC level, 48.3% of survey respondents had been subject to monitoring from the district/city office's team, and 45.7% received monitoring from DIY Health Office staff. Conversely, 40% of respondents from UPS facilities were monitored by PHC staff. Almost all survey respondents reported receiving feedback from the monitoring, mainly from the district/city and DIY health offices. Forty percent of respondents from UPS facilities reported receiving feedback from PHC. Immunization coordinators from the district/city health offices received feedback from the DIY health offices.

> "In a [evaluation] meeting, the DIY Health Office or District Health Office showed the progress of our data entry – correct or not, proper or not." (M02)

It is worth noting that DIY province is quite a small geographic area. Because it consists of only five districts and one city, this province is relatively easy to monitor across all phases, from planning through monitoring and evaluation.

System performance

While SIMUNDU predominantly contains individual-level immunization records, it also serves as a source for aggregation and can synergize with other information systems. Notably, SIMUNDU can link to the DHIS2 and generate immunization-specific reports as per the Ministry of Health's requirements. These reports are sent to the upper levels automatically if SIMUNDU is operated online or submitted via email if SIMUNDU is operated offline. This functionality has had an essential role in ensuring the acceptability and adoption of the system.

Informants noted how transitioning from paper-based tools to an electronic system made data entry easier and reduced errors. SIMUNDU also facilitated the implementation of protocols for data storage and security. It enabled follow-up and defaulter tracking. Finally, integration with the DHIS2 meant reduced workload for the staff.

> "We can track children who may have received vaccinations in different locations faster. For example, when the first dose of a vaccine is given in Bantul and the second one in Yogyakarta, the record can be linked within SIMUNDU." (M01).

> "SIMUNDU makes detecting what data and vaccinations are missing easier since we enter data from the children's birth through the end of the immunization schedule. So, we will know where they miss any vaccine." (S03).

> "The benefit of using SIMUNDU is first: we know the situation of immunizations more accurately….so our vaccine forecasting is more accurate …. and our budget, staff, facilities can be more effective and efficient in providing services." (S05).

> "Colleagues from the mother and child health (KIA) program enter the data via the KIA "Sembada." So, these data will appear automatically in SIMUNDU because the two systems are connected." (S01).

SIMUNDU is user-friendly and can be flexibly operated offline or online, allowing the responsible staff to maintain data entry irrespective of connectivity; 82.3%, 96%, and 100% of survey respondents from PHC, UPS, and DHO, respectively, reported operating SIMUNDU online.

People's behavior

The interview showed that staff commitment was critical for the successful implementation of SIMUNDU, as indicated by their willingness to work overtime and bring home the data to enter into the system.

> "I take it [the data] home too, for example, after immunization sessions – in my clinic, immunization runs four times per month, every week. So, when the session is finished, we can take the data home, [and] do the entry at home while relaxing." (S03).

The interviews confirmed this dedication, which spoke to a societal culture of helping others and responsibility and commitment to the team. This contributed to shaping an environment where people approach SIMUNDU as a shared responsibility and a collective endeavor. Informants also noted the high motivation of dedicated staff.

> "That's all; we cannot judge by money [people's kindness, culture, and behavior]; explaining how good people are in Yogyakarta is essential. I was in another place before, and could not find people's kindness like in Yogyakarta – different characters." (M02).

> "The second thing is that we need human resources that are concerned about, and have a love for, data; otherwise, even if we have a good system, it will amount to nothing without good human resources. But good implementation will come more easily when people are concerned about data." (M04).

Resources: material, human, and financial

Infrastructure and equipment emerged as critical factors in introducing and sustaining SIMUNDU implementation. Some desktops were explicitly allocated to the immunization program, and some had to be shared with other staff. Other data entry officers reported using their laptop or smartphone (36.3% of survey respondents from PHC). In UPS facilities, 40.7% reported using office desktops; in the DHO, more than half of the respondents said they used an office-supplied laptop. The majority of respondents – regardless of the type of facility – said their current device was sufficient to perform their work on SIMUNDU. In terms of connectivity, 64.6% of PHC survey respondents and 67.7% of UPS's reported operating SIMUNDU online, relying on the office's Internet connection.

Management of financial resources was also crucial. According to the key informants, no special funds were allocated to SIMUNDU in the initial stages. Resources were leveraged through sharing activities – e.g., monitoring visits or transportation – with other programs, thus allowing cost efficiencies. Integration with other programs proved critical to ensuring sustainability.

> "SIMUNDU's budget comes from the state budget known as Anggaran Pendapatan dan Belanja Negara (APBN). Every year the APBN allocates funding envelopes for immunization to DIY and other provinces, where the budget is

apportioned across the program [not an explicitly written budget for SIMUNDU].” (M02).

Human resources are critical to the operation of SIMUNDU. According to the interviews, SIMUNDU data entry clerks must have patience, work carefully and not rush, be interested in data, be responsible, and have basic computer skills in word processing and spreadsheet software tools such as Microsoft Word and Excel, respectively. As shown by the survey, the large majority of SIMUNDU-operating staff were educated: At least 80% of data entry clerks in both PHC and UPS facilities have secondary education (> 80%), while at the managerial level (DHO), 75% of respondents have a bachelor’s degree (see Table 2). However, 19.4% and 9.1% of respondents from PHC and UPS facilities have low computer literacy.

Various data entry clerks looked for strategies to resolve the obstacles they encountered when entering data into SIMUNDU. Based on the interviews, some clerks furthered their computer skills by taking private computer classes. Others learned from colleagues in their offices, or reached out for help to the district person in charge. To deal with the accumulation of data needing to be entered in SIMUNDU, staff would sometimes work at home after office hours, as their busy schedule at work did not allow time for data entry.

> “If we found obstacles, we asked people in charge in PHC – asking for a solution or sharing by WhatsApp – or sometimes I asked the IT person in the DIY Health Office.” (S03)

Potential threats

As of today, SIMUNDU can be said to be a successful experience. However, some obstacles were encountered and addressed during implementation. Potential system sustaining includes individual capacity, technical or system issues, and high workload. Staff computer literacy was identified as one of the main sustainability challenges. Internet connectivity was another obstacle, as a good network did not support all health facilities. The survey shows that 64.6% and 67.7% of PHC and UPS staff, respectively, used the office Internet, while others had to rely on their home Internet.

Further incomplete and inconsistent records – such as a different child's date of birth or name spelling across relevant entries – make it challenging to consistently record immunization information. These challenges have arisen during implementation and were promptly addressed. Yet, they had an impact on staff who were already juggling busy schedules in the office, causing delays in data entry. As shown by the survey, almost all respondents said they had other responsibilities besides operating SIMUNDU – notably 97.3%, 88%, and 100% of participants from PHC, UPS and district and city offices, respectively.

Weakness

Some informants said that SIMUNDU assisted in their daily work, but they also reported that sometimes they needed more time to find the children's names on the next visit. This is because SIMUNDU data entry did not use a single national ID that could be valid anywhere. As a result, when a name input error occurs, the officer will need time to check the name with the child's parents or the manual register.

> “Sometimes, there was an incorrect name during the data entry; for example, Dita was written as Dieta. So, it is difficult for us to find them. If that happens, we must look back at the register or medical record data.” (S04).

