

MOBILISING ARTIFICIAL INTELLIGENCE FOR **MATERNAL HEALTH** IN BANGLADESH



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1.0 Introduction

Maternal health in Bangladesh has improved greatly in the last two decades but the rate of improvement has stalled in recent years and further efforts are needed to support the health of expecting and new mothers. To explore the potential use of Artificial Intelligence (AI) in supporting pregnancy monitoring services in Bangladesh, a study had been conducted from May 2022 to May 2023.

The study focuses on two central sets of questions:

- **Perception and Use of AI Tools:** What are the opportunities and barriers in perceptions and usage of AI among maternal health service providers and users relating to deployment of AI into antenatal care systems? What enabling conditions are required for adoption?
- **Assessment of Technological Readiness:** What are the technological requirements of the digital ecosystem needed to enable the application of AI into antenatal care? What is the back-end infrastructure required for implementation?

The report and is divided into 8 chapters:

1. **Introduction:** Brief description of project objectives and outline.
2. **Context:** Background context of antenatal healthcare provision in Bangladesh.
3. **Methodology:** Description of the study approach and methods.
4. **Key informant interview findings.**
5. **Literature review.**
6. **Technological readiness assessment.**
7. **Comparative evaluation of interventions** focusing on two criteria – usefulness and feasibility.
8. **Recommendations.**

2.0 Context

Bangladesh has made striking progress in the delivery of antenatal care (ANC). Maternal mortality has fallen significantly from **323 maternal deaths per 100,000 live births in 2001 to 196 in 2016**. The number of women receiving the complete continuum of pregnancy related care has increased from **19% in 2010 to 43% in 2016**, and the number of women seeking facility-based care for complications has grown from **29% in 2010 to 46% of in 2016**.

Community health workers (CHW) play an essential role in the continuum of care that has led to lower maternal mortality, particularly in rural and low-income areas. Through door-to-door house visits, they disseminate pregnancy-related information, provide family planning advice and distribute supplies.

While much progress has been made, significant challenges remain in the provision of ANC, particularly in the rural areas – rural women are likely to have only one check-up during their pregnancies as opposed to the WHO guideline of four check-ups. A significant number of births take place outside medical facilities and many families still turn to traditional birth attendants even though they do not have any form of formal training. The proportion of women seeking treatment for obstetric complications (antepartum and postpartum) also remains low.

There are several factors deterring pregnant women from seeking ANC – long waiting times at medical facilities, poor standards of service and unsatisfactory behaviour from healthcare providers, lack of trust and comfort towards healthcare providers and lack of access for some marginalised groups. These observations are congruent with WHO ANC recommendations which were derived from a systematic review of women's views – in addition to clinical services, women desire flexible appointments, a supportive provider relationship, advice for common physiological symptoms, clear explanations, women-held case notes, midwifery-led care, group antenatal care and, perhaps most fundamentally, respect.

Another phenomenon of concern to sector stakeholders is the rapid increase in the number of babies delivered by Caesarean section. These numbers are well beyond the level that would be expected out of medical necessity and they suggest that C-sections are excessively promoted by private medical service providers for profit. Government, with the support of donors and the professional association of obstetricians, is addressing this through information, education and communications (IEC) interventions and by strengthening regulations on private clinics.

Comprehensive evaluation of the many ANC initiatives and programmes is inhibited by the absence of interoperable maternal health data. There are no digital health records for most expecting mothers. While some ANC providers capture data at the local level and share them with government agencies and other ANC providers, there are no unique identifiers or metadata which enable the cross-referencing of an individual's data. This makes it impossible to track the care a pregnant mother receives if she visits different ANC providers over the course of her pregnancy and postnatal period. Digitalization of medical records is considered by many to be a prerequisite for the deployment of AI.

Bangladesh's technological readiness is rising rapidly. There is a very high mobile phone penetration rate and a high rate of mobile broadband subscriptions. These achievements have prompted a range of pilot initiatives around digital and mobile health interventions for expecting and new mothers. However, the enabling conditions for national level roll-out have yet to be met in many cases – for example, most people in rural areas only have access to 2G services. These opportunities and constraints are discussed in more depth in Section 6.

3.0 Approach & Method

The study drew on three sources of data: stakeholder interviews, documentary review and secondary data analysis. This section describes the data sources and methods.

