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Patient Perspectives on mHealth for Maternal and Pre-maternal Health Services in Resource-Constrained Settings

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Background and Purpose: With the rapid evolution of computing trends and the growing use of technology in the healthcare sector, maternal healthcare delivery and accessibility require a transformative shift. However, studies indicate that the integration of technology into maternal service delivery remains slow. This is largely due to the absence of comprehensive frameworks that support diverse access to maternal electronic services (e-services), as existing scholarly work has mainly focused on maternal information provision. While such information provision has been valuable in enabling pregnant and new mothers to access appropriate educational content from accredited healthcare workers, it is predominantly delivered through text-based SMS, reflecting limited use of multimedia and mobile capabilities. Therefore, the purpose of this study was to investigate the requirements for developing an improved and comprehensive framework for maternal e-service delivery from patients' perspectives.
Methods: This study has been conducted following the user-centred design (UCD) approach where both pregnant and new mothers were engaged in the requirement-gathering process by responding to a questionnaire tool to understand what should be considered while developing an improved framework to comprehensively support the delivery of maternal e-services in this era where technology is seen as a source of solutions to various aspects. The requirements centred on four themes: 1) demographic information of the participants, 2) awareness of maternal e-services, 3) assessment of the utilization of maternal e-services relative to maternal health challenges, and 4) security and privacy of data in technologically supported applications.
Results: As a result, this paper reveals a set of requirements identified as potential for developing a mobile health framework to improve access to maternal healthcare through the digitized delivery of maternal services, based on patient (pregnant and new mothers) perspectives.
Conclusion: This paper contributes to scholarly knowledge by identifying key requirements for developing a framework to enhance maternal healthcare access through technological solutions, particularly in settings where technology itself is a limited resource. These requirements serve as a foundation for creating interventions that have the potential to transform maternal service delivery and improve healthcare outcomes.

Keywords: Maternal E-Services, Maternal Healthcare, Health Informatics, Mobile Health.

1 Introduction

Mobile health (mHealth) regards the application of information technology that pertains to the utilization of mobile devices such as smartphones, tablets, wearables, and wireless technology to strengthen and enhance different spheres of healthcare and medicine [1–5]. The core objective of mHealth is to harness the capabilities of these devices to offer more accessible, streamlined, and tailored health services [6] The healthcare industry has embraced the potential of mHealth through numerous innovative developments that have aided various aspects of health management [7–9]. Medical innovations in the realm of mobile health are integral across various domains, spanning computer-aided disease diagnosis and automated patient care in critical settings, including Intensive Care Units, and computer-based systems for managing patient information [10,11]. These extend to patient-centric healthcare approaches, facilitating in-store transactions

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for medical products such as medications and cosmetics in pharmacies and clinics, supporting well-informed clinical decision-making, telemedicine, and more care [12, 13]. Notable examples of medical innovations include HealthTap, Augmented Infant Resuscitator (AIR), WebMD, Pocket Pharmacist, and Teladoc [14–16]. These have steadily transformed health systems around the world [17, 18].

The success of mHealth is facilitated by the growing adoption of mobile devices due to their resilient features [19]. These include seamless connectivity, low cost of ownership (affordability), support for data persistence and offline capabilities, portability of devices to enable mobility of users, and high-performing location-awareness features typically using Global Positioning Systems [20,21]. This provides cohesive support for the introduction and development of mHealth applications [22]. In Uganda, the number of smartphones recorded has experienced a consistent increase in each quarter, starting from 4.57 million in the initial quarter of 2018 and subsequently surpassing 10 million by the initial quarter of 2022 [23]. Further studies showed that at the beginning of 2023, Uganda had approximately 11.77 million individuals using the Internet, with an Internet penetration rate of 24.6% [23,24].

In the context of maternal health, it is regrettably observed that the adoption of technological innovations remains significantly delayed, particularly in resource-constrained environments, including developing nations such as Uganda [25]. This delay is worsened by the absence of interventions to improve access maternal healthcare services [26]. Consequently, maternal healthcare challenges in developing countries become even more complex, increasing the risks associated with inadequate care [27–29] .In this situation, several crucial problems become apparent as discussed below.