> “I experienced difficulty entering data in SIMUNDU when a new patient came from another health facility to us. It was challenging to find their record on SIMUNDU.” (S05).

Opportunities

Informants appreciated SIMUNDU as an excellent system to manage immunization data. SIMUNDU has become necessary for program managers and policymakers; it allows them to monitor coverage and can help inform planning and programming. Currently, SIMUNDU is stable, thus it is easier to manage than when it was in the development phase. It is also viable and no longer requires heavy reliance on the core workforce that started the system. The hopes expressed by data entry clerks in the interviews are that SIMUNDU is easier to operate and system errors are less frequent. Informants also stressed the need for refresher training to ensure that knowledge and practice of the system is not lost.

> “In my opinion, SIMUNDU is the best program in DIY, a collaboration between program managers and IT. It will continue to be implemented because it is a necessity. It has been stably used for more than five years, meaning this is needed.” (M01).

> “If I have the tool, in this case SIMUNDU, when it is stable, whoever will be able to run it, I am sure that anyone can operate it. It means that it doesn't matter if we have people shifting [jobs].” (M01).

> “In the future, if SIMUNDU is still used, other reports are not necessary. Now we have two different reports: SIMUNDU and stock card of vaccine – each stands alone and needs a separate report.” (S05).

Based on the key informants’ interviews, SIMUNDU is likely to be developed further or expanded to other provinces. The DIY Health Office is open to supporting other provinces interested in introducing the system – for instance, through the lending staff for training and orientation. However, informants advised that a successful introduction requires a strong commitment from staff and management.

Discussion

Robust health information systems (HIS) are essential components of robust health systems [13]. At the most basic level, immunization registries are systems that collect and report individual-level vaccine administration record data, thus facilitating individual follow-up of vaccination status. Registries also allow for the monitoring of vaccination coverage and enable analysis of AEFIs and surveillance data to

inform the design of coverage interventions and outbreak investigations. When an electronic registry has interoperability with other electronic systems – such as in the case of SIMUNDU – it is considered an immunization information system (IIS) [14]. This paper presents lessons learned from DIY's experience of implementing an IIS.

DIY is the only province in Indonesia – out of 34 – that uses an IIS. This work has shed light on the strengths of, and underlying barriers to, implementing an IIS in this context. The objective of this study was to draw lessons that inform sustainable scaling-up in other provinces and possibly at the national level. This study highlighted individual capacity, technical or system issues, and high workload as the major barriers to sustainability. Conversely, management, system performance, people's behavior, and available resources emerged as the main determinants of SIMUNDU's successful implementation – notably in improving acceptability, implementation costs, and adoption of this innovation [15].

Despite several obstacles encountered during the implementation of SIMUNDU, this study showed that this innovation was well accepted by key stakeholders. On the one hand, data entry clerks noted that the system is relatively user-friendly and makes it possible to organize the data better and enhance its quality. On the other hand, managers noted the benefits this innovation brought about, namely in the potential for cohort data to support planning and monitoring and ultimately improve immunization coverage.

Effective management – across planning, organization, leadership, and control functions – is a crucial reason why SIMUNDU has been viable for over five years. Managers use their control to encourage the beliefs and actions of the staff with a dedicated and robust managerial process [16]. SIMUNDU was born from the need for credible data to assist in carrying out DIY Health Office duties at the managerial and operational levels. At the managerial level, the disease prevention and control department and the IT department collaborated in designing a system that intended users readily accepted. Immunization officers and IT programmers played a central role from the early stages of development through implementation with effective coordination and communication. They were helped in this task, with the full support of their respective superiors.

SIMUNDU is cost-effective in several ways. During the introductory period of its implementation, immunization programmers, IT officers, and other staff assisted in introducing SIMUNDU in all districts in the province. This was done by integrating some of the activities across programs, thus building efficiency in terms of time and costs for both managers and staff. Sharing resources across programs was critical in the first years of building sustainability. Additionally, maintaining SIMUNDU does not incur high costs because the DIY Health Office has developed the system and thus possesses in-house technical skills. The IT department has the capacity to monitor and improve processes and tailor them to user needs without much additional cost.

A good program without good leadership could fail in its implementation, and even if it was initially successful, it might not be sustainable [17]. In the context of SIMUNDU, leadership and effective management support facilitated the program's adoption. The uptake of the new system was good and all health facilities providing immunization services have successfully transitioned to SIMUNDU. The strong network of the prominent persons in charge of SIMUNDU also facilitated the adoption. Good communication, care, and attention to staff concern positively affected staff performance. They felt that they were well supported and treated kindly, and this helped them carry out their work joyfully. According to several informants, the DIY immunization program manager's leadership played an essential role in this effect.

The monitoring and evaluation mechanisms of SIMUNDU were also important. Preferred monitoring and evaluation activities include monthly reports and staff discussions during site monitoring visits. The immunization program manager suggested this approach to maintain data quality and ensure the system's sustainability. These chosen mechanisms allow program managers to assess the actual practice in the field and the challenges faced to inform decisions about the follow-up actions to be taken. These processes supported the ongoing development of, and learning from, SIMUNDU as a tool for data collection, analysis, and visualization, as well as the benefits for managers in carrying out monitoring and evaluation. The same sentiment was reflected in previous research undertaken in India [18].

Human resources are a key determinant of the successful implementation of any HIS [19]. People's behavior affects how the system works, develops, and survives [20, 21]. In the case of SIMUNDU, implementation was facilitated by a culture of care, established networks, and a positive attitude towards data on the part of both the program manager and the IT team. From the staff's point of view, the local culture of helping each other and doing their job correctly and responsibly translated into staff carrying out their duties with enthusiasm and great commitment. Although facilities, funding, and human resources were limited, the individuals involved were highly motivated and supportive.

Despite the many strengths of SIMUNDU, some obstacles may potentially challenge its sustainability in the long term. These obstacles can be divided into human variables and technical variables. In terms of human variables, unequal capacity distribution at the operational level can result in differing levels of data quality across facilities and districts. Staff workload is another challenge that needs addressing, as their willingness to work overtime is not a sustainable strategy. Technical problems were another obstacle during the introduction of SIMUNDU, but qualified technicians/developers were able to solve these issues. During our research, we recognized the weakness of SIMUNDU that it had not used the person number as a unique (single) code (ID) in data entry. This impacts on the challenge of finding a person when the previous entry was inaccurate. The in absence SIMUNDU single ID also affects SIMUNDU's inability to synchronize with other health programs that use a person's number as a unique code. However, this weakness can be seen as room for improvement for SIMUNDU shortly. Another thing that needs to be considered for other regions that want to implement SIMUNDU, so far SIMUNDU is implemented in DIY province, which consists of five districts/cities with relatively easy regional accessibility. For areas with more difficult access, the commitment of the leadership and subordinates is the key to successful implementation.

Conclusion

SIMUNDU is a promising innovation for the entire country, beyond DIY. There is agreement about the potential for scaling-up of this IIS to other provinces. Experience of implementing this system in DIY over the past five years has shown that the benefits outweigh the challenges, and SIMUNDU has grown into a robust yet user-friendly system. Regular training for dedicated staff to strengthen their capacity as the system evolves and is updated, and a plan for anticipating and responding to staff turnover, have proven critical strategies

towards sustainability. SIMUNDU's success also rests on remarkable leadership, both in creating and enabling a supportive environment and pursuing integration with other programs to share limited resources.