3.1 Stakeholder interviews

We identified relevant stakeholders providing ANC and engaging in pregnancy monitoring in Bangladesh. The following groups were identified:

- Healthcare professionals providing ANC (doctors, nurses, trained midwives);
- International organisations, donors, NGOs and others providing support (financial, training etc) to ANC providers;
- Government agencies responsible for policy-making, resource allocation, regulation, monitoring and evaluation of ANC;
- Health sector administrators (hospitals, clinics, etc.); and
- Technology solution providers.

Further groups, pregnant women and their families, and providers of ANC without professional clinical training, are also central stakeholders. They however, are usually not directly involved in the formal pregnancy monitoring process.

As the focus of this study is on applications of AI in pregnancy monitoring, and taking into account the constraints on time and resources available, interviews and data collection were primarily targeted at stakeholders at the senior managerial level of key sector institutions. Secondary data collection was then conducted with end recipients and implementers of pregnancy monitoring, such as CHWs.

Institutions and individual interviewees were identified through our designated government contact and through extensive internet search. A snowball sampling was used to identify relevant stakeholders who could provide useful insight to the study. A total of XX interviews were conducted with experts from government, civil society organisations, international organisations, academia, healthcare organisations and technology companies. The list of informants is in Annex 1.

Our interview protocol covered:

- a)** Technologies currently used in Bangladesh for ANC and what are its functions (e.g. provide generic or tailored information to patients or CHWs; provide guidance to health workers on specific cases; provide training and information to health workers; send reminders to patients for clinic visits; schedule appointments with health care providers; schedule visits of CHWs etc.);
- b)** Current working practices in data collection and management and record-keeping;
- c)** Attitudes to new and existing technologies, perceptions of risk relating to the technologies;
- d)** Perceived gaps in the availability of information; and
- e)** Perceived gaps in communication of risks and appropriate actions. The interview protocol was tailored to the interviewee's organization and role in order to maximise the information collected and to allow for triangulation between interviewees wherever possible.

Interviews were conducted online, recorded with the permission of the interviewees and transcribed for analysis on key project themes. Where possible, the data provided by interviewees was triangulated and corroborated with other interviews or published sources (project evaluations, official reports etc).

3.2 AI in ANC Documentary review

We conducted a review of the scholarly and grey literature on the application of AI in healthcare, with a specific focus on its applicability to antenatal care, and the use of digital technologies in ANC and community healthcare in developing countries and specifically in Bangladesh. <to add more if necessary> In total, 24 papers published between 2011 and 2021 were reviewed.

3.3 Secondary data analysis

Data related to the digital technology infrastructure of Bangladesh was obtained through data requests from relevant government agencies in Bangladesh, and out other open source channels such as the International Telecommunication Union and the World Bank. The Data includes: healthcare data/quality of data and data standards, data and system integration and interoperability issues, and information and communication infrastructure (e.g., latest data on the mobile cellular network, latest data on bandwidth in Bangladesh, Fixed broadband, mobile broadband, household Info Communication Technology (ICT) use, and individual use, etc.). These data were analysed with reference to international standards of technical requirements for the adoption of applications of AI.



4.0 Findings: Key informant interviews

A recurring theme identified through the interviews was the need to address weak monitoring and overall accountability to improve maternal health outcomes. To further reduce maternal mortality rates, informants emphasised the need to raise the quality of care in facilities, and improve the provision of care in emergency cases. In more than 35% of cases of preventable maternal deaths, the woman reaches a health facility but does not receive adequate care (Key informant 5). Three sources of delay were identified in seeking emergency treatment during a delivery. First, the family members often delay the decision to visit a medical facility for emergency care; second, lack of reliable transportation for commute to the hospital; third, excessive administrative requirements in the hospital and the presence of middle men who try to divert mothers to private clinics. Together, access to treatment may be delayed for 2-3 hours, resulting in fatalities (Key informant 4). Social, cultural and economic issues were also frequently mentioned by informants.

Several digital and mobile technologies have been piloted in Bangladesh in the maternal sector to address these priorities, and a few have been adopted at scale. Sections 4.1 – 4.3 details these interventions, their implementation, barriers and challenges encountered and potential for wider adoption. Broadly there are three types of interventions:

1. Interventions around the digitalization of records and management information;
2. Interventions directed towards training and supporting health care workers; and
3. Information and communications interventions directed towards expecting mothers and the gatekeepers of maternal health (husbands, mothers-in-law etc.).

4.1 Digitalisation of record-keeping, management information systems

Digitalisation of record-keeping and reporting was seen as essential to improve the ability and incentives of managers to supervise frontline service providers.