Pregnant women and new mothers often find themselves facing distressing and potentially dangerous situations due to limited access to critical health information. This extends to essential aspects of maternal care, such as proper prenatal care, recognition of warning signs during pregnancy and receiving guidance on postnatal care [30]. Unfortunately, this information gap can result in far-reaching consequences, including delayed or inappropriate responses to maternal health issues. When expectant mothers and new parents are unable to access the necessary knowledge and resources, they are vulnerable to potentially life-threatening complications that might otherwise be preventable or manageable with timely intervention. As such, addressing this disparity in health information access appears imperative to ensure the well-being of both mothers and their newborns, highlighting the need for better maternal health education and support systems.

The absence of mHealth platforms, which facilitate telemedicine consultations and appointment management, could pose significant barriers for pregnant women seeking timely healthcare services. These obstacles have detrimental consequences as delayed care may intensify maternal complications [31]. In the absence of technological solutions, pregnant individuals may struggle to schedule and promptly access the healthcare they need. Delayed care further compounded the challenges already faced during pregnancy, potentially compromising the health and well-being of both the mother and unborn child. To mitigate these barriers and ensure prompt provision of maternal healthcare, it is crucial to promote the adoption of mHealth platforms and telemedicine services, thereby enhancing accessibility and responsiveness in maternal care delivery [32–35].

The absence of mobile health (mHealth) frameworks is particularly concerning during emergencies across the three critical stages of maternal life pregnancy, childbirth, and the postnatal period. Emergencies such as severe bleeding, high blood pressure, prolonged labour, pregnancy and postpartum complications (especially among mothers who deliver via caesarean section) often demand immediate medical intervention. However, many mothers lack timely access to healthcare support during these life-threatening situations, leading to preventable complications and increased maternal morbidity and mortality. MHealth interventions play a vital role in enabling rapid communication with healthcare providers when urgent assistance is required. Without these technologies, there is a significant risk of hindering the timely summoning of emergency support, potentially resulting in adverse outcomes for both the mother and the unborn child [36]. In moments of crisis, every second counts and the ability to swiftly connect with healthcare professionals can make a crucial difference in ensuring the safety and well-being of expectant mothers. Therefore, the integration of mHealth solutions into maternal care is not only essential for convenience but also for the preservation of life, underlining the critical need to bridge this gap in emergency support for pregnant women.

The utilization of mobile health (mHealth) technologies plays a pivotal role in tracking and monitoring critical maternal health data, such as pregnancy trimesters, weeks of amenorrhea, foetal growth indicators, and maternal vital signs. Monitoring these parameters is essential for aligning maternal education, preparing

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for delivery, and detecting potential complications early. Without these tools, healthcare providers may face challenges in recognizing warning signs, increasing the risk of maternal mortality [37,38]. Continuous collection and analysis of maternal data through mHealth solutions allow healthcare professionals to identify deviations from normal health patterns promptly, enabling timely interventions and appropriate medical measures. Therefore, integrating mHealth for comprehensive data tracking is not merely a convenience but a vital component in improving maternal healthcare outcomes and reducing maternal mortality.

In light of this situation, the integration of technology is crucial to facilitate convenient and immediate delivery and support for services necessitated by mothers during the different stages of maternal health, that is, prenatal, delivery, and postpartum stages [39] Therefore, the involvement of technology in maternal health is required to deliver and support core maternal e-services [40]. The perpetuated goal is to mitigate the crucial problems discussed above ensure safe deliveries and achieve satisfactory postpartum outcomes to preserve the lives of both mothers and newborn infants [41,42].

Studies have consistently emphasized the growing integration of mobile health (mHealth) innovations in maternal healthcare, emphasising significant advancements, particularly in the realm of maternal e-services. Many studies have explored the potential of mHealth to deliver maternal education through mobile messages, typically disseminated by healthcare providers to expectant mothers, covering a wide array of critical topics. Notably, most existing frameworks primarily rely on text-based messages for this purpose, with only a few rare attempts to explore voice interactions. While these initiatives have their merits, the current frameworks are limited by their heavy reliance on text and voice communication for maternal health education. This accentuates the pressing need for an improved framework that broadens the scope of maternal e-services, harnesses multimedia capabilities for content delivery and takes a more holistic approach to address the multifaceted needs of maternal care [51]. With emphasis on this situation, this paper discusses the requirements and determinants for developing an improved framework to comprehensively support access to maternal e-services in low-resource settings using Uganda as the case study.

2 Materials and Methods

To attain the set objectives, the study formulated a research question (RQ) that was fundamental in guiding the deliverability of the projected results. The question stated as follows;

RQ1: What are the requirements to be considered in developing a mobile health-driven framework to enhance maternal e-services delivery in Uganda?

