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Mobile Health Application to Strengthen Postnatal Care: A Case of Tanzania

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*Mobile Health (m-Health),
Postnatal Care (PNC),
Mobile Framework,
Health Intervention,
Tanzania*

Postnatal care (PNC) refers to the care given to the mother and the newborn from the time of delivery until six weeks of age. Despite attempts, postnatal care (PNC) delivery still falls short of meeting mothers' and newborns' needs. With approximately 90% of mobile phone users coming from underdeveloped nations, there is more room for improved maternal and neonatal health interventions. With the aid of mobile technologies, this study attempts to boost PNC adoption. Studies showed that the case study area, Tanzania, had little evidence of PNC intervention frameworks and mobile applications. First, it was determined which factors affected how well health systems handled postpartum care (PNC). Data were gathered from health facilities at every level in Mbeya, Tanzania. Following the examination of descriptive statistics, postpartum women had lower levels of satisfaction with the advice given to them by healthcare professionals regarding clinical attendance (mean = 2.81). After giving birth, postpartum mothers who remained in the medical centre longer had an 85% lower likelihood of being happy with the health system. Higher educated postpartum women had less favourable sentiments about PNC delivery. The findings pointed to the necessity of raising PNC awareness in order to enhance both health worker performance and the well-being of a mother and her newborn. These findings were used to create a framework that also included PNC performance indicators from the WHO and services that might help the mother and the health worker. Using JavaScript's React native technology and the SQLite database engine, the Afya Mama mobile application was created. This study is of considerable importance to communities in Tanzania as a whole as it improves the uptake of PNC.

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INTRODUCTION

Despite reducing maternal mortality to at least 43% globally, standard postnatal care (PNC) has remained a major challenge in the last couple of decades (Konje et al., 2021). Among several factors associated with the low uptake of PNC services are illiteracy among postnatal women, less compliance to clinical attendance, insufficient clinical staff, and consciousness of the importance of PNC among women (Olajubu et al., 2020).

Mobile technology is among the electronic technologies used to enhance health services delivery and other health affairs (Susanto, 2017). It is becoming increasingly evident that mobile phone solutions that support health provisions such as text messaging (SMS), voice calling, video messaging, and internet connectivity can upgrade medication compliance, appointment adherence, and keeping track of patients (Free et al., 2013). In the provision of PNC, mobile health (m-Health) intervention proves to live a remarkable mechanism in low and middle-income countries (LMIC) (Mbuthia et al., 2021). The use of phone-based applications with characteristics of decision support, clinical visit reminders, and educational text messaging crucially increases PNC delivery and service utilisation nevertheless age group, accommodation (rural or urban), and consistency (Shiferaw et al., 2016).

According to estimates, Tanzania had 50.15 million mobile connections as of January 2021, or 82.7% of

the country's 60.61 million people (Kemp, 2021; Malakata, 2021). 15.15 million people use the internet overall, which is 25.0% of the population (Kemp, 2021). This highlights how important it is to employ mobile technology to enhance lives, particularly in the health sector. According to the UNICEF/KOICA experiment, a lack of awareness was one of the factors contributing to high maternal and neonatal ratios (Report, 2020). The widespread usage of mobile devices can play a crucial role in the dissemination of fundamental knowledge about pregnant women and newborns.

Mobile Afya, an application for family planning and HIV prevention, and numerous other mobile health applications are available in Tanzania. These apps have a good effect on their users (Mauka et al., 2021). This demonstrates the efforts made by experts and the Tanzanian government to use mobile technology.

Notwithstanding inclusive mobile health systems and the government's commitment to PNC global recommendations in Tanzania, the delivery of PNC seem not to comply with the needs of mothers and neonates (Macdonald et al., 2019). Tanzania was listed among the twenty sub-Saharan countries leading to maternal mortality ranking from 500 to 900 per 10,000 live births (Konje et al., 2021). A significant gap has been found between current health concerns and models used for building m-Health solutions, which, once solved will lead to the promotion of PNC delivery (Muhambe et al., 2017).

The causes of high rates of maternal mortality in Tanzania were unpleasant health care quality, poor maternal and neonate care awareness, less support from surrounding communities, detained decision-making, and poor infrastructure (Report, 2020).

This paper analyses factors that influence health systems' performance in delivering postnatal services within Mbeya, urban Tanzania. A framework to strengthen PNC services is designed and a mobile application to support the designed framework is developed. The implication of factors obtained showed that the current PNC concerns can be interlinked with the models that build sustainable m-Health solutions.

LITERATURE REVIEW

Mbuthia et al. (2021) developed and validated the m-Health framework to uptake postnatal care in rural settings based on communication. A theory-based framework was developed to strengthen PNC. A multi-methods research design was used, which incorporated a change logic model theory (Davies, 2018). The results showed that in order to reinforce postnatal services in rural areas, directional mobile messaging was mainly considered (Mbuthia et al., 2021). Results showed that postnatal mothers have a beneficial experience with healthcare providers (Smith et al., 2016). The challenge was that the designed m-Health framework captured only a few WHO PNC recommended services which are standardised regulations for PNC care delivery. The study only used a one-way mobile messaging platform with no interactive voice response (IVR).

Olajubu and the others evaluated the effectiveness of the m-Health intervention, which focused on the provision of messages based on education and reminders in attending postnatal clinical visits (Olajubu et al., 2020). The type of research design was quasi-experimental, where control and intervention arms were included with equal distribution of 190 pregnant women in each arm. After the analysis, 30.9% of mothers in the

intervention arm had followed the four visits, while the control arm consisted of only 3.7% of mothers (Alkema et al., 2016). However, this study did not explore the effective exploitation of m-Health utilisation to enhance the performance of health workers in delivering PNC (Olajubu et al., 2020).

Feroz et al. (2017) reviewed m-Health solutions to assess the effectiveness of postnatal health outcomes through the categorisation of m-Health applications. The peer reviews of m-Health interventions show that the applications are effectively improving postnatal care services. However, there is little evidence on how they work to support client education, behaviour change communication, SMS, and voice reminders (da Costa et al., 2010). The study did not analyse what range was education covered to mothers in support of PNC, also which guide has been used to refer the PNC services to mothers; again, no clear mobile platform has been mentioned regarding the technology fit for low- and medium-income countries' usage (Feroz et al., 2017).