Informants pointed to problems at the field, facility and district level which diminishes the integrity and usability of the data collected. At the field-level, one key informant took the view that CHWs, who are often over-burdened and under-resourced, “took advantage” of weak monitoring processes to exaggerate performance. As a result, “We have data but we cannot be confident that this data is valid,” the informant explained (Key informant 5). Another informant agreed that data validity was an issue, but perceived the problem to be further downstream during data consolidation at the district level when data were potentially “massaged” before reporting to the central level (Key informant 10).

Informants agreed that digitalization, increased scrutiny and greater usage would improve the quality of the data over time. In the future, data quality could be further enhanced through the use of GPS tracking data from field workers’ devices.

4.1.1 Electronic Management Information System (eMIS), Directorate General Family Planning (DGFP)

The eMIS is DGFP's major programme to digitise health information of pregnant women and newborns. The system was developed and piloted in two districts in 2015 and then gradually scaled up to other districts. By the end of 2019, it had been deployed to 237 upazilas in 30 districts (Mamoni, 2019, mamoni.info) and was deployed to another 10 more districts by the end of 2022 (Key informant 10).

The system allows CHWs and local clinics to input data digitally through mobile applications. The data are stored on the cloud and web-based tools are available for users to consolidate data for viewing and reporting. The system is linked with DGFP's FP-DHIS2 (District Health Information System v.2) and the Logistics Management Information System (LMIS). The system collects and manages the exact same data that were previously being collected on paper. This was a deliberate design decision in order to reduce the barriers to adoption by health workers and government officials (Key informant 10).

In addition to record-keeping, eMIS can automatically generate a list of clients for CHWs based on an initial census, and provides in-app alerts and reminders. eMIS is also able to identify high-risk cases for further follow up based on standard health information collected during ANC check-ups (age, height, weight, high blood pressure, pre-existing conditions etc.). For mothers, the system also plays an m-Health function to generate SMS reminders for ANC appointments and vaccination due dates. For managers, eMIS offers a dashboard with real-time information for monitoring and consolidated information for monthly reporting. The system is able to track provision of care at DGFP facilities but is not able to track the full continuum of care if mothers use other facilities for ANC and delivery care.

Digitalization of the logistics system has helped to improve availability of supplies and to reduce 'stock-outs' (Key informant 5). In the future, eMIS and LMIS should be inter-operable to increase efficiency and reliability of supplies.

Outcomes: Although eMIS has been introduced in most districts in Bangladesh, only two districts have discontinued the paper-based system and moved to a totally digital system. All others are operating a dual paper-electronic system, which multiplies the administrative burden for health care workers and managers. Efforts are ongoing to transit to a fully digital system, and there are varied accounts of the rate of progress amongst informants. The administrative burdens introduced by the dual paper-electronic system has made it more difficult to evaluate the impacts of the digitalization programme.

Informants agreed that under the digital system, there were fewer opportunities for data manipulation, making it easier for managerial oversight, performance management and improving procedural adherence. While a programme evaluation has yet to be completed, informants were convinced that digitisation was essential to improving maternal health outcomes and DGFP is committed to implementing the system nationwide.

Issues: The system does not cover care received by women at private facilities, DGHS facilities or in the home. As a significant number of deliveries take place in these settings, delivery and post-partum data is often not captured in the system, making it difficult to associate ANC data with these outcomes. A second risk relates to the reliance on devices for data input. An informant expressed the concern that low-cost devices (tablets) used for data input were more likely to develop faults or break. Third, and most importantly, adequate financial and technical resources need to be mobilized to ensure the sustainability of the system. "There is currently no central team at DGFP to backstop or troubleshoot," explained a key informant. "The system needs continuing technical support for software updates and database management."

Prospects: Government and development partners are strongly committed to digitalization but additional resources are needed to ensure that all districts are covered and that system functionality is maintained.

4.1.2 Hospital organisational automation

A pilot has been conducted for an Open Medical Records System (OMRS) for maternal healthcare in one district hospital (Key informant 6). This included an automated ticketing system for mothers and newborns to allocate appointments, doctors and rooms and digital feedback mechanism for mothers to provide feedback on the facility. The pilot was conducted under USAID's Mamoni project and will be handed over to the government for continued operation and potential replication.