Recommendations

This study's recommendations address three different stakeholder groups: the DIY Health Office, the national government, and researchers. First, to ensure continuity and sustainability and reduce the system's dependency on a particular person or party, SIMUNDU management and maintenance should be managed by people who have competency and interest in a good reporting system. Furthermore, a human resources plan should be developed in preparation for SIMUNDU rollout in other provinces or at the national level; this is necessary to avoid vacancies when DIY province staff are seconded to other areas for mentoring support. Second, the fact that SIMUNDU emerged from an actual need for immunization program implementers and saw these at the front line of its development and implementation positively impacted its feasibility and viability. This suggests that the approach to scaling up SIMUNDU should be stepwise, taking into consideration each region's specific characteristics and needs. To this effect, a readiness map and a timeline may be developed to roll out SIMUNDU in a particular region. Third, further research is needed to assess the impact of SIMUNDU on immunization coverage. Based on our conversations with stakeholders, it would be particularly relevant to focus on a low-performing region and observe the impact over a two- to three-year time window.

Study limitations

The empirical results reported herein should be considered in light of limitations. First, the results of the quantitative study must be considered in view of the limited sample size, particularly for UPS health facilities. However, given the top-down immunization program and the characteristics of UPS, which will not be significantly different from each other, the results of this study are still valid and relevant to the existing condition. In qualitative research that aims to explore, caution is needed in interpreting the interview results. There is still a need for in-depth studies with different approaches, such as focus group discussions, to confirm the results.

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Authors' contributions

SS, TAW, RR, ASDN, and MF designed the study. SS, TWS, SKW, and SAM collected the data. SS and RR conducted data analysis. SS developed the paper with inputs and comments from MF on each draft. All authors agree with the manuscript's results and conclusions.

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Availability of data and materials

The data sets generated and/or analyzed for this study can be requested from the corresponding author.

Declarations

Ethics approval and consent to participate This study was approved by the Ethical **AQ7** Review Board of Universitas Ahmad Dahlan, Yogyakarta, Indonesia (ethical approval code: 012005021). Written informed consent was obtained from the participants before data collection started.

Consent for publication Not applicable.

Competing interests The authors declare that they have no competing interests.

Supplementary Information

Additional file 1.

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RESEARCH ARTICLE Open Access

Introduction and implementation of an immunization information system in the Indonesian province of Daerah Istimewa Yogyakarta: lessons for scaling-up

Sulistyawati Sulistyawati[1*], Trisno Agung Wibowo[2], Rokhmayanti Rokhmayanti[1], Andri Setyo Dwi Nugroho[2], Tri Wahyuni Sukesi[1], Siti Kurnia Widi Hastuti[1], Surahma Asti Mulasari[1] and Marta Feletto[3]

Abstract

Background Immunization is critical to saving children from infections. To increase vaccination coverage, valid and real-time data are needed. Accordingly, it is essential to have a good report system that serves as defaulter tracking to prevent children's immunization failure. The Daerah Istimewa Yogyakarta (DIY) Health Office introduced an electronic immunization registry and successfully implemented it for more than five years. It is the only individual-based record system in Indonesia that has been sustainably operated for a long time. Yet, no systematic assessment of this system has been conducted to date. This study examines the Sistem Informasi Imunisasi Terpadu (SIMUNDU) introduction and implementation process with a view to extracting lessons that could inform scalability and sustainability across the country.

Methods This study used an explanatory sequential mixed-method design, which collected quantitative data from 142 participants and qualitative data from nine participants. The data entry clerk at a health facility was systematically selected to participate in the survey, while in the key informant interview, the informant was selected based on the survey result. A descriptive and thematic approach was adopted to analyze the quantitative and qualitative data. Results from across the two approaches were integrated for comparison and contrast.

Results Findings are presented according to three core themes that emerged from the data: system strengths, potential threats, weakness and opportunities for scaling-up. Strengths, i.e., factors contributing to the success of SIMUNDU, include management, system performance, people's behavior, and resources. Potential threats to sustaining the system include individual capacity, technical or system issues, and high workload. Opportunities – i.e., a promising factor that influences the SIMUNDU ability to operate sustainably – such as continuity, expectation, and the possibility of scaling up.

Conclusions SIMUNDU is a promising innovation for Indonesia, beyond DIY. There is agreement about the potential for scaling up this IIS to other provinces. The experience of implementing this system in DIY over the past five years has shown that the benefits outweigh the challenges, and SIMUNDU has grown into a robust yet user-friendly system.

*Correspondence:
Sulistyawati Sulistyawati
sulistyawati.suyanto@ikm.uad.ac.id
Full list of author information is available at the end of the article

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Keywords Immunization, Electronic immunization registry, Immunization information system, Interoperability, Implementation research

Background

Neonatal and childhood vaccination is essential for infectious disease prevention and an absolute human right [1, 2]. Vaccination has been proven to reduce the burden of infectious diseases globally [3]. According to the WHO, in 2020, an estimated 23 million children under the age of one year did not receive their essential vaccinations. Of these, 60% live in just ten countries, one of which is Indonesia [4]. Indonesia is the fourth most populous country globally. It is composed of thousands of islands organized into 34 provinces. Various geographical and cultural factors influence population inequalities in accessing health services [5]. In 2001, the Indonesian government's decentralization policy was enacted. This was an excellent strategy for fostering development by engaging regional resources [6]. However, this strategy was not without consequence. One primary concern was the health information system (HIS) fragmentation.

Indonesia's federal structure results in provinces and districts being relatively independent of the national Ministry of Health. This means that provincial- and district-level information systems are locally regulated [7]. For instance, *Pemantauan Wilayah Setempat* (PWS) is a management tool used to monitor the coverage of specific health services within an administrative boundary. Depending on the service and region, it can be paper- or electronic-based. PWS-KIA is the monitoring system specific to maternal and child health (KIA), including immunization. PWS-KIA data are reported to the District or City Health Office, go to the Province Health Office, and are finally reported to the main level. Generally, the data are in Microsoft Excel formats; they will be reported via emails or various information systems, including Komdat Kesmas, SITT, SIHA, PISPK, and SIKDA Generik. PWS-KIA data feed into District Health Information System 2 (DHIS2). Regional information systems have varying data quality, which reflects inequities in resources across regions. This adds to data integration challenges at the national level [7, 8] and affects strategic policymaking.

In Indonesia's federal system, Daerah Istimewa Yogyakarta (DIY) province has the authority to regulate and use its budget within its four districts plus one city (Sleman, Gunungkidul, Bantul, Kulonprogo, and Yogyakarta). This province is classified as a small province in terms of area size and the number of regions inside [9]. However, this region can be considered a representation of Indonesia when viewed from the geographical, socioeconomic, and heterogeneous population perspective. With regard to childhood vaccination, DIY is among the top ten performing provinces in the country, with 97.7% of children completing basic immunization coverage in 2019 [10]. Immunization services are provided by primary health centers or Puskesmas (PHC), as well as private clinics, hospitals, and midwives' practices (typically referred to as *Unit Pelayanan Swasta* or UPS).