To answer the research question (RQ1), researchers adopted the user-centred design approach where mothers were involved in the study. The study prioritized the active involvement of mothers as the primary stakeholders in the determination of the requirements necessary for designing a mobile health framework to enhance the delivery and support of maternal electronic services. The study targeted mothers aged 15 to 50 years, as this age range includes the majority of women who are pregnant or have recently given birth. By focusing on this age group, the study aimed to capture the experiences and needs of most of the population utilising maternal e-services

Participants were recruited from Mbarara Regional Referral Hospital (MRRH), commonly known as Mbarara Hospital, located in Mbarara in the Western Region of Uganda. MRRH is the referral hospital for the region, serving the districts of Mbarara, Bushenyi, Ntungamo, Kiruhura, Ibanda, and Isingiro. The hospital was chosen for this study due to its extensive capacity to accommodate pregnant and new mothers from various parts of southwestern Uganda, offering both private and public healthcare services. This made it an ideal location to gather a diverse group of participants and ensure balanced data collection for the study. Participants were purposively selected based on specific criteria to ensure their direct involvement in maternal health matters and their willingness to provide relevant insights and information regarding maternal e-services. This sampling method was chosen because it allows for the intentional selection of individuals who possess specific characteristics or experiences pertinent to the research objectives, thus ensuring a more focused and relevant data collection process. Therefore, researchers sampled 60 mothers although a larger sample could have been determined using Yamane's formula, 60 participants were chosen for in-depth engagement. The corresponding estimated margin of error was 5%, which is acknowledged as a limitation of the study.

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Participant views and insights were collected using a questionnaire tool, a structured set of questions designed to gather information efficiently. This approach was chosen for its ability to standardize responses, ensure participant anonymity, and provide accessibility through various distribution methods. The questionnaire was administered in person by trained research assistants, who provided clear instructions and explanations to all participants. Utilizing questionnaires, the study aimed to efficiently gather insights from mothers about their experiences with maternal e-services, facilitating comprehensive analysis and informed decision-making. The questionnaire was structured into four sections, denoted as Sections A, B, C, and D.

Section A: Demographics captured non-identifiable information from mothers, including age (15–50 years), language proficiency, education level, area of residence, and mobile device ownership.

Section B: Awareness of Maternal E-Services explored mothers' knowledge and use of digital maternal health services, access methods, service types, language preferences, cost considerations, and offline accessibility.

Section C: Current Assessment of Maternal E-Services evaluated perceptions of four key areas: maternal education, emergency support, telemedicine consultations, and medication and investigation management, focusing on effectiveness, accessibility, and reliability.

Section D: Privacy and Security of Data gathered views on data protection, existing security measures, and concerns about insecure platforms, and preferred features to ensure confidentiality and safety in maternal e-service delivery.

Following the completion of data collection, respondents' responses were entered into SPSS, a widely used data analysis tool. This process began with coding the data to prepare it for analysis. Since all data variables were categorical, with some being nominal and others ordinal values, each response was assigned a numerical code for easier interpretation and manipulation. For instance, Likert scale values indicating the level of agreement were coded using numeric values (e.g., Strongly Agree as 5, Agree as 4, Neutral as 3, Disagree as 2, and Strongly Disagree as 1). Subsequently, descriptive analysis was conducted to gain insights into the distribution of responses. This involved generating cross tables, frequency tables, and histogram graphs to examine relationships and patterns within the data. Cross tables were particularly useful in exploring associations between two categorical variables, providing valuable insights into the respondents' perceptions and behaviors. Frequency tables provided a summary of the distribution of responses for each variable, while histogram graphs visually depicted the frequency distribution of responses. SPSS was selected for its extensive features, which enabled comprehensive statistical data analysis, facilitating the exploration and interpretation of the collected data.

The validity and reliability of the data were ensured through several measures implemented by the researcher. Firstly, to enhance validity, careful attention was paid to the design of the questionnaire, ensuring that it accurately captured the relevant constructs and variables of interest related to maternal e-services. Questions were selected based on literature, study objectives, and relevance to maternal experiences and validated by experts. While some researchers' judgments were unavoidable, efforts were made to minimize bias by using clear, neutral, and participant-centred wording, providing consistent instructions, and standardizing administration. This ensured the responses genuinely reflected participants' experiences. This explains why the questionnaire tool was a composition of various sections, each with a unique purpose. Furthermore, efforts were made to minimize biases during data collection by providing clear instructions to participants and maintaining consistency in administration procedures. To ensure reliability, inter-rater reliability tests were conducted for any subjective assessments or coding processes involved in the data analysis, ensuring consistency in interpretation among different researchers. Moreover, test-retest reliability checks were performed by administering the questionnaire to a subset of participants on two separate occasions and assessing the consistency of their responses over time. SPSS served as the tool for data analysis, while STATA was occasionally used to cross-check and confirm the consistency of results between the two platforms. This measure supported confidence in the reliability of the study's findings and analytical procedures. Overall, these rigorous validation and reliability procedures helped to strengthen the credibility and trustworthiness of the data collected for the study. The figure below summarizes the process under which the study was executed.