Among several m- Health applications that exist in Tanzania, Mobile Afya, m- Health application for HIV prevention, and m-Health application for family planning are some with a positive impact on its users (Lucile, 2013; Mauka et al., 2021). This proves the initiatives by professionals and the Tanzanian government to utilise mobile technology to cope with WHO guidelines of 1 doctor per 1000 people which is contrary to Tanzania, where the average is 1 doctor per 20,000 people (Timimi et al., 2012).

METHODOLOGY

Study Design

The study included mothers who identified as women and were over the age of 18. These mothers are those who gave birth to a baby between the ages of three and six weeks and were released following the first postpartum clinical care.

Sample Size

The study comprised 254 mothers of newborns as a sample of subjects. The estimated number of women giving birth at various levels of health facilities in Mbeya city was used to calculate the sample size. Seven hundred women give birth each month in Mbeya city, according to information from the Tanzania health management information system (Mangu et al., 2021). Since the maternal death rates can be larger annually than they are monthly, it was decided to utilise monthly data rather than yearly data to illustrate how complex the issue is. A representative sample of 254 was calculated with a 5% error margin. The formula $n = N / (1 + Ne^2)$ was used to calculate the sample size (Adam, 2020).

Sampling

To support primary data collection, stratified and random sampling techniques were used to achieve representation from three groups of health facilities. Health facilities within Mbeya were stratified according to their level of health centres and Hospitals). The random stamping technique was used to select 2 facilities at each level. A total of 6 health facilities were selected. Care was taken to include public and private health facilities including those run by Religious-based organisations. A convenient sampling approach was implemented to include women in the study.

Study Settings

This study was conducted in Mbeya urban, Tanzania. Mbeya being among the five highly populated regions, experiences not only high childbirth but also a high mortality rate of neonates. Where between 2006-2015, neonatal deaths that occurred in the first six days reached 684, and 134 deaths between seven to twenty-eight days (Mangu et al., 2021). The urban area of Mbeya has been selected as a case study because it has both urban-rural settings and all levels of health systems, from primary to tertiary.

Data Collection

The questionnaire was used as the main tool for quantitating data collection from mothers of neonates. The questionnaire had the following sections; section 1 consisted of questions on respondents' personal information such as age, marital status, level of education, occupation, and gravida. Section 2 comprised questions on women's satisfaction with postnatal care.

Semi-structured in-depth interviews were used to explore qualitative data from the health systems. The qualitative component of the study collected data from hospitals and health centres. The exact number of interview guides depended on saturation assessed during ongoing data collection and analysis. This refers to the point at which no new additional information or themes were generated with consecutive data collection.

Variables

Six items from the questionnaire were used to gauge the outcome, which is performance. These inquiries are on age group, mode of delivery, degree of education, number of kids, days spent in hospitals, and levels of medical facilities. Four of these six questions—those with high-performance outcomes—were thought to best highlight the output. Whereby the four accurate responses out of the six questions demonstrate the health systems' strong performance in delivering PNC and services. These details included the number of children, delivery method, and age group that spent time in hospitals.

Data Analysis

Descriptive statistics were used to analyse data, where the mean and standard deviation were used for numeric data and frequencies and percentages for categorical data. The relationship between categorical variables was tested using the Chi-square test. Statistical significance was checked using a value less than 0.05. Questionnaire's

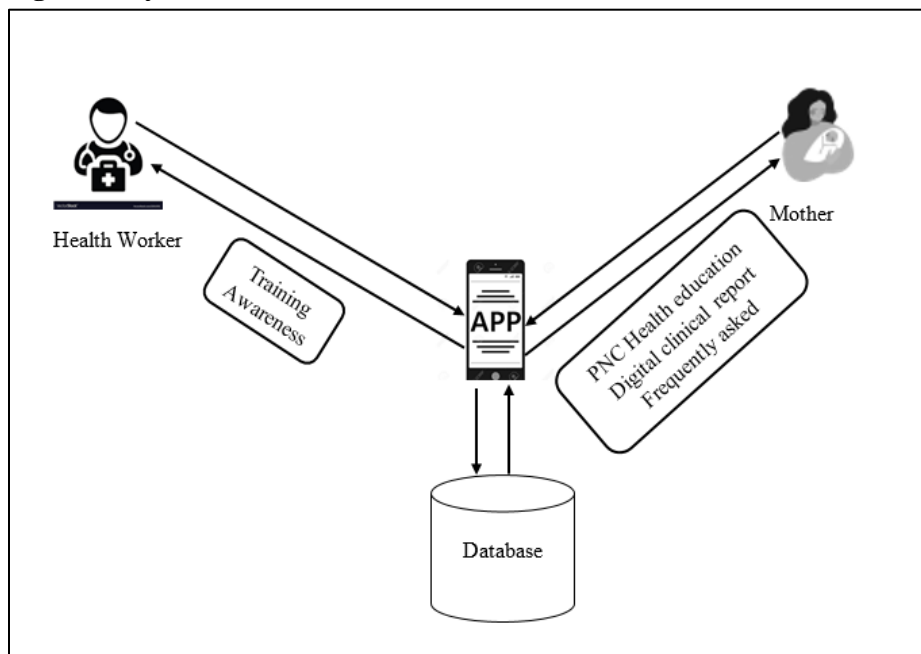
internal reliability was tested using Cronbach’s Alpha.

Mobile Application System Development Overview

The system is created utilising the react native platform, which combines JavaScript with the SQLite database engine. One codebase can target both the Android and iPhone operating systems thanks to react native technology (iOS). Because it is a file-based engine and does not need a server, SQLite is employed as a database engine in this development. Relational databases can be communicated using SQL, which is a simple language to learn. The interface was created for Android-based systems. Where the database is located within the created application, these two components of the system are interdependent.

System Architecture

Figure 1: System Architecture



Source: Authors, 2022

Mobile Application Design

Use case diagrams and the Unified Modelling Language (UML) was used in the design of the

The application system’s two components are situated on the same platform. A user’s mobile phone’s Android operating system is built to execute mobile applications. The user, who is a postnatal mother, can use this program to input the clinical cards information, such as their name and the date of delivery, learn about PNC education, and monitor their child’s progress using the reports that are generated. An HW can access training materials and awareness reports that help them get better at giving PNC.

As seen in *Figure 1*, a mobile application requests information from a database that has been deployed within the system itself. This section enables users and developers to view the generated reports and stored data. Because they periodically help update the system’s contents in accordance with recommendations from the MoH, developers are not listed as the system’s primary actors.

mobile application. An essential module in UML that demonstrates the connections between items grouped into classes is the class diagram.