An electronic immunization registry is a tool for recording individual children's immunization histories. In 2014, the DIY Health Office introduced an electronic immunization registry named SIMUNDU (*Sistem Informasi Imunisasi Terpadu*/ Integrated Immunization Information System). An electronic registry provides essential functions at all levels of the health system. At the district and higher levels, it allows for monitoring vaccination coverage by vaccine, dose, cohort, and other variables – and can support microplanning and vaccine management. The service delivery level can facilitate individual follow-up of vaccination status and enable health workers to identify children due for vaccination and those who have missed their vaccinations (defaulters).

SIMUNDU was designed to link with PWS-KIA for immunization and interoperability with the DHIS2. While it predominantly contains individual-level immunization records, SIMUNDU also serves as a source for aggregation and can synergize with the *Pemantauan Wilayah Setempat* (PWS) reporting system. For this reason, it can be considered an immunization information system (IIS). This means that city and district levels feed into provincial and national levels *(Personal communication with DIY immunization program officer)*.

The original prototype was designed by the information and technology (IT) department of the DIY Health Office to be operated offline. In DIY, three out of the four districts and the city introduced the system in 2015. The final district introduced it in 2017. At this stage, the point of data entry was the PHC only. By 2018, UPS facilities were also equipped with SIMUNDU and could enter data into the system. In 2019, the prototype was further developed to operate online. The online version was rolled out in 2020 (Fig. 1). As of May 2021, 79.4% of all PHC and UPS facilities complied. This average rate masks, however, the fact that while all PHCs adopt SIMUNDU, it is more challenging to enforce its use in UPC facilities (Suyani 2020, oral communication, 2020, May 11).

When a child receives a vaccination in a health facility, information on the child and the vaccination is entered

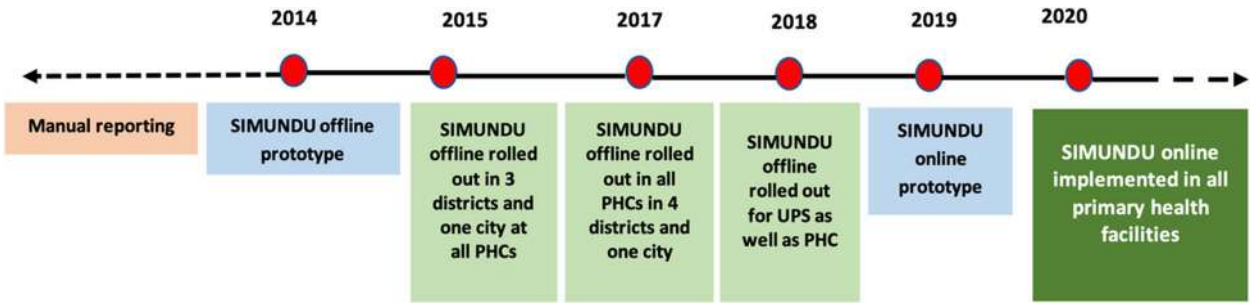

Fig. 1 SIMUNDU's development and introduction

in SIMUNDU as an individual child record. Each record includes a personal identifier, the child's sociodemographic characteristics (e.g., name, gender, date of birth, name of parents, address), the antigen administered, and the date and place of vaccination. SIMUNDU has been recently updated to allow the recording of vaccinations administered in schools (e.g., human papillomavirus (HPV), diphtheria toxoid (DT), tetanus-diphtheria (TD), and measles-rubella (MR)), albeit in the form of aggregate data only. Furthermore, SIMUNDU has been developed to record COVID-19 vaccinations in health facilities and those carried out en masse.

Monitoring is conducted monthly to assess data completeness across health facilities, while an evaluation is conducted yearly. These exercises have allowed the identification of several challenges related to implementing the system (e.g., workload, staff turnover, and rotation) and data quality (e.g., accuracy and timeliness). However, no systematic assessment of the system has been conducted to date. SIMUNDU is the first immunization information system ever introduced in Indonesia. Other districts and provinces have shown interest in rolling it out, and the Ministry of Health has acknowledged the innovation. The work presented here aims to examine SIMUNDU's introduction and implementation process with a view to extracting lessons that could inform scalability and sustainability across the country.

Methods

From May to October 2020, we examined the experience of introducing and implementing an immunization information system in DIY province using an explanatory sequential mixed-method design, where each step informed the next [11]. First, we reviewed all relevant documentation available in the DIY Health Office – e.g., staff notes, meeting notes, and monitoring notes – documenting SIMUNDU development and management processes. We also examined online documents, including health profiles and regulations on health-reporting systems in Indonesia. This served as the initial data source and provided an overview of who was involved and how in developing and implementing SIMUNDU. This informed the survey design that we conducted as a second step. The survey targeted any staff responsible for entering data in SIMUNDU (i.e., data clerks) across all PHC and selected UPS facilities and any staff responsible for managing the system at the district and city level (i.e., immunization coordinators). Sampling and recruitment strategies are outlined in Table 1.

All immunization coordinators in each district/city and data entry clerks from all primary health facilities (PHCs) were invited to participate in this survey. For UPS facilities, we selected two clinics, two midwives' practices, and two hospitals per district/city and invited all of their staff who were involved in SIMUNDU data entry and management.

We developed and pretested an online survey in Bahasa Indonesia to inquire about SIMUNDU implementation, processes, and outcomes across PHC, UPS clinics, and district or city and province offices. The questionnaire consisted of closed-ended and Likert scale questions – ranging from 45 to 50 depending on the target type of facility and/or level of the health system – and enquired about respondents' sociodemographic characteristics as well as the process of implementing and managing SIMUNDU. Some questions provided an additional field for clarifying the reason for a particular answer choice.

All participants were invited to the DIY Health Office to complete the survey on their laptops, with their prior consent. All participants in a room allowed researchers to monitor any missing or incomplete responses in real time and follow up with individual participants on-site to fill any gaps. We don't believe this may have introduced any significant bias as researchers would simply flag any missing responses and invite respondents to address those. Data were then exported and analyzed in Microsoft Excel. The topic areas for the qualitative

Table 1 Survey participants

Level of the data entry and reporting system	Total number of facilities/ offices	Study population	Sampling strategy	Recruitment	Sample size
Primary Health Center (PHC)	121	Data entry clerks	All facilities	Open invitation across all facilities	113
UPS – Central, General, Maternity, and Pediatric Hospitals	65	Data entry clerks	Randomly selected 2 facilities per district/city (2*5 = 10)	Open invitation across selected facilities	8
UPS – Clinics	73	Data entry clerks	Randomly selected 2 facilities per district/city (2*5 = 10)	Open invitation across selected facilities	7
UPS – Midwives' Practices	271	Data entry clerks	Randomly selected 2 facilities per district/city (2*5 = 10)	Open invitation across selected facilities	10
District/City Health Office	5	Immunization coordinators	Total sampling	Open invitation	4*
Total					**142**

* When the immunization coordinator recently changed, the former was also invited

interview were informed by an exploratory analysis of the survey data.