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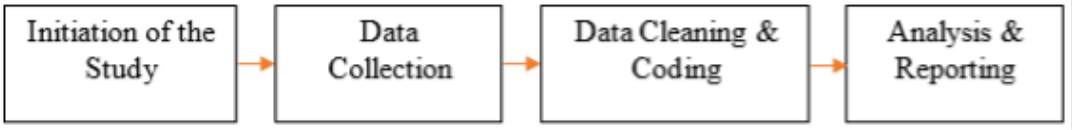

Figure 1. Organization of the study activities

The research was ethically cleared by the Vice Chancellor of the University of Dodoma on behalf of the University Research Ethics Committee, the Government, and the Tanzania Commission of Science and Technology (COSTECH) on 27th October 2023 under Ref. No. MA.84/261/02/'A'/60/124. The study was also approved at the data collection centre, Mbarara Regional Referral Hospital, on 12th February 2024. Furthermore, before engaging in the study, participants provided implicit consent by willingly responding to the data collection questionnaire, signifying their voluntary participation. The consent statement was stated at the beginning of the data collection tool as "By responding to this questionnaire, you have consented to be part of the study." Participants also retained the right to withdraw their involvement at any time. To protect participant privacy and confidentiality, collected data was anonymized. These ethical measures ensured the commitment to upholding the highest standards of research integrity and participant well-being.

3 Results

In this study, requirements are defined as the essential conditions or capabilities that a mobile health-driven framework must fulfill to effectively enhance maternal e-services delivery in Uganda. These are meant to ensure that the framework meets the needs of both healthcare providers and expectant mothers. On the other hand, determinants are regarded as the factors that influence the successful implementation and adoption of the framework. These may encompass socio-cultural attitudes, economic conditions, healthcare infrastructure, technological literacy, and policy environment that affect how the framework is utilized and its overall impact on maternal health outcomes. Understanding both requirements and determinants is crucial for developing a robust, user-centered, and contextually appropriate mobile health solution.

3.1 Age Variations and Support to Multimedia Content Delivery

Understanding the age groups and differences among mothers is a key factor in designing an inclusive e-service framework, as it provides insight into how mothers of different ages respond to various aspects such as the use of multimedia in delivering maternal education. As presented in Table 1, 78.3% (48.3% and 30%) agreed on the multimedia capability to improve access to maternal education. Upon diving into various age groups, it becomes clear that a large percentage agreed upon this at each variation. For instance, among mothers aged 26 – 35 years, 45.9% agreed, whereas 35.1% strongly confirmed the need for multimedia in this regard.

In general, multimedia, including videos and infographics, serves as a versatile tool in e-service frameworks, appealing to mothers of all age groups. Its dynamic nature offers an engaging platform for accessing information, accommodating diverse learning styles and preferences. Whether through interactive modules or educational videos, multimedia facilitates comprehension of complex concepts and enhances information retention. Its visual appeal not only enriches user experience but also encourages active engagement. By integrating multimedia elements into e-service frameworks, designers can create inclusive environments that cater to mothers' varied needs and preferences across different age groups. Therefore, with support for multimedia from mothers of different age groups, the Framework should be developed, placing multimedia as a key requirement to enhance access to maternal education.

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Table 1. Correlation between age and support for multimedia content delivery

Age Groups	Mothers' Support to Multimedia Capabilities					
	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Total
15 – 25 years	0	1	4	4	3	9
	0%	11.1%	44.4%	44.4%	33.3%	100%
26 – 35 years	3	1	3	17	13	37
	8.1%	2.7%	8.1%	45.9%	35.1%	100%
36 – 45 years	0	0	4	8	1	13
	0%	0%	30.8%	61.5%	7.7%	100%
46 and above	0	0	0	0	1	1
	0%	0%	0%	0%	100%	100%
Total	3	2	11	29	18	60
	5%	3.3%	13.3%	48.3%	30%	100%

