Mobile-based Vaccine Registry to Improve Collection and Completeness of Maternal Immunization Data

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***Abstract*—Immunization during pregnancy and infancy significantly reduces morbidity and mortality of mothers, unborn fetuses, and young infants. Several studies show the merits of getting complete, quality, and accurate data on time to enhance policy and decision-making for society or country development. Despite the efforts by nations to ensure the success of maternal immunization through electronic immunization registries, limited resources such as poor internet access, shortage of electricity, and digital illiteracy in developing countries hinder the goal of full immunization of mothers and infants. Since 2015, immunization programs in Tanzania use internet-based information systems to collect immunization data from health facilities and submit them to the responsible authority for further decision-making such as the allocation of vaccines to health facilities. The internet-based media is not fully achieved in developing countries due to its cost and resource setting, thus, the responsible authority does not receive instant data to update its vaccine inventory and management activities which often results in partial immunization due to the unavailability of vaccines in some facilities. This challenge can be solved by having an affordable system that instantly incorporates and transmits vaccination details such as the utilization of vaccines and demands from each health facility to responsible authority with less resources. The present study proposes a USSD platform to enhance the receipt of real-time data by immunization authorities from both health facilities with poor and good internet connectivity at a lesser cost. A greater number of health facilities in Tanzania prefer to use both online and offline platforms for collecting and recording immunization data. As electronic immunization registry has been introduced in areas with limited resources, it is recommended the use online and offline platforms for data collection so that they can submit immunization data in real-time without the delays caused by poor resource setting.**

Keywords*—*Maternal immunization; electronic immunization registry; USSD; data collection; limited resource setting

I. Introduction

Vaccination is among the most common measures in the world to improve maternal immunity and reduce the morbidity and mortality of babies and women. The reduction or elimination of maternal morbidity and mortality is critical for improving maternal health [1] to achieve the expansion of health access in middle and low-income countries and attain the Sustainable Development Goals regarding maternal health [2], [3].

According to the World Health Organization (WHO) [4], current statistics indicate that more than 3 million people die worldwide annually from vaccine-preventable diseases such as measles, tetanus, poliomyelitis, and rubella, whereby approximately 50% of these deaths occur among children less than 5 years. Recent reports show that child mortality rates have reduced by 60% from 93 deaths per 1000 live births in 1990 to 38 deaths in 2019 worldwide [5]. However, measles and tetanus are still the leading cause of death to infants and mothers worldwide which can be preventable by vaccines (Fig. 1). The WHO, therefore, recommends that developing countries issue the tetanus vaccine during pregnancy to avoid maternal and neonatal deaths due to low levels of anti-tetanus antibodies [6].

Tanzania has made substantial progress in the area of health [7]. For instance, the life expectancy of its people has improved from 40 years in 1960 to 65 years in 2019 [8]. Similarly, the United States Agency for International Development (USAID) reports [9] show that child mortality has declined rapidly from 49.1 deaths per 1000 live births in 2009 up to 36 deaths per 1000 live births in 2019 [10] after achieving a 75% reduction of unvaccinated children in one year. In 2021, the immunization program in Tanzania ensured that every child got lifesaving vaccines through equal availability and distribution of vaccines in all regions. It further initiated the national immunization strategy to meet the immunization agenda 2030, by ensuring everyone is protected from vaccine-preventable diseases throughout their lives with high quality, effective, efficient, and equitable immunization services; and ensure an effective, efficient, and resilient immunization [11]. The present work is organized as follows: The background to the study is presented in Section II and a description of the developed system is provided in Section III. Sections IV and V provide the methodology and system requirements respectively. Sections VI, VII, and VIII present the results, discussions, and conclusions respectively.