Similarly, some informants were purposefully selected among survey participants to follow up on the range of perspectives that had emerged from the survey. Other informants had been identified at the desk review stage and chosen for their management functions. Selected informants were invited to the DIY Health Office for the interview, and COVID-19 prevention protocols were observed. Every informant was informed about the study and asked to sign the informed consent. All invited informants agreed to participate. A total of nine 30-min semi-structured interviews were conducted in the Bahasa Indonesia language and recorded with prior consent from participants. The interview team consisted of three researchers with the respective tasks of running the interview, observing, and taking notes. A research assistant transcribed all interviews into Bahasa Indonesia.

Thematic analysis was conducted using the Quirkos qualitative tool following Braun and Clarke's approaches [12]. Researchers familiarized themselves with the data, searching for initial codes and allowing themes to emerge. The principal investigator led the coding process, and led the research team too in defining and naming the core themes emerging from the data, organizing and analyzing the data across the themes, and triangulating information from the desk review, the survey, and the interviews. This stage was also performed in Bahasa Indonesia. Data were translated into English only at subtheme and core themes levels.'

Results

Participant characteristics

Quantitative study

In total, 142 respondents participated in this study spread across five districts/cities in DIY province. Among them, Gunungkidul has a higher proportion of respondents than the other district, with 24.8%, 24%, and 25% for PHC, UPS, and DHO, respectively. For all research units, the majority were women. At the UPS and DHO/CHO levels, most respondents were aged 41–45 years, i.e., 28.3% and 75%, respectively, while at the UPS level, the majority were aged 25–30 years (56.0%). In terms of education level, PHC and UPS are dominated by Diploma 3 graduates, namely 86.7% and 80%, respectively, while in DHO/CHO, there are predominantly undergraduate graduates (75%) (Table 2).

Qualitative study

Nine informants were recruited to provide the required information to explore the quantitative study results more deeply. They serve as managers and staff at DHO/CHO, PHC, and UPS. Among the nine informants, two were men and seven were women. Three informants graduated with a master's, one with a bachelor's, and there were five graduates with diplomas (Table 3).

Findings

Findings from the study are organized and presented across the three core themes that emerged from the qualitative analysis, notably system strengths, potential threats, and opportunities for scale-up. However, data from qualitative and quantitative data fed into the analysis of these core themes to cross-validate the findings (Fig. 2. Detailed findings from the survey are presented in Table Supplement 1.

System's strengths

Factors contributing to the success of SIMUNDU include management, system performance, people's behavior, and resources.

Table 2 Characteristic participants in three groups of respondents

Characteristic	PHC (*n* = 113) n (%)	UPS (*n* = 25) n (%)	DHO/CHO (*n* = 4) n (%)
District/City			
Bantul	23 (20.4)	5 (20.0)	1 (25.0)
Gunungkidul	28 (24.8)	6 (24.0)	1 (25.0)
Yogyakarta	17 (15.0)	4 (16.0)	0 (0.0)
Kulonprogo	21 (18.6)	4 (16.0)	1 (25.0)
Sleman	24 (21.2)	6 (24.0)	1 (25.0)
Sex			
Male	3333(2.7)	0 (0.0)	2 (50.0)
Female	110 (97.3)	25 (100)	2 (50.0)
Age			
< 25	0 (0.0)	5 (20.0)	0 (0.0)
25–30	3 (2.7)	14 (56.0)	0 (0.0)
31–35	30 (26,5)	3 (12.0)	0 (0.0)
36–40	19 (16.8)	1 (4.0)	0 (0.0)
41–45	32 (28.3)	0 (0.0)	3 (75.0)
46–50	18 (15.9)	0 (0.0)	1 (25.0)
> 50	11 (9.7)	2 (8.0)	0 (0.0)
Education			
Master	0 (0.0)	1 (4.0)	1 (25.0)
Bachelor	5 (4.4)	1 (4.0)	3 (75.0)
Diploma 4	9 (8.0)	2 (8.0)	0 (0.0)
Diploma 3	98 (86.7)	20 (80.0)	0 (0.0)
Senior high school	1 (0.9)	1 (4.0)	0 (0.0)

Management

SIMUNDU arose due to concerns from the DIY Health Office immunization section around data quality, notably the need to address data inaccuracy, duplicate or missing data and a lack of timely data, and the need for quality data to support follow-up and appropriate planning. The need for SIMUNDU arose from these challenges and needs.

> *"To our knowledge, [SIMUNDU development] started with a problem: estimates of the target population varied depending on the data source." (M02)*
> *"Yes, I think [SIMUNDU management team] started to tire of managing a large volume of data with dubious validity. They need to know the situation in each district." (M04)*

Effective management of SIMUNDU from development to implementation was highlighted as an essential determinant of its success across the critical functions of planning, organization, leadership, and control.

Careful planning was ensured at each stage of the development and implementation of SIMUNDU. These stages included developing an initial business plan, providing training on and socialization to SIMUNDU, and developing a staff replacement plan to respond to turnover or retirement of staff in charge of operating the system or entering data. The parties involved in planning included the Head of the Disease Prevention and Control Department, IT personnel, and, from the DIY Health Office, immunization program staff.

Organization – the organization of SIMUNDU is carried out at several levels. The top level is the DIY Health Office, the second level is the district/city health office, and the third level is health facilities (Fig. 3). A third party was also involved in developing the system interface.

At the beginning of the development of SIMUNDU, essential functions included database administrators, interface designers, and server administrators, and their interplay facilitated the system's smooth operation. Training specific to SIMUNDU was integrated with other training, typically immunization-related. This enabled us to share resources with other programs, thus ensuring viability. The training was delivered in the district/city

Table 3 Informants' characteristics for the qualitative study

Sex	Age (years)	Education	Position	Subject group	Informant's code
Female	56	Master's	Head of disease prevention and control department at PHO level	Managerial	M 01
Male	57	Master's	The former head of the disease prevention and control section at the PHO level	Managerial	M 02
Male	54	Bachelor's	Immunization programmer (coordinator) at the PHO level	Managerial	M 03
Female	47	Master's	IT person	Managerial	M 04
Female	34	Diploma	Data entry at the PHC level	Staff	S 01
Female	25	Diploma	Data entry at the UPS level	Staff	S 02
Female	31	Diploma	Data entry at the UPS level	Staff	S 03
Female	42	Diploma	Data entry at the PHC level	Staff	S 04
Female	24	Diploma	Data entry at the PHC level	Staff	S 05