Table 1: First actor’s role

Actor	Description
Postnatal Mother	Interacts with the application to obtain main PNC services using a mobile app. Add clinical card information, view education information, view frequently asked questions and reports.

Source: Authors, 2022

Table 2: Second actor’s role

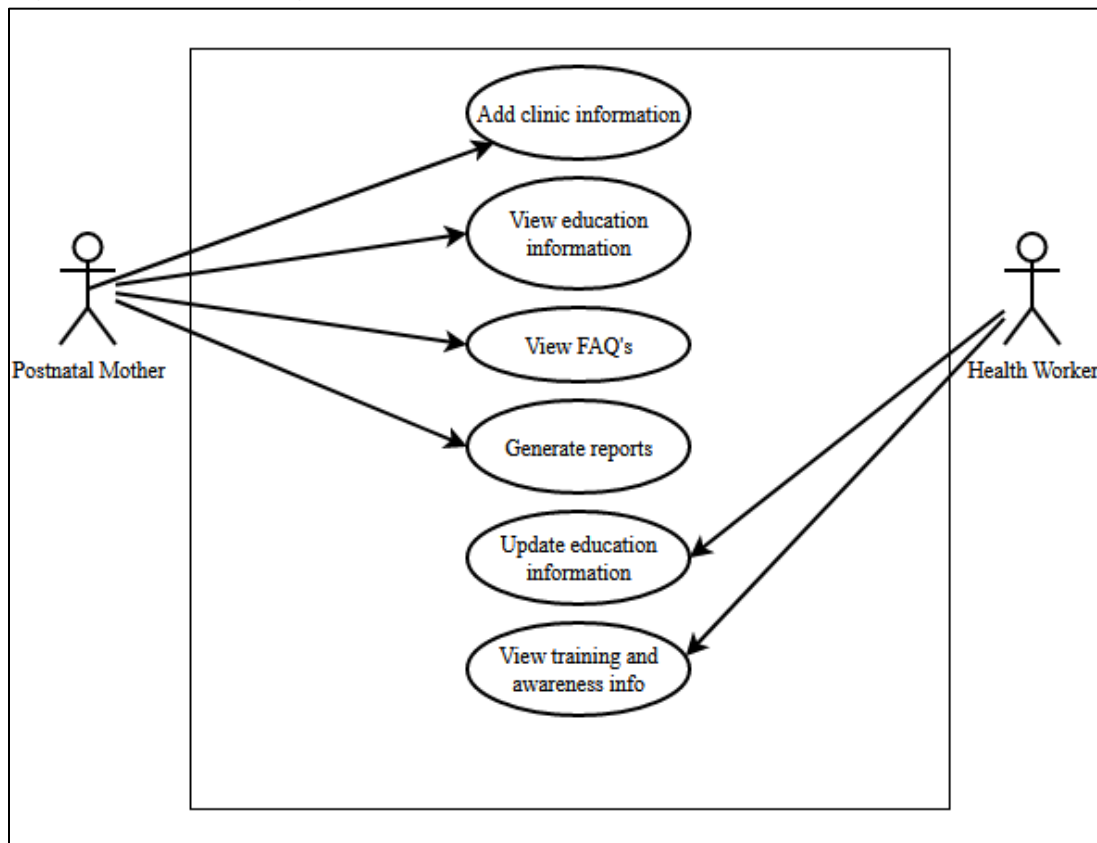
Actor	Description
Health Worker	Assist mothers in entering vital required information into the system and learn PNC services from the application.

Source: Authors, 2022

The below UML presented in *Figure 2* describes the practices of all objects in the implementation of the mobile application to support postnatal women with reaching for health care and educating information.

It explores the potential communication among the parties and validates processes workflows from a woman with a newborn and a health worker in an interactive way.

Figure 2: Use Case Diagram



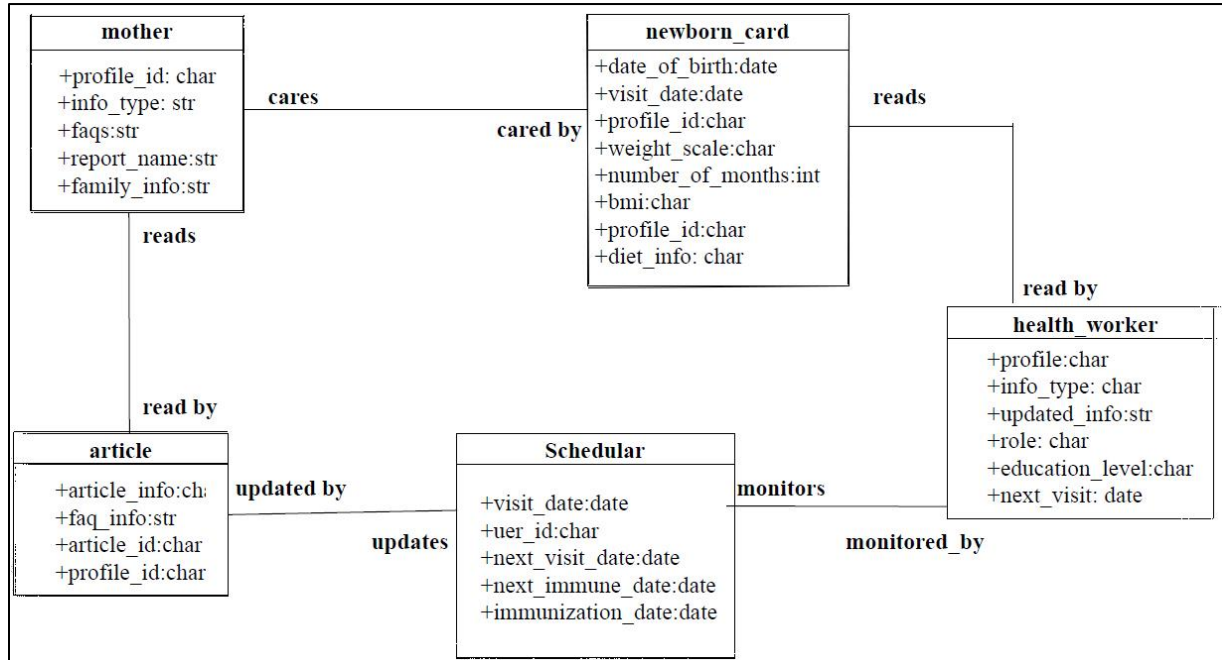
Source: Authors, 2022

Class Diagram

A class diagram is another UML diagram that is used in the designing phase. It is a technique that operates centrally closer to all object-oriented procedure that represents object categories and different types of relationships that exists between themselves within a system. *Figure 3* is the class

diagram which describes the structure of a system by showing the system’s classes, their attributes, operations, and the relationships among objects. For example, a class Mother has attributes which are profile-id, info-type, FAQs, report-name, and family-info. This class is related to other classes, which are newborn card and article classes.