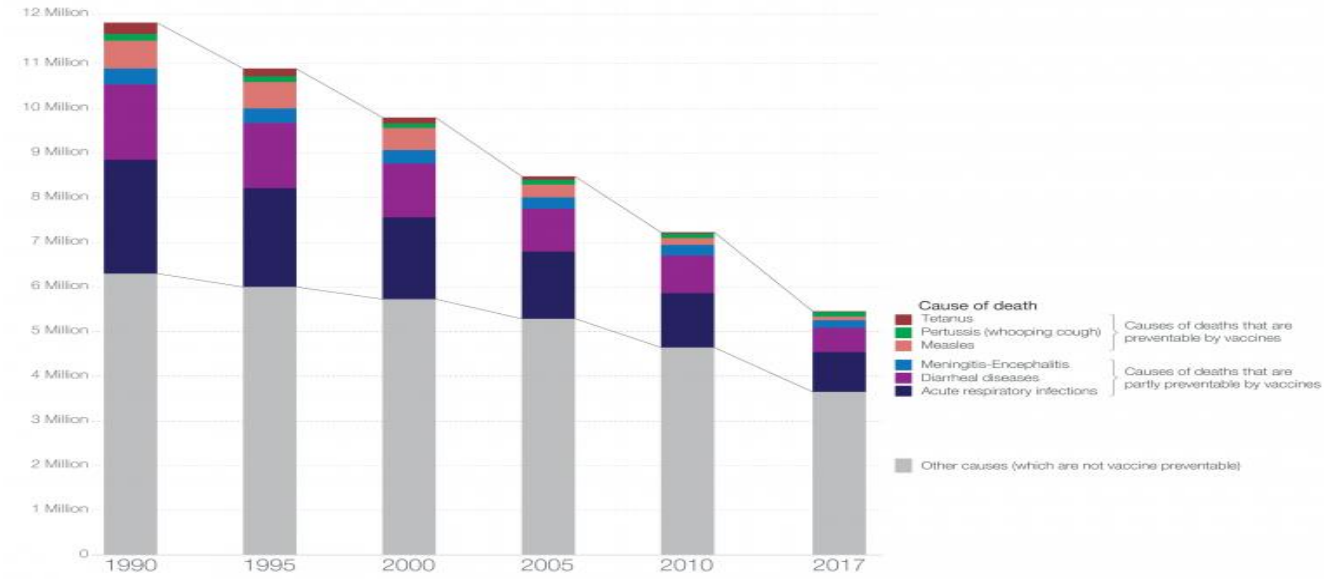

Fig. 1. Child Death due to Vaccine-preventable Disease [12].

II. BACKGROUND

According to Seymour et al. [13], the current immunization management system used for collecting and reporting immunization data in Tanzania is an internet-based platform. However, it is not yet fully achieved in Tanzania because the number of internet users is less compared to the total population. In January 2020, only 14.72 million people in Tanzania (25% of the population) had access to the internet out of a total population of 59,734,218 people [14]. Also reported by [15], another challenge is the rural-urban digital divide in developing countries which leads to poor performance of internet-based systems. Various techniques used to collect immunization data such as Electronic Immunization Register (EIR) and the vaccine immunization management system (VIMS) perform critical routine immunization service delivery by providing better collection, quality, and use of data [13] The EIR, for instance, aims to improve immunization programs through better information management systems [16]. However, it is necessary to stimulate data collection, quality, and use [17].

The Tanzania immunization management registry (TiMR) which is integrated with a digital supply chain named the electronic immunization registry and logistics management information system (EIR-eLMIS) is used for stock notifications and supply of vaccines into various regions [18]. A model tested to check the impacts of EIR-eLMIS in 2017 provided an estimation of the declining stock-out rates in health facilities. Despite the adoption of eLMIS in health facilities, there still exist barriers such as poor internet connections, lack of electrical power, and digital illiteracy [18]. A second platform that is used to collect immunization data from the district level to the national level in Tanzania is VIMS which combines the existing platforms into single data collection [19]. However, there are various discussions about the poor internet access in some areas which hinders the installation of VIMS in all health facilities [19]. The introduction of EIR in Zambia and Tanzania has enhanced regular reporting of vaccine stocks-out rates or declines in health facilities and shown that the EIR be built-in system for easy and routine monitoring [20].