3.2 Proficiency in languages and support for Multilingual E-service access

Understanding the language proficiency of participants was crucial for designing a comprehensive framework, aiming to assess mothers' satisfaction with the language used in rendering maternal e-services on digital platforms. Table 2 shows that 50 (83.3%) mothers expressed proficiency in English. However, regarding satisfaction, only 46.7% (15% and 31.7%) confirmed being satisfied with the language used on digital platforms for maternal e-services, indicating a significant gap in meeting mothers' language preferences. Presenting information in mothers' preferred languages ensures comprehension of critical healthcare instructions and educational content, empowering informed decision-making and fostering user engagement. This promotes inclusivity by eliminating language barriers for all mothers seeking access to healthcare information and support through e-services. Consequently, the framework's design can prioritize English as the primary medium for delivering maternal e-services, while acknowledging the potential for multilingual innovations to cater to the diverse language preferences of mothers.

Table 2. Language Proficiency and Correlation with Satisfaction

Language	Measure of Satisfaction in Language						
	Extremely Dissatisfied	Dissatisfied	Neutral	Very Satisfied	Satisfied	N/A	Total
English	2	1	14	9	16	8	50
	4%	2%	28%	18%	32%	16%	100%
Runyankole	0	0	4	0	3	0	7
	0%	0%	57.1%	0%	42.9%	0%	100%
Luganda	0	1	0	0	1	0	2
	0%	50%	0%	0%	50%	0%	100%
Other	0	0	1	0	0	0	1
	0%	0%	100%	0%	0%	0%	100%
Total	2	2	19	9	19	8	60
	3.3%	3.3%	31.7%	15%	31.7%	15%	100%

3.3 Area of Residence and Data Persistence Features

Examining participants' areas of residence (rural vs. urban) was important for designing a maternal e-service framework that caters to diverse locations, aiming to understand the relationship between residence and internet affordability. Table 3 indicates that 88.3% (53) of respondents lived in urban areas compared to rural residents. However, the affordability of the internet remains a challenge, with 66.3% (15% as not affordable at all, 15% as slightly affordable, and 33.3% as moderately affordable) not positively indicating the ability to afford internet connectivity while accessing e-services, regardless of residence. With this in mind, 88.3% of respondents agreed that enabling offline features in mobile apps for maternal service

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delivery can reduce reliance on internet connectivity, thus enhancing accessibility and usability. This observation denoted the importance of incorporating features that enable low resource utilization, such as downloadable educational resources and data persistence, to facilitate offline access to information. By including such features, the framework can ensure accessibility and usability across diverse settings, including areas with limited internet and power infrastructure.

Table 3. Residence areas against Internet affordability

Residence	Not at all affordable	Slightly affordable	Moderately affordable	Very Affordable	Extremely Affordable	Total
Urban areas	8	8	17	17	3	53
	15.1%	15.1%	32.1%	32.1%	5.7%	100%
Rural areas	1	1	3	2	0	7
	14.3%	14.3%	42.9%	28.6%	0%	100%
Total	9	9	20	19	3	60
	15%	15%	33.3%	31.7%	5%	100%

3.4 Possession of Mobile Devices and Adoption of the Framework

Given that mothers are the primary beneficiaries of the maternal e-service framework, it was essential for the study to examine their access to mobile devices like smartphones or tablets. This investigation provides insight into the prevalence of mobile devices within the community, indicating the potential viability of the mobile application for maternal e-services. As presented in Table 4, the study revealed that 96.7% of participants, possessed smartphones, while a minority (3.4%), comprising two mothers, had access to smartphones through sharing or family members. This observation exposes the significance of designing a mobile health framework for maternal e-services given the widespread presence of mobile devices among the participants.

Table 4. Possession of Mobile Phone Results

Access to Mobile Devices	Frequency	Percent (%)
Own a smartphone	58	96.7
Borrow or share a smartphone	1	1.7
Use a family member's phone	1	1.7
Total	60	100.0

3.5 Utilization of Maternal E-Services and Stage of Services Access

Building upon the understanding of mothers' awareness of maternal e-services, the study further investigated utilization through a simple "Yes/No" question. This aimed at understanding the stage of maternal health at which the services were accessed, as well as the type/nature of the services, to inform on the gap between service coverage and maternal stage consideration. As presented in Table 5, only 41.7% (25) confirmed having accessed maternal e-services, compared to the 58.3% (35) who had never accessed these services. Delving into stages, although 60% expressed not accessing maternal health services across all three stages, only 28% reported accessing them during prenatal care, indicating a gap in the labor and delivery stage and newborn care stage. Reflecting on these findings, the framework should consider the provision of maternal e-services to mothers across the three core stages of maternal health to support the diverse needs of mothers, especially pregnant and new mothers.