Fig. 2 Strengths, potential threats, and opportunities for scaling-up

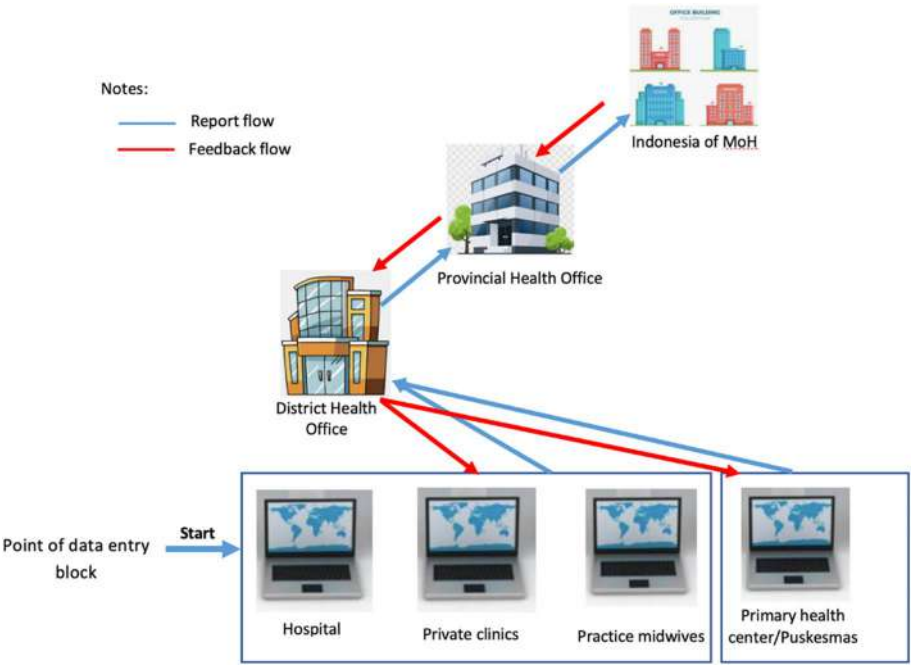

Fig. 3 Visual organizing framework of SIMUNDU – DIY province, Indonesia

health office: 87.6%, 72%, and 75% of survey respondents from PHC, UPS, and DHO/CHO, respectively, participated in in-house training. Training typically consisted of short sessions and included practice on the trainee's device in operating the system in both online and offline mode. Informants indicated that day-to-day operations were carried out autonomously by the staff through flexibly adjusting their work to protect the time to enter the data. This seemed to work effectively.

Leadership – the success of SIMUNDU implementation is arguably related to strong leadership. Informants noted that managers played a crucial role in bridging the needs

of the immunization program with the system design, closely monitoring the initial implementation process, and creating an enabling environment.

> *"I try to combine supporting and managing and monitoring the people involved. Currently, I monitor whether [SIMUNDU] can run optimally as our users are health facilities. I also monitor program development and the system's output." (M01).*
> *"[SIMUNDU] was born from program managers, primary health centers, districts, and DIY health offices wanting to build systems together. We – DIY Health Office – give them motivation in every meeting." (M03).*
> *"I see that [management] is very good at networking. Staff data entries in the field always indicated that these people are very kind." (M02)*

The role of IT workers in developing SIMUNDU was also significant. They helped develop the system and facilitated correct entries by entry clerk whenever technical issues arose. IT workers also helped resolve inconsistencies in data records. Acknowledgment of staff efforts was also important to maintain motivation and buy-in.

> *"In the early days of SIMUNDU's development, the system was challenging to operate, as it wasn't as stable as it is now. I praise the enthusiasm and dedication of the users." (M01)*

The control function – consisting of quality assurance management – was critical to avoid data duplication or missing entries and ultimately ensure data quality. This process was not regulated by specific standard operating procedures but was addressed during training and monitored monthly. In addition, the DIY Health Office provided negative incentives to health facilities that were not submitting complete records and provided regular feedback from monitoring and evaluation exercises.

Specifically, 94.2%, 100%, and 100% of survey respondents in PHC, UPS, and DHO, respectively, reported that their work had been subject to monitoring. More than half of the respondents in PHC and UPS facilities had been observed by supervisors while performing data entry at least once over the past year. At the PHC level, 48.3% of survey respondents had been subject to monitoring from the district/city office's team, and 45.7% received monitoring from DIY Health Office staff. Conversely, 40% of respondents from UPS facilities were monitored by PHC staff. Almost all survey respondents reported receiving feedback from the monitoring, mainly from the district/city and DIY health offices. Forty percent of respondents from UPS facilities reported receiving feedback from PHC. Immunization coordinators from the district/city health offices received feedback from the DIY health offices.

> *"In a [evaluation] meeting, the DIY Health Office or District Health Office showed the progress of our data entry – correct or not, proper or not." (M02)*

It is worth noting that DIY province is quite a small geographic area. Because it consists of only five districts and one city, this province is relatively easy to monitor across all phases, from planning through monitoring and evaluation.

System performance

While SIMUNDU predominantly contains individual-level immunization records, it also serves as a source for aggregation and can synergize with other information systems. Notably, SIMUNDU can link to the DHIS2 and generate immunization-specific reports as per the Ministry of Health's requirements. These reports are sent to the upper levels automatically if SIMUNDU is operated online or submitted via email if SIMUNDU is operated offline. This functionality has had an essential role in ensuring the acceptability and adoption of the system.

Informants noted how transitioning from paper-based tools to an electronic system made data entry easier and reduced errors. SIMUNDU also facilitated the implementation of protocols for data storage and security. It enabled follow-up and defaulter tracking. Finally, integration with the DHIS2 meant reduced workload for the staff.

> *"We can track children who may have received vaccinations in different locations faster. For example, when the first dose of a vaccine is given in Bantul and the second one in Yogyakarta, the record can be linked within SIMUNDU." (M01).*
> *"SIMUNDU makes detecting what data and vaccinations are missing easier since we enter data from the children's birth through the end of the immunization schedule. So, we will know where they miss any vaccine." (S03).*
> *"The benefit of using SIMUNDU is first: we know the situation of immunizations more accurately….so our vaccine forecasting is more accurate …. and our budget, staff, facilities can be more effective and efficient in providing services." (S05).*
> *"Colleagues from the mother and child health (KIA) program enter the data via the KIA "Sembada." So, these data will appear automatically in SIMUNDU because the two systems are connected." (S01).*

SIMUNDU is user-friendly and can be flexibly operated offline or online, allowing the responsible staff to maintain data entry irrespective of connectivity; 82.3%, 96%, and 100% of survey respondents from PHC, UPS, and DHO, respectively, reported operating SIMUNDU online.

People's behavior

The interview showed that staff commitment was critical for the successful implementation of SIMUNDU, as indicated by their willingness to work overtime and bring home the data to enter into the system.

> *"I take it [the data] home too, for example, after immunization sessions – in my clinic, immunization runs four times per month, every week. So, when the session is finished, we can take the data home, [and] do the entry at home while relaxing." (S03).*

The interviews confirmed this dedication, which spoke to a societal culture of helping others and responsibility and commitment to the team. This contributed to shaping an environment where people approach SIMUNDU as a shared responsibility and a collective endeavor. Informants also noted the high motivation of dedicated staff.

> *"That's all; we cannot judge by money [people's kindness, culture, and behavior]; explaining how good people are in Yogyakarta is essential. I was in another place before, and could not find people's kindness like in Yogyakarta – different characters." (M02).*
>
> *"The second thing is that we need human resources that are concerned about, and have a love for, data; otherwise, even if we have a good system, it will amount to nothing without good human resources. But good implementation will come more easily when people are concerned about data." (M04).*

Resources: material, human, and financial

Infrastructure and equipment emerged as critical factors in introducing and sustaining SIMUNDU implementation. Some desktops were explicitly allocated to the immunization program, and some had to be shared with other staff. Other data entry officers reported using their laptop or smartphone (36.3% of survey respondents from PHC). In UPS facilities, 40.7% reported using office desktops; in the DHO, more than half of the respondents said they used an office-supplied laptop. The majority of respondents – regardless of the type of facility – said their current device was sufficient to perform their work on SIMUNDU. In terms of connectivity, 64.6% of PHC survey respondents and 67.7% of UPS's reported operating SIMUNDU online, relying on the office's Internet connection.