The present work focuses on a real-time collection of immunization data using the Unstructured Supplementary Service Data (USSD) technology as an offline network access media because the use of the online-based systems in Tanzania is not yet fully achieved due to barriers like poor internet connections, shortage of electricity and digital illiteracy [18]. The USSD technology is a less-costly asset with better collection and aggregation of data [21], support resource-limited areas [22] as has been used for home-based health workers in South Africa [23], and health data reporting from lower levels to the national level in Uganda [22]. It can also be implemented with all kinds of users, including the illiterate and literate [24]. Other studies have used interactive voice response (IVR) and short message service (SMS) for data collection in information systems. However, the USSD shows more benefits such as providing a user interactive menu with its open-up design space compared to IVR and SMS [25] and is a more secured platform [26].

According to Vasuvedan et al. [27], there is slow-up immunization in sub-Saharan countries including Tanzania, where 72% of mothers reported delayed vaccination, especially in rural areas. Therefore, the USSD technology is proposed in the present study due to the following reasons: i) it works offline as well as online, ii) it works with less cost so can be implemented even in limited-resource setting areas, iii) it is a real-time data collection technique, iv) it can be used with digital illiteracy, and v) it has open up design space to receive more input from clients [21], [25].

III. Description of the Developed System

The system which has been developed by this study has four components namely: login module, services menu, stock notifications, and vaccines ordering module. Users of the proposed system include health workers, heads of departments from reproductive and child health (RCH), regional immunization officers, and the regional database administrator. The health workers can access the system by dialing the given USSD code. The network operator submits the query to the USSD gateway which has been embedded with a mobile-based vaccine registry. Health workers and heads of departments will receive the immunization register for data submission as well as stock details. The regional immunization officer will view data submitted from various health facilities in his/her region and generate a report on the utilization of vaccines and their demand in a particular region. The regional database administrator will be responsible for developing and maintaining the computerized database for his/her region. The conceptual framework of the proposed system is shown in Fig. 2.