Figure 3: UML Class Diagram



Source: Authors, 2022

RESULTS AND DISCUSSION

Results from the multivariable regression show that having more than one child and having an Elective caesarean were significantly associated with 91% and twice more odds of being satisfied with the

performance of health systems in delivering postnatal services, respectively. In contrast, the increase in the days spent in the hospital and being older was significantly associated with 85% and 64% lower odds of being satisfied with the performance during delivering services (*Table 3*).

Table 3: Results of the first outcome

Performance	Odds Ratio	p> z	95% Conf. Interval	
Education Level				
Ref. Secondary				
No Schooling	1.790	0.412	0.446	7.191
Primary	1.536	0.227	0.765	3.080
Post-Secondary	0.576	0.239	0.231	1.441
Number of children	1.907	0.000	1.326	2.742

Performance	Odds Ratio	p> z	95% Conf. Interval	
Days spent in the hospital				
Ref. 1 Day				
2 days	0.275	0.001	0.131	0.579
More than 3 days	0.145	0.001	0.046	0.458
Level of Health Facility				
Ref. Hospital				
Health Centre	1.025	0.937	0.562	1.869
Mode of Delivery				
Ref. Normal Virginal				
Elective Caesarean	2.727	0.013	1.231	6.043
Emergency Caesarean	1.147	0.824	0.342	3.849
Age Group				
Ref.< 25				
>25	0.365	0.014	0.164	0.815

Source: Field Data

Table 4 shows the factors that were associated with the attitude of the mothers toward the performance of health systems in delivering postnatal services. The results show that more days spent in the hospital after delivery, having normal virginal

delivery and having a high level of education were significantly associated with lower attitudes towards postnatal services delivery, while divorced women had twice high a perception towards the quality of care when compared to married women.

Table 4: Results of the second outcome

Attitude	Odds Ratio	p> z	95 % Conf. Interval	
Age Group				
Ref. 25<				
>25	0.466	0.058	0.212	1.026
Education Level				
Ref. Secondary				
No Schooling	0.929	0.914	0.248	3.479
Primary	0.963	0.915	0.478	1.937
Post- Secondary	0.261	0.007	0.096	0.698
Marital Status				
Ref. Married				
Not Married	0.723	0.373	0.354	1.475
Divorced/Separated	2.714	0.034	1.079	6.824
Widow	1.087	0.925	0.188	6.274
Number of children	1.348	0.107	0.937	1.938
Days spent in the hospital				
Ref. 1 Day				
2 days	0.385	0.013	0.182	0.815
More than 3 days	0.146	0.002	0.043	0.489
Level of Health Facility				

Attitude	Odds Ratio	p> z	95 % Conf. Interval	
Ref. health Centre Hospital	1.538	0.154	0.851	2.778
Mode of Delivery Ref. Elective Caesarean				
Emergency Caesarean	1.238	0.704	0.411	3.725
Normal Virginal	0.315	0.008	0.134	0.741