Management of financial resources was also crucial. According to the key informants, no special funds were allocated to SIMUNDU in the initial stages. Resources were leveraged through sharing activities – e.g., monitoring visits or transportation – with other programs, thus allowing cost efficiencies. Integration with other programs proved critical to ensuring sustainability.

> *"SIMUNDU's budget comes from the state budget known as Anggaran Pendapatan dan Belanja Negara (APBN). Every year the APBN allocates funding envelopes for immunization to DIY and other provinces, where the budget is apportioned across the program [not an explicitly written budget for SIMUNDU]." (M02).*

Human resources are critical to the operation of SIMUNDU. According to the interviews, SIMUNDU data entry clerks must have patience, work carefully and not rush, be interested in data, be responsible, and have basic computer skills in word processing and spreadsheet software tools such as Microsoft Word and Excel, respectively. As shown by the survey, the large majority of SIMUNDU-operating staff were educated: At least 80% of data entry clerks in both PHC and UPS facilities have secondary education (> 80%), while at the managerial level (DHO), 75% of respondents have a bachelor's degree (see Table 2). However, 19.4% and 9.1% of respondents from PHC and UPS facilities have low computer literacy.

Various data entry clerks looked for strategies to resolve the obstacles they encountered when entering data into SIMUNDU. Based on the interviews, some clerks furthered their computer skills by taking private computer classes. Others learned from colleagues in their offices, or reached out for help to the district person in charge. To deal with the accumulation of data needing to be entered in SIMUNDU, staff would sometimes work at home after office hours, as their busy schedule at work did not allow time for data entry.

> *"If we found obstacles, we asked people in charge in PHC – asking for a solution or sharing by WhatsApp – or sometimes I asked the IT person in the DIY Health Office." (S03)*

Potential threats

As of today, SIMUNDU can be said to be a successful experience. However, some obstacles were encountered and addressed during implementation. Potential system sustaining includes individual capacity, technical or system issues, and high workload. Staff computer literacy was identified as one of the main sustainability challenges. Internet connectivity was another obstacle, as a good network did not support all health facilities. The survey shows that 64.6% and 67.7% of PHC and UPS staff,

respectively, used the office Internet, while others had to rely on their home Internet.

Further incomplete and inconsistent records – such as a different child's date of birth or name spelling across relevant entries – make it challenging to consistently record immunization information. These challenges have arisen during implementation and were promptly addressed. Yet, they had an impact on staff who were already juggling busy schedules in the office, causing delays in data entry. As shown by the survey, almost all respondents said they had other responsibilities besides operating SIMUNDU – notably 97.3%, 88%, and 100% of participants from PHC, UPS and district and city offices, respectively.

Weakness

Some informants said that SIMUNDU assisted in their daily work, but they also reported that sometimes they needed more time to find the children's names on the next visit. This is because SIMUNDU data entry did not use a single national ID that could be valid anywhere. As a result, when a name input error occurs, the officer will need time to check the name with the child's parents or the manual register.

> *"Sometimes, there was an incorrect name during the data entry; for example, Dita was written as Dieta. So, it is difficult for us to find them. If that happens, we must look back at the register or medical record data." (S04).*
> *"I experienced difficulty entering data in SIMUNDU when a new patient came from another health facility to us. It was challenging to find their record on SIMUNDU." (S05).*

Opportunities

Informants appreciated SIMUNDU as an excellent system to manage immunization data. SIMUNDU has become necessary for program managers and policymakers; it allows them to monitor coverage and can help inform planning and programming. Currently, SIMUNDU is stable, thus it is easier to manage than when it was in the development phase. It is also viable and no longer requires heavy reliance on the core workforce that started the system. The hopes expressed by data entry clerks in the interviews are that SIMUNDU is easier to operate and system errors are less frequent. Informants also stressed the need for refresher training to ensure that knowledge and practice of the system is not lost.

> *"In my opinion, SIMUNDU is the best program in DIY, a collaboration between program managers and IT. It will continue to be implemented because it is a necessity. It has been stably used for more than five years, meaning this is needed." (M01).*
> *"If I have the tool, in this case SIMUNDU, when it is stable, whoever will be able to run it, I am sure that anyone can operate it. It means that it doesn't matter if we have people shifting [jobs]." (M01).*
> *"In the future, if SIMUNDU is still used, other reports are not necessary. Now we have two different reports: SIMUNDU and stock card of vaccine – each stands alone and needs a separate report." (S05).*

Based on the key informants' interviews, SIMUNDU is likely to be developed further or expanded to other provinces. The DIY Health Office is open to supporting other provinces interested in introducing the system – for instance, through the lending staff for training and orientation. However, informants advised that a successful introduction requires a strong commitment from staff and management.

Discussion

Robust health information systems (HIS) are essential components of robust health systems [13]. At the most basic level, immunization registries are systems that collect and report individual-level vaccine administration record data, thus facilitating individual follow-up of vaccination status. Registries also allow for the monitoring of vaccination coverage and enable analysis of AEFIs and surveillance data to inform the design of coverage interventions and outbreak investigations. When an electronic registry has interoperability with other electronic systems – such as in the case of SIMUNDU – it is considered an immunization information system (IIS) [14]. This paper presents lessons learned from DIY's experience of implementing an IIS.

DIY is the only province in Indonesia – out of 34 – that uses an IIS. This work has shed light on the strengths of, and underlying barriers to, implementing an IIS in this context. The objective of this study was to draw lessons that inform sustainable scaling-up in other provinces and possibly at the national level. This study highlighted individual capacity, technical or system issues, and high workload as the major barriers to sustainability. Conversely, management, system performance, people's behavior, and available resources emerged as the main determinants of SIMUNDU's successful implementation – notably in improving acceptability, implementation costs, and adoption of this innovation [15].

Despite several obstacles encountered during the implementation of SIMUNDU, this study showed that this innovation was well accepted by key stakeholders. On the one hand, data entry clerks noted that the

system is relatively user-friendly and makes it possible to organize the data better and enhance its quality. On the other hand, managers noted the benefits this innovation brought about, namely in the potential for cohort data to support planning and monitoring and ultimately improve immunization coverage.

Effective management – across planning, organization, leadership, and control functions – is a crucial reason why SIMUNDU has been viable for over five years. Managers use their control to encourage the beliefs and actions of the staff with a dedicated and robust managerial process [16]. SIMUNDU was born from the need for credible data to assist in carrying out DIY Health Office duties at the managerial and operational levels. At the managerial level, the disease prevention and control department and the IT department collaborated in designing a system that intended users readily accepted. Immunization officers and IT programmers played a central role from the early stages of development through implementation with effective coordination and communication. They were helped in this task, with the full support of their respective superiors.

SIMUNDU is cost-effective in several ways. During the introductory period of its implementation, immunization programmers, IT officers, and other staff assisted in introducing SIMUNDU in all districts in the province. This was done by integrating some of the activities across programs, thus building efficiency in terms of time and costs for both managers and staff. Sharing resources across programs was critical in the first years of building sustainability. Additionally, maintaining SIMUNDU does not incur high costs because the DIY Health Office has developed the system and thus possesses in-house technical skills. The IT department has the capacity to monitor and improve processes and tailor them to user needs without much additional cost.