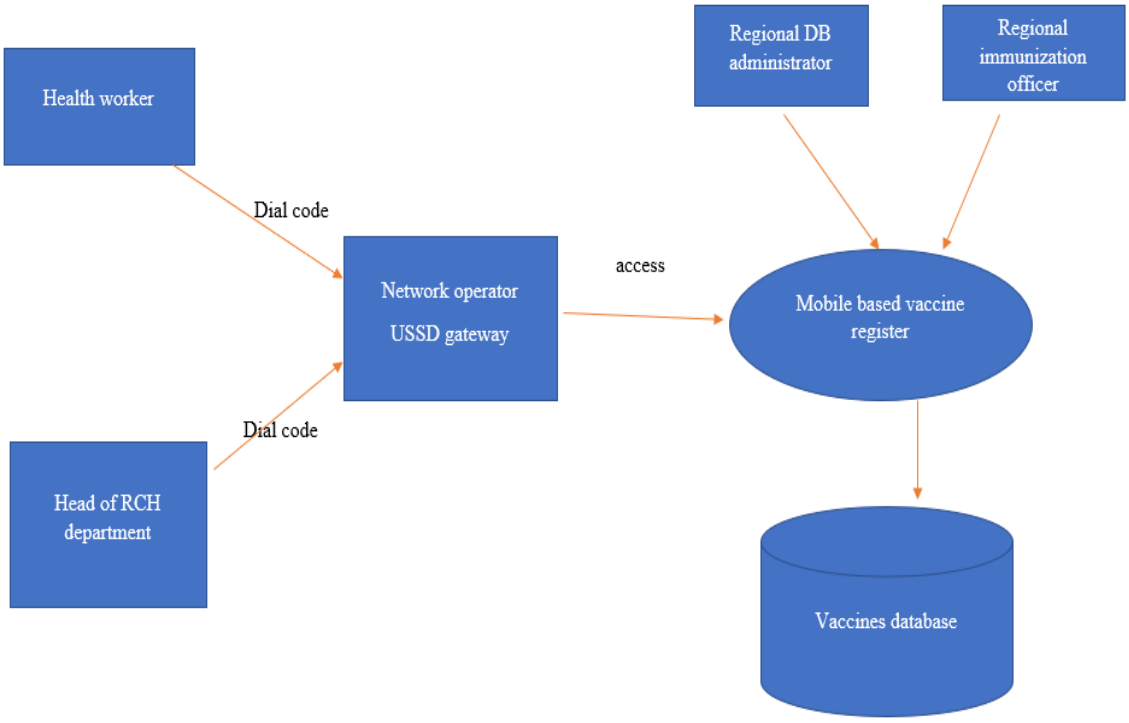

Fig. 2. The Conceptual Framework: Source: Authors.

IV. Methodology

A. Sampling

The study was conducted at 17 health facilities in Mpwapwa district Dodoma and 8 hospitals in Arusha town. A sample of 75 respondents was selected based on the sampling procedure given in sub-section B. The sample included 25 health officers (one per health facility) from the RCH department for the selected health facilities in Dodoma and Arusha region and 50 women (pregnant women and mothers) from various areas in Tanzania. The selection of the health facilities was based on accessibility to data, time to conduct research, and budget.

B. Sampling Procedure

Random sampling techniques were used to select the subset of health facilities while incorporating the time factor [28]. Snowballing sampling methods were used to select pregnant women and mothers because their total population is not easily accessible [29]. According to Parker et al. [30], snowballing is also a networking technique whereby one participant can help to identify another participant.

C. Data Collection

Based on the nature of the study, in-depth interviews and questionnaires were used as data collection tools. Individual in-depth interviews are used in most healthcare research because they provide a wide room to answer research questions [31]. Well-prepared questionnaires were also used to collect primary data from the health workers and pregnant women. The health workers were asked about the platform they used for collecting immunization data as well as stock management. However, the mothers were asked about their vaccination awareness and availability of vaccination services in the maternal clinic.

D. Data Analysis

The study used the R tool for the statistical computation of the collected data to get them cleaned, analyzed, and presented as shown in Tables III, IV, V, VI, and VII.

V. System Requirements

A. Functional and Non-Functional Requirments

The functional and non-functional system requirements are shown in Tables I and II, respectively.

TABLE I. FUNCTIONAL REQUIREMENTS

Requirements	Description
System should authenticate users	The system will allow only authorized users to log-in with their credential details such as password and facility number. Password categorize them into their roles whereby the health worker's password will be different from the head of department. After login they will interact with the system to view and submit vaccines details, they will not be able to edit any detail
System should record immunization details and submit to the regional immunization office	When the client attends the clinic, the health worker will issue the vaccines to him/her and after that should record it to the system
System should allow the health worker to view the card history	Every client will have a card number which he/she will get after registering in the clinic. Using the card number, the system should retrieve all vaccines she/he receive before. So that the health worker will be able to know the next required vaccine to issue to the patient
display the available stock	when the health worker issue the vaccines to the patient, the system should be able to deduct the number of vaccines in facility stock and when they require to view the available stock, they have to get exactly the remaining amount
Do ordering of vaccines	The system should allow only the head of RCH department to do ordering of vaccines based on his/her needs. This role will be available only to the head of department after log-ins, because he/she has the approval of ordering vaccines
To check nearby facility which has the available stock of vaccine	The system should be able to display the nearby facility which has the available stock so that can direct the patient to go and get the vaccines. Instead of asking them to come next time. This will help to reduce the number of partially-immunized patients