Table 5. Utilization of Maternal E-Services against Stage of Utilization

	Maternal Stage access the services				
Measure of Utilization	**Prenatal**	**Delivery /Birth**	**Postnatal**	**None of these**	**Total**
Yes	15	1	1	8	25
	60%	4%	4%	32%	100%

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No	2	2	3	28	35
	5.7%	5.7%	8.6%	80%	100%
Total	17.0	3	4	36	60
	28.3%	5%	6.7%	60%	100%

3.6 Location-Supported Access

With mobile devices equipped with real-time location capabilities, the development of mobile applications for delivering e-services should leverage this feature to enhance service access. Location-based functionalities offer significant benefits, particularly in rural areas. For example, e-service applications could utilize location data to identify nearby healthcare facilities, recommend relevant specialists, or facilitate connections with local support groups such as Village Health Teams. By incorporating such features, the framework goes beyond mere information dissemination, providing mothers with actionable resources tailored to their geographical location. As depicted in Table 6, a significant majority of 58.3% (35 participants) agreed, while 33% (20 participants) strongly agreed that facilitating access to services tailored to the user's current location could provide a more efficient way to access nearby services, ultimately saving time and reducing expenses. In alignment with this, the framework should be developed with the provision of location-customized services.

Table 6. Support for Location-Based Access to Maternal E-Services

Response	Frequency	Percent (%)
Strongly Disagree	2	3.3
Disagree	0	0
Neutral	3	5.0
Agree	35	58.3
Strongly Agree	20	33.3
Total	60	100.0

3.7 Maternal Health Education/Information Provision

The rapid expansion of the internet and mobile technology has transformed the landscape of information dissemination, presenting a tool for narrowing the knowledge gap in maternal healthcare. The maternal e-services framework has the potential to capitalize on this advancement by providing a comprehensive array of educational resources in intuitive digital formats. This is paramount as digital content transcends geographical constraints, ensuring accessibility for mothers residing in remote areas. The framework is viewed to facilitate seamless updates and broadcasting of the latest evidence-based information. By offering diverse formats such as text articles, captivating videos, informative infographics, and downloadable audio for offline access, the framework will cater to varied learning preferences, empowering mothers with the requisite knowledge for informed decision-making. The majority of participants, comprising 58.3%, accessed maternal education in text form, indicating a predominant preference for textual information over multimedia. This contrasts with the findings presented in Table 1, where a larger portion of participants agreed on the importance of multimedia for maternal education. As a result, the framework should be developed with an emphasis on the significance of multimedia content to enhance the accessibility of maternal health information, ensuring alignment with user preferences and needs.

3.8 Emergency Response and Support Services

The widespread availability of smartphones with GPS capabilities, coupled with the emergence of real-time API integrations, signifies a transformative shift in emergency response for maternal health. In dire situations where a mother faces complications, the emergency features of applications could be activated. Leveraging the smartphone's GPS functionality and secure API connections, the application can transmit the mother's precise location to emergency medical services. This real-time location data holds the potential to significantly reduce response time by promptly dispatching the nearest transport services, such as an

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ambulance, through another secure API integration. This could provide the mother with access to virtual support resources or deliver targeted educational materials on managing emergencies until assistance arrives. This seamless integration of mobile technology, location-based services, and emergency response systems equips mothers with immediate assistance and essential knowledge during critical junctures, instilling a sense of security throughout their pregnancy journey. The aim of this was to understand the rate at which emergencies occur in maternal life (pregnancy, childbirth, and the postnatal period) and also the response time to these situations. Recognizing the inevitability of emergencies, a substantial majority of participants, 60%, confirmed encountering emergencies during maternal life, including pregnancy, childbirth, or the postpartum period. Despite this high number, only 8.3% reported accessing emergency support immediately or within an hour. With 71.7% of mothers experiencing delayed access to support due to the lack of quick and reliable ways to connect to healthcare centres during critical moments, there is an urgent need for an improved framework. The framework should prioritize integrating rapid response mechanisms, such as transport support services, to enhance timely assistance and support during emergencies in maternal life.