Source: Field Data

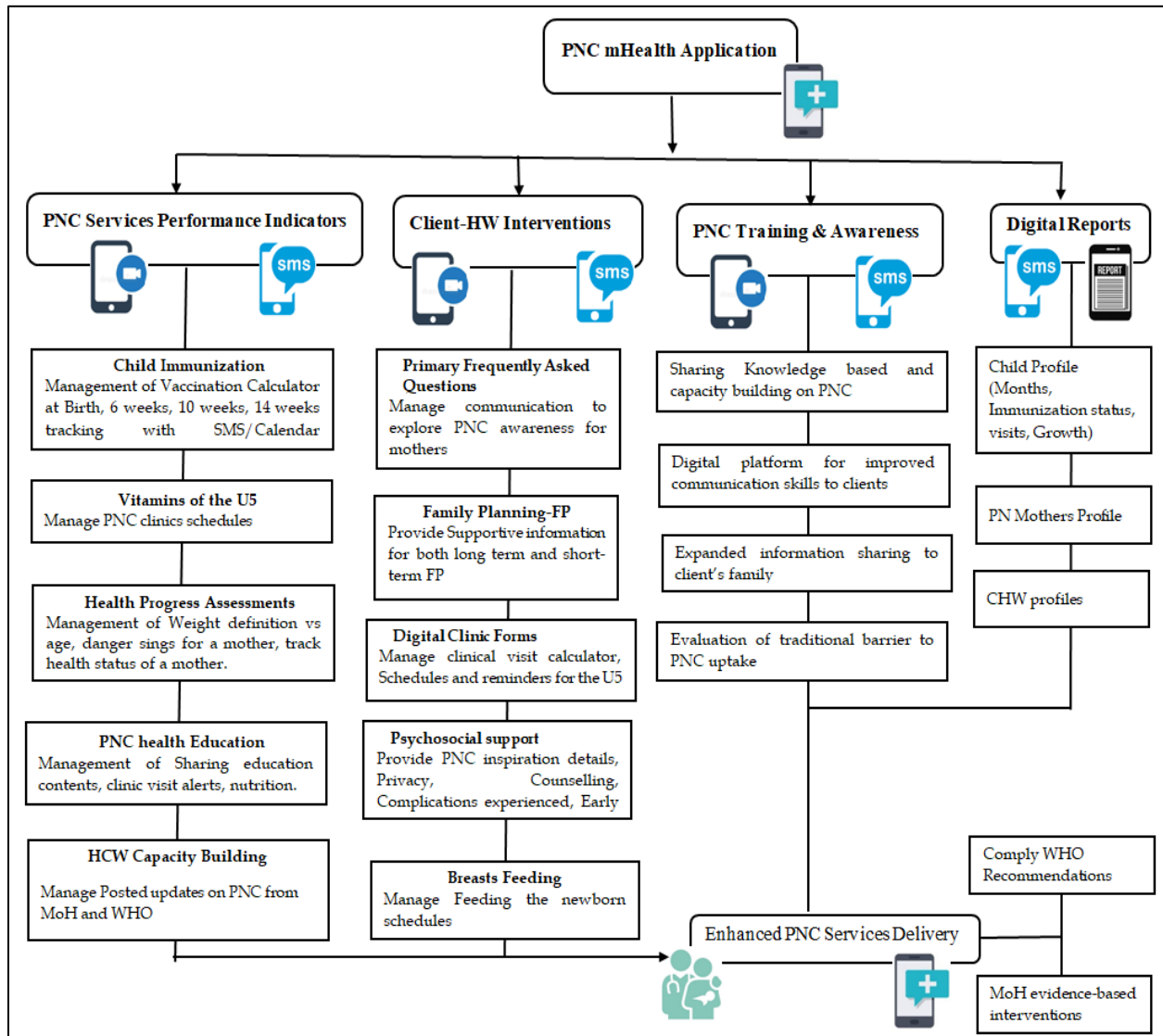
Proposed m-Health Framework

The study outcomes indicate some challenges facing PNC mothers during postpartum clinics as they try to achieve best practices to attain quality PNC services. Thus, mobile health interventional platforms based on performance indicators will strengthen remote support to mothers and their newborns on delivered PNC services. With the task technology fit (TTF) model used, the mobile framework prototypes basic clinical information and information into a digital platform to effectively support the mother using mobile phones and to understand clinical descriptions of health progress in local ways. The developed m-Health architecture will uptake quality PNC in terms of family planning, health assessments and awareness, child clinical card monitoring and visits calculator, immunisation control and scheduling, health workers learning platforms, child clinical profiles, nutrition, and feeding information as recommended by WHO for quality postnatal services and long-term continuation.

In addition, the study findings will help psychical social support to improve awareness and provide more information to mothers, including context-specific information (social and cultural aspects) in accordance with local and cultural practices hence developing counsel and support strategies for women in private modes. The study findings will advance health information understanding for the mother of the newborn and serve as crucial references using mobile technology to advance care at hand and reproductive health programs.

Moreover, the findings will build learning platforms for health workers (HWs) providing services to postnatal mothers with all updated information about mothers and children in a critical period and circulate essential information as evidence-based platforms to improve services awareness and hence improve the level of services delivered to mothers and newborns at clinics during PNC period.

Figure 4: Proposed m-Health framework



Source: Authors, 2022

Figure 4 is about the proposed m-Health intervention framework supporting a mother and child receiving PNC services. PNC services performance indicators enable a mother to access important areas such as child immunisation, health progress assessment and PNC health education and to build Health workers' capacity. Mother- HW intervention is made possible through the primary frequently asked questions menu. PNC training and awareness support both mother and HW to be aware of important issues about PNC. The digital reports

menu contains the generated reports on the mother, child, and HW.

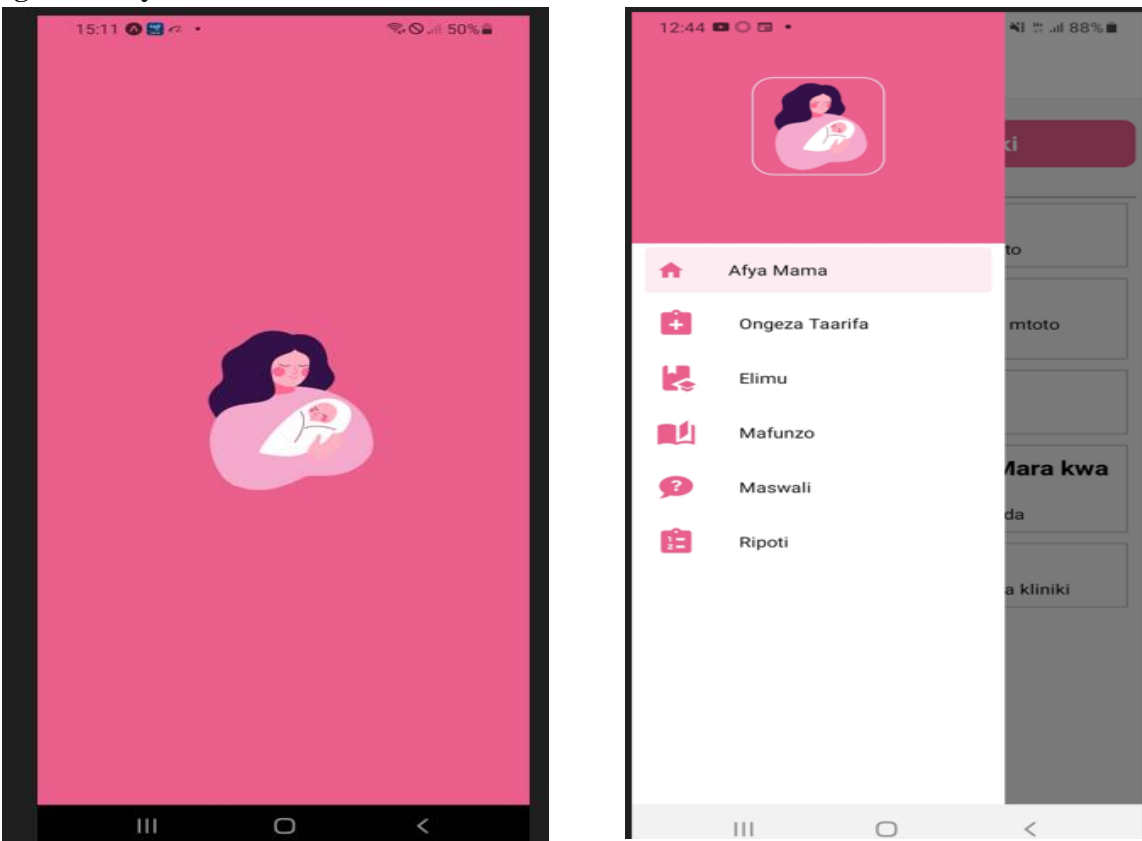
Developed Mobile Application

The developed m-Health application is named by the title "Afya Mama" and the whole application is in the Swahili language, which is user-friendly to the intended user, a postnatal woman from Tanzania communities. Afya Mama, a mobile application system, is an informational system where intervention between a health worker and a postnatal mother occurs, although it is not a one-to-

one intervention. An HW can occasionally update the content within the system with the help of a developer and a mother will continue to learn the content via the mobile phone. The category of FAQs allows a mother to deal with the worries that most postnatal women encounter since they contain answers from the HW for each question. Also, mothers receive notifications regarding clinical attendance as a reminder to follow the schedules.