TABLE II. NON-FUNCTIONAL REQUIREMENTS

Requirements	Description
Availability	The system will be available both online and offline depending on the resources
Maintainability	The system shall be able to integrate with other external platforms such as VIMS, TiMR, EIR-eLMIS To support immunization program
Security	The system will ensure the authentication of users with their password as well as facility number also will ensure authorization, confidentiality, and integrity
Performance	The data submission with responses will be instant because the USSD working with session ID

B. Hardware and Software Requirements to Run System

There are three users of the system, namely, health workers, heads of RCH departments, and regional immunization officers. While the health workers and the heads of departments require any kind of mobile phone, the regional immunization officer requires a computer with the following minimum specification; operating system windows 8, RAM 4 GB, Processor intel icore 5 @ 2.20GHz, Hard disk 500 GB, and internet access.

VI. RESULTS

A. Data Collected for Requirements Gathering

The data were analyzed using the R tool. As shown in Table III, more health facilities have poor internet access and there is a lot of manual work in maternal clinics, such as the recording of data in registers (Table IV) and counting of remaining vaccines to get the stock detail (Table V).

Due to limited-resource settings in health facilities, most immunization data is recorded in paper-based registers.

TABLE III. INTERNET ACCESS IN HEALTH FACILITIES

	Region(s)		
	Arusha (n, %)	***Dodoma (n, %)***	***Chi-squared test***
If your answer is Yes there is a need for having a system that incorporates instant vaccination information, which method should be used?			$X^2 = 6.618$, df = 1, p = 0.0101
With internet	0 (0.0)	9 (100.0)	
Without internet	8 (50.0)	8 (50.0)	

TABLE IV. DATA RECORDING

	Region(s)		
	Arusha (n, %)	***Dodoma (n, %)***	***Chi-squared test***
After issuing vaccines to patients, what is done next for the recording information			$X^2 = 16.69$, df = 2, p = 0.00024
information is entered into the system instantly	7 (87.5)	1 (12.5)	
the information is copied to the paper and later entered into the system	0 (0.0)	2 (100.)	
the information is only recorded on paper	1 (6.7)	14 (939.3)	

TABLE V. COUNTING STOCK

	Region(s)		
	Arusha (n, %)	***Dodoma (n, %)***	***Chi-squared test***
As a health worker, how do you know the number of remaining vaccines in stock?			$X^2 = 3.4064$, df = 1, p = 0.06494
Counting	6 (27.3)	16 (72.7)	
Information systems	3 (75.0)	1 (25.0)	

B. User Requirements

Since health workers face limited resources such as poor internet, electricity, and digital literacy, they recommended a data collection platform that can work both online and offline (Table VI) and feature phones rather than smartphones for data collection (Table VII).

TABLE VI. SUGGESTED PLATFORMS

	Region(s)		
	Arusha (n, %)	***Dodoma (n, %)***	***Chi-squared test***
If your answer is Yes there is a need for having a system that incorporates instant vaccination information, which method should be used?			$X^2 = 6.618$, df = 1, p = 0.0101
With internet	0 (0.00)	9 (100.0)	
Without internet	8 (50.0)	8 (50.0)	

TABLE VII. TYPES OF MOBILE PHONES TO BE USED

	Region(s)		
	Arusha (n, %)	***Dodoma (n, %)***	***Chi-squared test***
If your answer is Yes for the health worker to use mobile phones, what type of mobile phones should be used?			$X^2 = 9.2437$, df = 1, p = 0.0024
Feature phones	8 (578.1)	6 (42.9)	
Smart phones	0 (0.0)	11 (100.0)	

C. Developed System

1) User interface: The system will give the user interface for health workers to access it by dialing a USSD code, but this will only be used by the RCH unit for the submission of immunization data. The health worker will be given a unique code for accessing the immunization registry (Fig. 3) and will log in using their facility number and password for the system to record the immunization details to a particular facility.