3.9 Telemedicine Consultations and Appointments

In today's digital world, advancements in technology are rapidly reshaping the landscape of healthcare delivery. Telemedicine consultations and appointment services are increasingly vital components of modern healthcare systems, particularly for geographically isolated communities or individuals facing mobility limitations. This trend is driven by the growing demand for remote healthcare services, fueled by factors such as convenience, accessibility, and the need for timely interventions. By eliminating the need for lengthy commutes, these services ensure timely access to essential healthcare, especially during critical periods like pregnancy. Utilizing appointment scheduling systems enables mothers to conveniently book appointments online and receive electronic reminders, overcoming geographical barriers and facilitating timely interventions. With this requirement in mind, the study aimed to investigate the state of queues and the presence of applications to manage the appointment process as one of the approaches to mitigate long queues. The study observed that the majority of participants, constituting 66.7%, encountered prolonged wait times in queues while seeking attention from healthcare professionals during their maternal journey. Additionally, 58.3% admitted the absence of platforms for handling appointments, whether web-based or mobile, to schedule appointments related to maternal healthcare, with an additional 13.3% (seven participants) expressing uncertainty about their usage. Although there may be existing tools supporting appointment booking in other healthcare domains [52], the comprehensive nature of the maternal health framework should also integrate such services to enhance accessibility and minimize delays in receiving maternal care.

Delving into the telemedicine aspect, the majority of participants, comprising 76.7%, endorsed the idea of engaging in remote consultations with healthcare professionals for maternal health issues, and 95% confirmed the convenience of these virtual meetings and consultations. In conjunction with appointment services, the framework can incorporate a dedicated component for integrating telemedicine consultations, recognizing the importance of remote consultations for maternal health support. This does not imply a replacement of physical facility visits but rather serves to assist and support the initiation and continuation of maternal care, especially in distance-constrained situations.

3.10 Treatments and Investigations Management Services

The proliferation of mobile health (mHealth) apps and secure online portals presents a significant opportunity for the maternal e-service framework to enhance medication adherence and treatment management. By integrating with e-prescription platforms, mothers can receive electronic medication prescriptions directly from healthcare providers. This process can be complemented by medication reminder apps to ensure timely dosing, significant portion, representing 86.6%, confirmed convenience in using a secure digital platform. This illustrates the critical role of data security measures in fostering user trust and promoting the adoption of mobile-based e-services.

Security being an important aspect in utilizing digital platforms, the majority of respondents, accounting for 55% highlighted that improved encryption methods are perceived as the most robust security mechanism in mobile health frameworks. This was followed by other mechanisms such as user education on privacy

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and data, with 41.7% endorsing this approach. In consideration of these preferences, the framework can contemplate the implementation of robust security measures, including but not limited to password protection and data encryption, to ensure the security of user data when accessing maternal services. These measures aim to address the security concerns and privacy needs of users.

4 Discussions

This study focuses on low-resource countries, characterized by limited technology adoption, with Uganda serving as a case study for developing nations. The integration of technology-based innovations in maternal health services remains minimal in these settings. Instead, traditional methods are predominantly used to support maternal health. A common practice is maternal education delivered through antenatal visits to health facilities. However, these traditional approaches come with significant challenges. The long distances between homes and health facilities, geographical barriers, and adverse climatic conditions can endanger the lives of pregnant women. Additionally, during the COVID-19 pandemic, physical meetings were restricted, further complicating access to these services. Health facilities often face long queues due to a shortage of healthcare workers, resulting in delayed care. Emergencies in maternal health are also inadequately addressed under these constraints. These limitations highlight the urgent need for improved technological interventions in maternal health services in low-resource countries. Numerous frameworks such as 1) The Mobile Alliance for Maternal Action (MAMA) framework [43,44], 2) the AI Pregnancy Companion Chatbot (PCC) Framework [45,46], 3) the AI Framework for Fetal Health Status Prediction [47], 4) The Mobile Health Communication Framework for Postnatal Care in Rural Kenya [22], [48], 5) The Mobile Health Messaging Service and Helpdesk Framework for South African Mothers (MomConnect) [49]. 6) KIA E-Health Framework Maternal and Child Health Services in Indonesia [50] have been studied to support access to maternal e-services to improve maternal healthcare delivery. However, these frameworks have predominantly focused on maternal education delivered through SMS and mobile messages as systematically reviewed and discussed by Ssegujja et al [51]. There has been little emphasis on other e-services that have the potential to enhance maternal healthcare delivery significantly.