In this App there is a registration category; a mother will be able to access details within the App straight forward. When a mother starts using this application, the following interfaces in *Figure 5* will appear where she will opt for whatever she wants to access, whether to add clinical card information “Ongeza taarifa”, to view PNC education “Elimu”, to view frequently asked questions “Maswali” or to view the generated reports “Ripoti”. A HW can view the training and awareness “Mafunzo” to learn more about PNC services.

Figure 5: Afya mama interfaces



Source: Authors, 2022

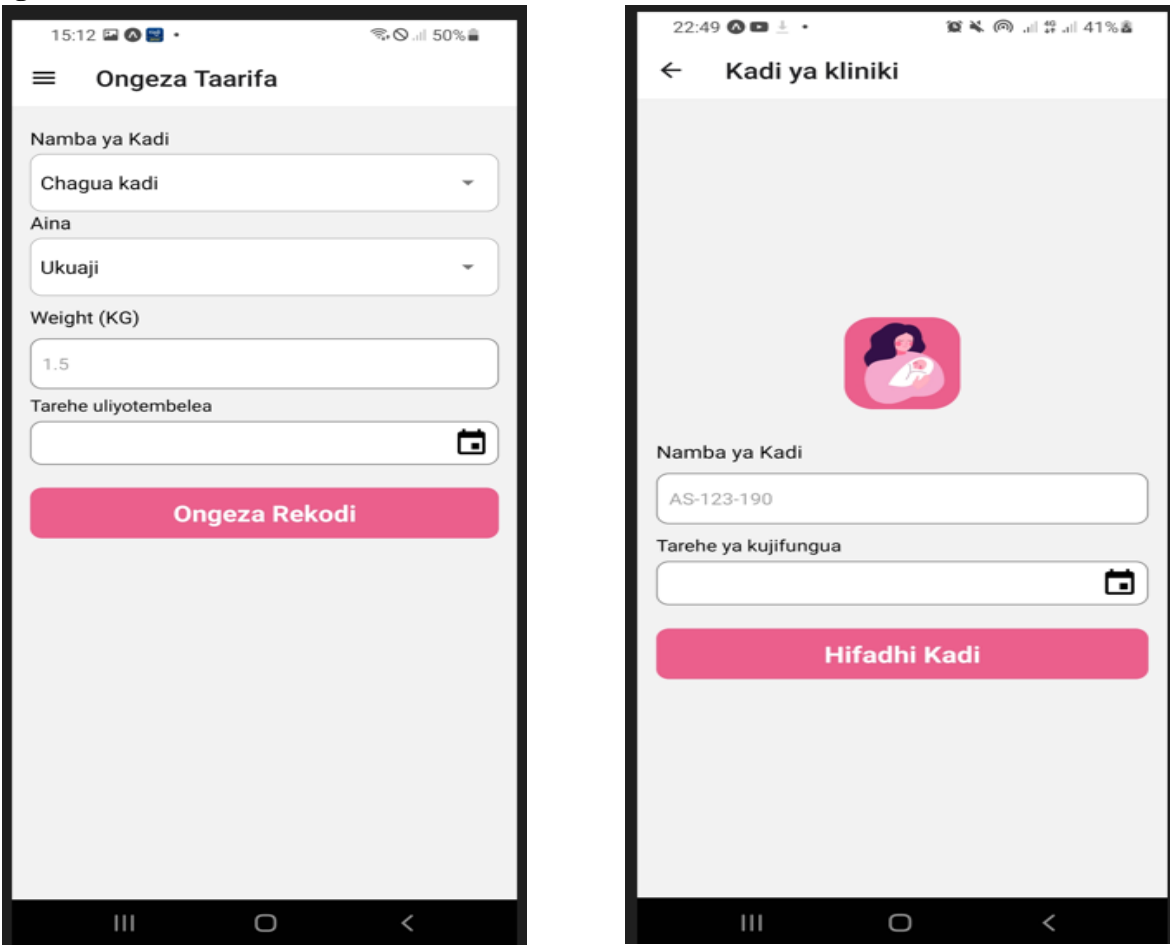
System Operations

The system has functions done by the postnatal mother and functions done by the HW. In most cases, functions done by the postnatal woman could be done by the HW. A HW could assist a mother in

filling in clinic card information if the mother will not be able to do so.

In order to generate reports, there is information as inputs from the postnatal mother, which are ID “Namba ya kadi” and delivery date “Tarehe ya kujifungua”, as seen in *Figure 6*.