The health worker has to select the kind of service to be offered to a patient (Fig. 4A), for example, if the health worker is to issue a vaccine to a mother, she/he will select option 1 so the vaccines menu to be displayed (Fig. 4B). Similarly, if option 2 is selected, the period of children's vaccines will be displayed as shown in Fig. 4C. After those services, the data has to be submitted to the regional immunization office as shown in Fig. 4D.

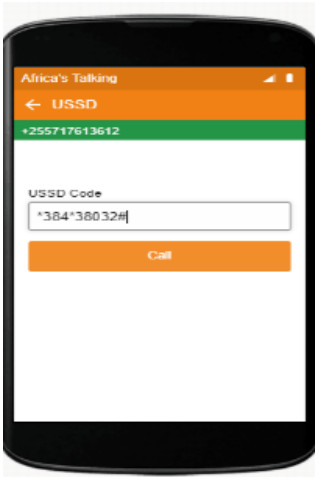

Fig. 3. Dialing USSD Code to Receive the Vaccine Registry.

Fig. 4. A Representation of the user Interface that will be used to Submit Immunization Data. (a): List of Services Available in the Registry, (b): List of Vaccines Issued to Mothers, (c): Periods of Vaccines to Children, (d): Data Submission.

2) Backend interface: The system dashboard will be used by the regional immunization officers to view real-time immunization data submitted by various health facilities. The data will be used to measure performance as well as vaccines utilization as shown in Fig. 5 to generate reports.

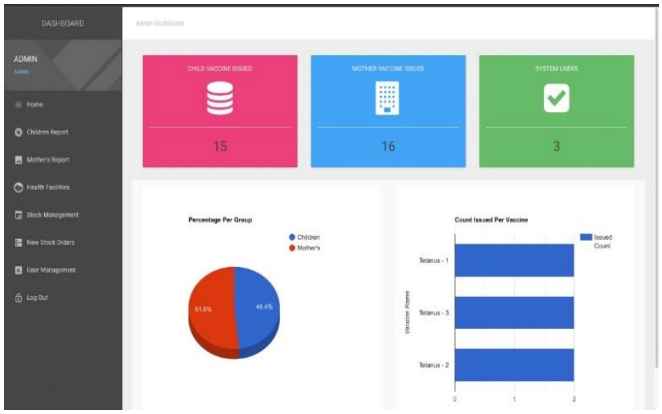

Fig. 5. System Dashboard.

VII. Discussion

The EIR-eLMIS digital supply chain is used for stock notifications, the supply chain of vaccines into various regions [17]. Some researchers have tested various models to check the impact of EIR-eLMIS in Tanzania, and the findings show that the overall stock-out rate may be reduced from 7.1 to 2.1% monthly through the system compared to the excel-based system of recording health data [17]. Therefore, the use of an electronic immunization registry in the vaccine supply chain plays a major role in the availability of vaccines. However, the adoption of eLMIS in health facilities still faces some barriers such as poor internet connection, lack of electrical power, and digital literacy [17].

After system development and validation, the proposed system showed huge potential of having a platform that is suitable for the exchange of health information for both good and limited internet connectivity [32] by using a non-internet-based system to improve the routine reporting of health data [22]. However, Garner et al. [33] advance the need for affordable mobile phones for the achievements of mHealth in resource-limited areas since the use of smartphones remains limited. The USSD technology ejects the use of SMS in quick information exchanging service because USSD is almost seven times faster than SMS and cost-effective [34]. There is a need for real-time tracking of health data which is why we opted for the USSD [35].

VIII. Conclusion

In this study, a system was developed to enhance Tanzania's Ministry of Health and other immunization partners to receive real and accurate data instantly from health facilities from both rural and urban areas, showing the utilization of vaccines in maternal health so that the relevant authority can allocate vaccines based on demand. The use of the USSD platform will enable the remote health facilities which having poor internet access and electricity to submit immunization data instantly to the responsible authority and reduce the use of registers. The developed system may be used by the decision-makers of immunization programs.

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