A good program without good leadership could fail in its implementation, and even if it was initially successful, it might not be sustainable [17]. In the context of SIMUNDU, leadership and effective management support facilitated the program's adoption. The uptake of the new system was good and all health facilities providing immunization services have successfully transitioned to SIMUNDU. The strong network of the prominent persons in charge of SIMUNDU also facilitated the adoption. Good communication, care, and attention to staff concern positively affected staff performance. They felt that they were well supported and treated kindly, and this helped them carry out their work joyfully. According to several informants, the DIY immunization program manager's leadership played an essential role in this effect.

The monitoring and evaluation mechanisms of SIMUNDU were also important. Preferred monitoring and evaluation activities include monthly reports and staff discussions during site monitoring visits. The immunization program manager suggested this approach to maintain data quality and ensure the system's sustainability. These chosen mechanisms allow program managers to assess the actual practice in the field and the challenges faced to inform decisions about the follow-up actions to be taken. These processes supported the ongoing development of, and learning from, SIMUNDU as a tool for data collection, analysis, and visualization, as well as the benefits for managers in carrying out monitoring and evaluation. The same sentiment was reflected in previous research undertaken in India [18].

Human resources are a key determinant of the successful implementation of any HIS [19]. People's behavior affects how the system works, develops, and survives [20, 21]. In the case of SIMUNDU, implementation was facilitated by a culture of care, established networks, and a positive attitude towards data on the part of both the program manager and the IT team. From the staff's point of view, the local culture of helping each other and doing their job correctly and responsibly translated into staff carrying out their duties with enthusiasm and great commitment. Although facilities, funding, and human resources were limited, the individuals involved were highly motivated and supportive.

Despite the many strengths of SIMUNDU, some obstacles may potentially challenge its sustainability in the long term. These obstacles can be divided into human variables and technical variables. In terms of human variables, unequal capacity distribution at the operational level can result in differing levels of data quality across facilities and districts. Staff workload is another challenge that needs addressing, as their willingness to work overtime is not a sustainable strategy. Technical problems were another obstacle during the introduction of SIMUNDU, but qualified technicians/developers were able to solve these issues. During our research, we recognized the weakness of SIMUNDU that it had not used the person number as a unique (single) code (ID) in data entry. This impacts on the challenge of finding a person when the previous entry was inaccurate. The in absence SIMUNDU single ID also affects SIMUNDU's inability to synchronize with other health programs that use a person's number as a unique code. However, this weakness can be seen as room for improvement for SIMUNDU shortly. Another thing that needs to be considered for other regions that want to implement SIMUNDU, so far SIMUNDU is implemented in DIY province, which consists of five districts/cities with relatively easy regional accessibility. For areas with more difficult access, the commitment of the leadership and subordinates is the key to successful implementation.

Conclusion

SIMUNDU is a promising innovation for the entire country, beyond DIY. There is agreement about the potential for scaling-up of this IIS to other provinces. Experience of implementing this system in DIY over the past five years has shown that the benefits outweigh the challenges, and SIMUNDU has grown into a robust yet user-friendly system. Regular training for dedicated staff to strengthen their capacity as the system evolves and is updated, and a plan for anticipating and responding to staff turnover, have proven critical strategies towards sustainability. SIMUNDU's success also rests on remarkable leadership, both in creating and enabling a supportive environment and pursuing integration with other programs to share limited resources.

Recommendations

This study's recommendations address three different stakeholder groups: the DIY Health Office, the national government, and researchers. First, to ensure continuity and sustainability and reduce the system's dependency on a particular person or party, SIMUNDU management and maintenance should be managed by people who have competency and interest in a good reporting system. Furthermore, a human resources plan should be developed in preparation for SIMUNDU rollout in other provinces or at the national level; this is necessary to avoid vacancies when DIY province staff are seconded to other areas for mentoring support. Second, the fact that SIMUNDU emerged from an actual need for immunization program implementers and saw these at the front line of its development and implementation positively impacted its feasibility and viability. This suggests that the approach to scaling up SIMUNDU should be stepwise, taking into consideration each region's specific characteristics and needs. To this effect, a readiness map and a timeline may be developed to roll out SIMUNDU in a particular region. Third, further research is needed to assess the impact of SIMUNDU on immunization coverage. Based on our conversations with stakeholders, it would be particularly relevant to focus on a low-performing region and observe the impact over a two- to three-year time window.

Study limitations

The empirical results reported herein should be considered in light of limitations. First, the results of the quantitative study must be considered in view of the limited sample size, particularly for UPS health facilities. However, given the top-down immunization program and the characteristics of UPS, which will not be significantly different from each other, the results of this study are still valid and relevant to the existing condition. In qualitative research that aims to explore, caution is needed in interpreting the interview results. There is still a need for in-depth studies with different approaches, such as focus group discussions, to confirm the results.

Abbreviations

AEFI	Adverse Events Following Immunization
APBN	Anggaran Pendapatan dan Belanja Negara (State Budget)
CHO	City Health Office
COVID-19	Coronavirus Disease 2019
DHIS2	District Health Information System 2
DHO	District Health Office
DIY	Daerah Istimewa Yogyakarta (Special Region of Yogyakarta)
DT	Diphtheria Toxoid
HIS	Health Information System
HPV	Human papillomavirus
ID	Identity
IIS	Immunization Information System
IT	Information Technology
KIA	Kesehatan Ibu dan Anak (Maternal and Child Health)
KOMDAT KESMAS	Komunikasi Data Kesehatan Masyarakat (Public Health Data Communication)
MR	Measles-Rubella
PHC	Primary Health Centers
PHO	Provincial Health Office
PISPK	Program Indonesia Sehat dengan Pendekatan Keluarga (Healthy Indonesia Program with Family Approach)
PWS	Pemantauan Wilayah Setempat (Local Area Monitoring)
SIHA	HIV AIDS Information System
SIKDA	Regional Health Information System
SIMUNDU	Integrated Immunization Information System
SITT	Integrated Tuberculosis Information System
TD	Tetanus-Diphtheria
UPS	Unit Pelayanan Swasta (Private Service Unit)

Supplementary Information

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Additional file 1.

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Authors' note

The authors alone are responsible for the views expressed in this article. They do not necessarily represent the views, decisions, or policies of the institutions affiliated with them.

Adherence to national and international regulations

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Authors' contributions

SS, TAW, RR, ASDN, and MF designed the study. SS, TWS, SKW, and SAM collected the data. SS and RR conducted data analysis. SS developed the paper with inputs and comments from MF on each draft. All authors agree with the manuscript's results and conclusions.

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Availability of data and materials
The data sets generated and/or analyzed for this study can be requested from the corresponding author.

Declarations

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Competing interests
The authors declare that they have no competing interests.

Author details
[1]Faculty of Public Health, Universitas Ahmad Dahlan, Kampus 3 - Jl. Prof Dr Soepomo, Janturan, Umbulharjo, Yogyakarta, Indonesia. [2]Daerah Istimewa Yogyakarta (DIY) Health Office, Yogyakarta, Indonesia. [3]Alliance for Health Policy and Systems Research, World Health Organization, Geneva, Switzerland.

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