Figure 6: Clinic card information

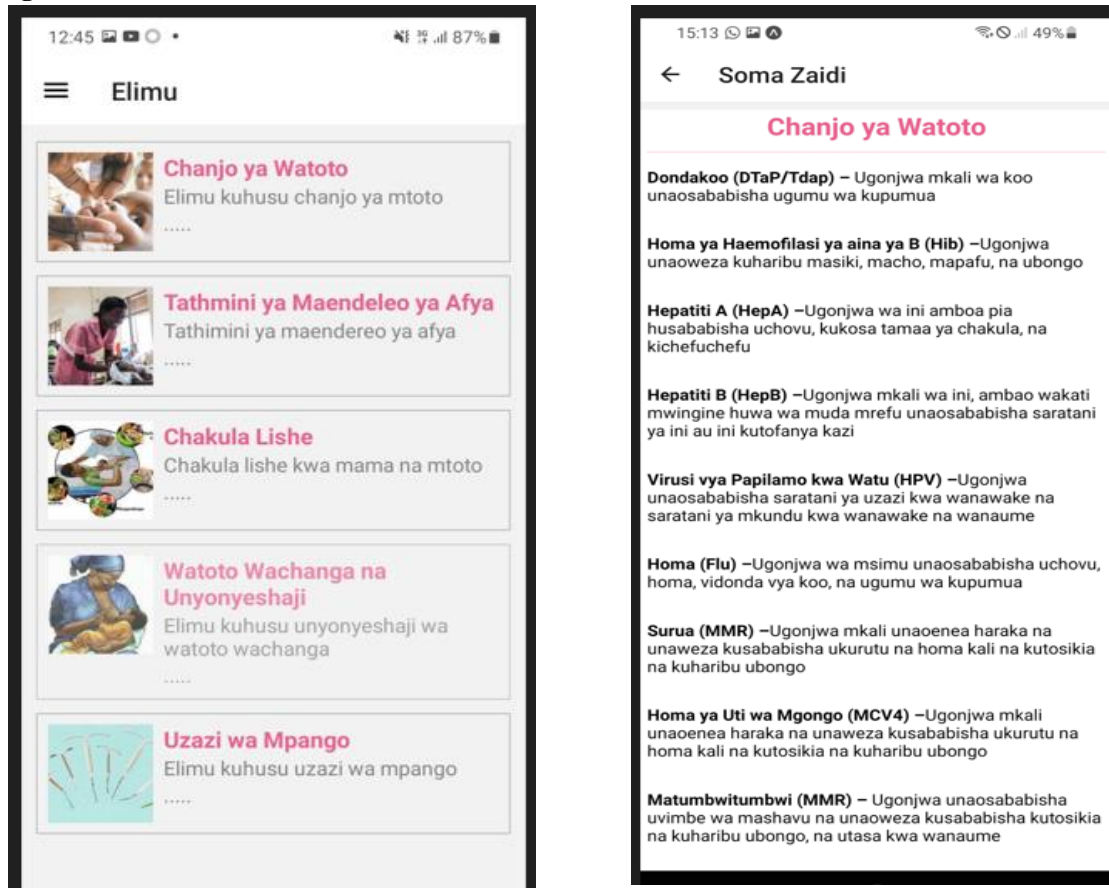


Source: Authors, 2022

On the “Elimu” tab, as shown in *Figure 7*, a mother will be able to view PNC education, such as child immunisation, Health progress, nutritional diet, and

family planning. Postnatal will also be able to view frequently asked questions as shown in the interfaces below;

Figure 7: View education screens

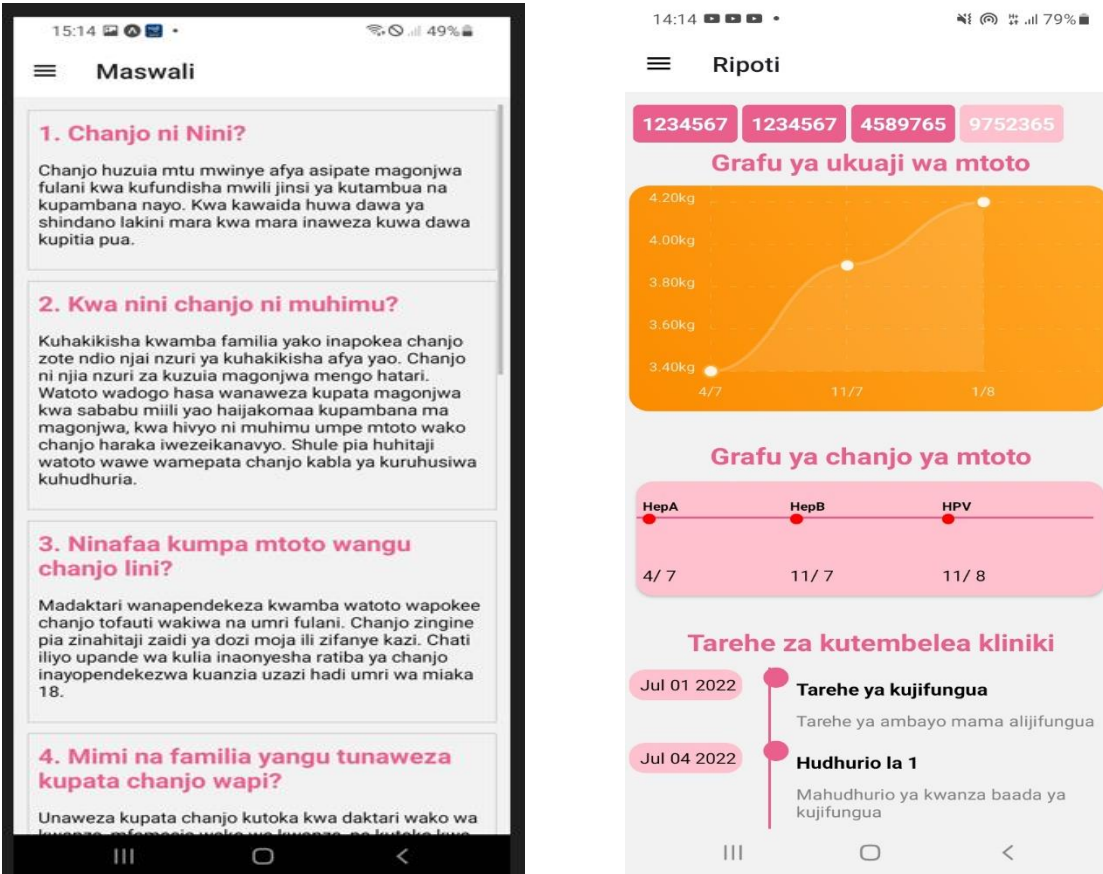


Source: Authors, 2022

Figure 7 shows two interfaces for the education category “Elimu”. Once a mother selects any options among those listed on the left screen will get informational details on a specific category. An

example has been demonstrated when the “Chanjo ya Watoto” link on the left interface was clicked. It gave detailed information, as seen in the right interface with the “Soma Zaidi” heading.

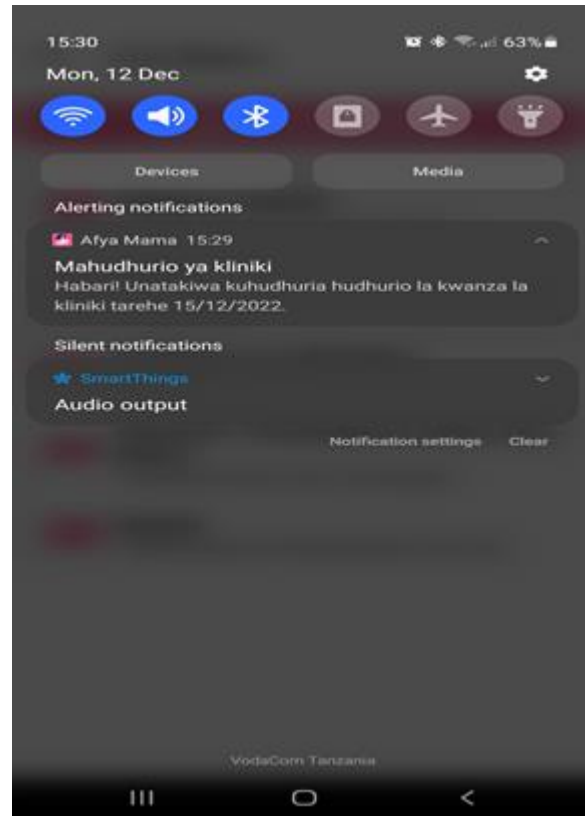
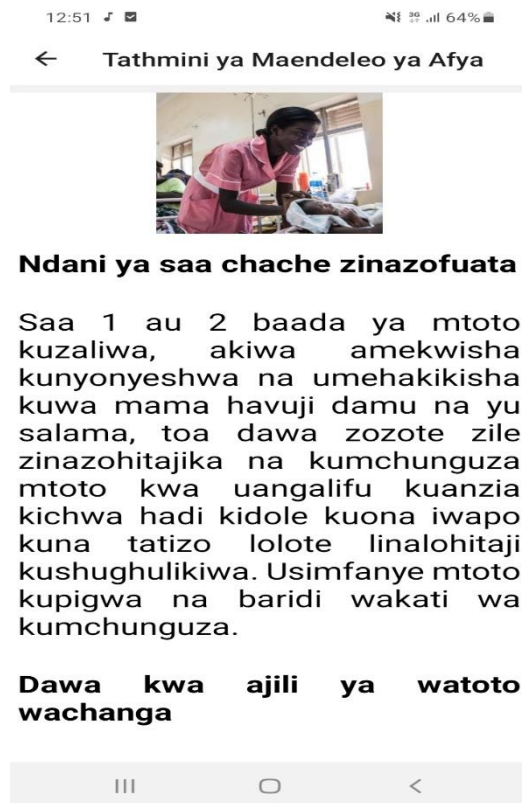
Figure 8: Frequently asked questions and report screen