Reflecting on these limitations, we have investigated the determinants and requirements necessary for designing a maternal e-services framework. Given the widespread use of mobile devices 96.7% of respondents reported having access to them the proposed framework should be mobile health-driven. This focus leverages the proliferation of mobile technology to address the identified needs. The framework will provide guidelines for developing mobile applications that translate these requirements into practical solutions, taking into account the relevant factors and determinants. Key determinants have been identified, each contributing to the selection of requirements for an effective maternal e-services framework. The table below illustrates the relationship between these factors and the corresponding requirements:

Table 7. Requirements for designing an mHealth framework to enhance the delivery and support of maternal e-services with supporting factors presented as determinants

Determinant	Supported Requirement	Code
Age variations	Multimedia content delivery for maternal education	R001
Language Proficiency	Integrating multilingual capabilities in maternal e-services delivery	R002
Area of Residence and Internet Affordability	Enabling data persistence for offline access even with no active internet content e.g., for maternal education information	R003
Possession of Mobile devices	Adoption of mobile application resulting from the framework implementation	R004
Utilization of maternal e-services and stage accessed	Ensuring service delivery to support mothers across all levels of maternal health typical prenatal, delivery/childbirth and postnatal.	R005
Geographic barriers	Offering access to services tailored to mother's location	R006
	Introducing telemedicine consultations for remote patient management	R007
Long Queues in health facilities seeking of maternal health support	Enabling appointment management services	R008
Occurrence of emergencies	Integrating emergency support services	R009

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Occurrence of medical challenges and forgetting medical prescriptions during maternal health	Integrating Treatments and Investigations Management services	R010
Need for security and convenience in using secure application	Integrating encryption protocols, secure logins, and robust access controls serve as vital safeguards for protecting sensitive maternal health information	R011

Proper attention to identified requirements and their determinants has the potential to significantly improve access to maternal e-services in low-resource settings. Considering factors such as age variations, language proficiency, geographic barriers, the occurrence of emergencies, possession of mobile devices, and the need for security and convenience in using secure applications, a comprehensive maternal e-services framework can be developed. This framework will facilitate the creation of user-friendly, multilingual mobile applications that function offline, provide real-time emergency support, and offer telemedicine consultations. Such a comprehensive approach ensures that maternal health services are more accessible, timely, and effective, ultimately leading to better health outcomes for mothers and their children. The integration of secure application protocols further enhances the reliability and trustworthiness of these e-services, encouraging widespread adoption and sustained usage.

Despite their complementary nature, certain requirements present contradictions that must be addressed for effective implementation. For instance, multimedia content delivery (R001) depends on internet connectivity, which may be costly or unreliable in low-resource settings. Therefore, offline access (R003) becomes essential to address this limitation by allowing pre-downloaded or cached low-bandwidth content, such as text summaries or compressed audio, to ensure continuous access to maternal education and support even without internet connectivity. Telemedicine also typically depends on real-time internet connectivity, which conflicts with the need for offline access in regions with poor or unstable networks. This can be resolved by incorporating asynchronous telemedicine options, such as text-based consultations or pre-recorded video guidance, which function offline or with intermittent connectivity, while still allowing real-time consultations when stable internet access is available.

5 Summary and Future Work

In conclusion, developing a mobile health-driven maternal e-services framework has the potential to greatly enhance maternal healthcare delivery, especially in low-resource settings. By addressing everyday challenges faced by pregnant and new mothers such as difficulty reaching healthcare facilities, long waiting times, limited support during complications, lack of guidance on maternal care, and interruptions in follow-up care while also ensuring data privacy and security, such a framework can use mobile technologies to provide timely, accessible, and user-centred maternal healthcare.

Future work should focus on the design, development, and practical implementation of this framework. This includes creating detailed technical guidelines that integrate the identified user requirements, Human Computer Interaction principles, and healthcare delivery standards to offer maternal e-services in a comprehensive, cohesive, and contemporary manner. Pilot studies across different regions should be conducted to evaluate the framework's effectiveness, usability, and scalability, ensuring that it accommodates diverse user needs and contextual challenges.

Additionally, continuous refinement of mobile applications within the framework is essential. This involves iterative testing with real users, collecting feedback to enhance usability, accessibility, and reliability, and adapting the system to incorporate emerging technologies and healthcare protocols. Ultimately, the aim is to create a robust, inclusive, and practical maternal e-services platform that supports mothers across pregnancy, childbirth, and the postnatal period, thereby contributing to improved maternal health outcomes at scale.

Statement on Conflicts of Interest

The authors declare no conflict of interest

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