Source: Authors. 2022

Figure 8 shows the FAQs interface, where a list of the most asked questions by postnatal mothers has been stated with their answers. These questions include all sections of PNC, is child immunisation, nutritional diet, health assessment, family planning

etc. The report screen indicates the generated reports on the child’s growth, child immunisation and dates on clinical visits that will help a mother to keep track of these issues.

Figure 9: Health assessment screen and notification screen

Source: Authors, 2022

A health evaluation test for the mother and the newborn is shown in *Figure 9*. Both the mother and the healthcare provider can use this screen. The mother will learn about important warning indicators that could be dangerous if they happen to her and the newborn and how she can offer early assistance to overcome those difficulties. The opportunity to learn more about how to care for the mother and newborn when such incidents happen is given to the health worker (HW).

As shown in *Figure 9*, Afya Mama additionally provides postpartum mothers with alerts about clinical attendance. Mothers will receive these fundamental reminders for clinical attendance via their mobile phones.

System Testing and Evaluation

Performance testing as a type of non-functional testing was done. Performance testing provides an

application's perception, such as speed, stability, and scalability. The test was done on a Samsung Android version 11. React native expo Performance Monitor, which is found within the development environment, was used to run the test.

On the "Ongeza kadi ya Kliniki" screen, information was presented on display at an average rate of 59.8 FPS (UI), 4 frames were dropped in a second so far and JS 42.7 fps. On a "Ripoti" screen, 59.8 fps (UI), 7 frames dropped and 59.8 fps for JS. On the 'Elimu' screen, 59.8 fps for UI, 106 frames were dropped and 55.6 fps for JS.

For a smooth performance, an App should run at 60 fps most of the time. The lesser the number of frames dropped, the faster or smooth the App is. A range of 50-60 fps for JS indicates smooth/faster performance. Table 5 below shows the comparison between the results obtained versus the required results of a smooth App. The performance results

from Afya Mama App indicate that the App is running fast and smoothly since the frames per second (fps) are close to the required results.

Table 5: Performance test results

Faster/Smooth App	Clinic-Card Screen	Report Screen	Education Screen
UI: 60fps	UI: 59.8 fps	UI: 59.8 fps	UI: 59.8
Less frames dropped	4 frames dropped	7 frames dropped	106 frames dropped
JS: 50-60fps	JS: 42.7 fps	JS: 59.8 fps	JS: 55.6 fps

Source: Expo Performance Monitor

Table 5 above shows the comparison between requirements for a smooth/fast App and results obtained from Afya Mama App. These results indicate the smooth/ fast running of the App since the results are close to the required results. The higher number of frames dropped (106) on the education screen is an interpretation of how busy the education screen is, in the sense of having many pages with many images.

Limitations of Afya Mama Application

Afya Mama is an offline informational application. It enables moms and healthcare professionals to learn, provide reports, and remind mothers about clinical visitation schedules via notifications. The Afya Mama app does not support one-on-one interactions between mothers and health professionals or between mothers.

CONCLUSION

A framework was created in order to improve the delivery of services and m-Health interventions for PNC. This framework was created using data on the variables that affect how well-performing health facilities operate in Tanzania's Mbeya Urban. The main goal was to deploy a mobile application framework to complement the created framework and improve the delivery of PNC services. Educational level, number of days spent in the hospital, the calibre of medical facilities, age group, and number of children were all taken into consideration when building the framework. Later, utilising react native technology, a mobile

application that supports the designed framework was created. A postnatal mother can now access important information on PNC even if she lives far from the clinic thanks to the developed application. Many of the concerns that the majority of postpartum mothers have are addressed in FAQs. The created reports will help a mother keep tabs on the newborn's development, as well as serve as a reminder for clinical attendance and immunisation status. Health workers are given training and information about PNC delivery.

The findings of this study will increase the public interest in PNC. The results of the analysis revealed that postpartum women should be considered for PNC awareness since some of them need an additional emphasis on PNC outside of hospitals. The study is extremely beneficial to health professionals because they can utilise the application's data to educate and remind themselves about better PNC services. Additionally, the application can be used by the neighbourhood strongly associated with the identified groups to promote and persuade the core users of the significance of PNC. Tanzanian community will gain the most from this study since it promotes knowledge of PNC services that help communities reduce maternal mortality.

Recommendations

Future research should allow the mobile application to include more features like instant messaging. This will make it possible for a one-on-one intervention between a mother and a HW, allowing

for direct contact and responses to their often-asked questions. In addition to that, an application should be made to serve online in order to allow mothers to share their experiences of the PNC period. The structure might be made better to enable doctors who serve as PNC professionals to attend to mothers' issues that do not need physical assistance. This will allow the expanded use of the mobile application, not only to the mothers and health workers at Mbeya urban but also to Tanzania communities as a whole. According to this study, PNC issues can be connected to models for enhancing mother-and-HW interaction when providing PNC services. With regard to infrastructure enhancement, the m-Health communication framework can be used in remote areas.

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CONFLICT OF INTEREST

The authors declare no conflict of interest regarding the publishing of this paper.

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