4.1.3 Manoshi, BRAC

The Manoshi programme for maternal, newborn and child health in urban slums incorporates an mHealth system for record-keeping, reporting, monitoring and referral, and has functions to support CHWs in their work. Both part-time CHWs, known as Shasthya Shebika (SS), and full-time supervisors, known as Shasthya Kormi (SK) use the programme (BRAC 2022)[1]. The digital data collection process enable CHWs to keep detailed lists of households and clients. SKs use android tablets to complete a standard form which includes dropdown menus. The following information are collected:

- Names and ages of pregnant woman and family members;
- Medical history of expecting mother;
- Patient risk categorisation (high risk patients with pre-existing conditions like diabetes or high blood pressure are flagged for separate follow-up.
- Health indicators from a physical examination: blood sugar, blood pressure, anaemia, weight, height etc and later in the pregnancy, height of uterus.

Data are used to track the pregnancies of individual women and how many rounds of ANC they received. It also enables supervisors to monitor how many women were advised by an individual SK and the number of births at each facility and locality.

Digital resources are also used in SK/SS training and for communicating with mothers. For example, there information videos watched by CHWs are often directly shown to mothers during visits. In health facilities, recorded dramas on pregnancy and delivery are screened while the women are waiting for their appointments (Key informant 4). The system does not include any online resources for pregnant women.

The programme also enables CHWs to contact a central support centre via their mobile phones to secure transportation and accompany a mother to a facility for delivery, or to a hospital in an emergency.

Outcomes: Manoshi operates in 10 cities and serves a population of 6.9 million people. It has been very effective in contributing to reducing maternal deaths and increasing facility deliveries among the target population. Maternal and neonatal deaths fell from 294 per hundred thousand live births in 2008 to 130 in 2013, and home deliveries fell from 86% at the start of the programme to 13% in 2013. Compared to the general population during the same period, cities with Manoshi had greater reductions in these numbers.

Issues: The project preparation involved a census which is costly and time-consuming[2] and may not be replicable in low density communities. While the mHealth elements of the programme are considered to be effective and appropriate, and the programme is meeting its objectives of reducing maternal deaths and home births in the target population, the Manoshi programme does not interconnect with other government-led mHealth initiatives. The Manoshi data do not feed into government databases and there is no common identifier which would allow for data to be linked as the national ID numbers of mothers are not collected or stored. [MOU1] The mHealth application for service providers "BRAC CSM" has over a thousand downloads on the Googleplay store.

Prospects: Manoshi provides an example of an effective standalone mHealth system supporting an integrated maternal health programme for an important target community – urban slum dwellers. However, the potential to integrate the mHealth elements of the programme with national digitalization efforts are limited.

4.1.4 Digitalised health record keeping

UNICEF is working with family healthcare clinics in urban areas to implement a fully digitised system interface to collect data. This includes linking medical apparatus with systems to automatically capture and log patients' vital sign measurements in their digital records. The patient's digital records include patient IDs, health vital signs, diagnosis and prescriptions.

[1] <http://www.brac.net/program/health-nutrition-and-population/maternal-neonatal-and-child-health/manoshi>

[2] <http://www.brac.net/sites/default/files/portals/Manoshi-book-v3-1.pdf>

Outcome: The digitisation of records has enabled the collection of data which can then be used to explore other potential AI applications. UNICEF is currently working with the United International University on this. The Ministry is also keen to deploy these solutions to other clinics.

Issues: Significant infrastructural investments and manpower training are required for deployment of such technologies in clinics at scale. Beyond the short-term implementational requirements, long-term maintenance and upkeep of the systems, hardware and software should also be considered.

4.1.5 OpenSys Individual Maternal and Immunisation Trackink System, UNICEF

system and has put up a procurement Request for Proposals in September 2022^[1]. Despite the successful implementation of the Expanded Programme of Immunisation (EPI), Bangladesh still does not have an integrated individual tracking system to support the continuum of care from maternal services to child vaccination.

The objective of the system is to register all pregnant mothers and eligible children for immunisation. Using an OpenSRP system, new pregnancies will be registered by CHWs during household visits, or when they visit healthcare facilities. Upon registration, a unique Shared Health Record ID (SHR ID) will be created and will enable automated generation of ANC, delivery, PNC and child immunisation schedules. Mothers can then be provided with these information through SMS systems.

Outcomes: The procurement process is still ongoing. However, UNICEF is currently working with DGFP and DGHS to implement a micro-planning programme at the community level to ensure that pregnant mothers are being sought out and identified (Key informant 9). With geospatial sampling and targeted surveys, administrators can estimate the average number of new pregnancies within a geographical region each month. These numbers are then used as target estimates and CHWs are tasked to conduct household visits within the region to identify these new pregnancies.

Issues: There are many overlapping jurisdictions between the two directorates and there is not clear ownership of the maternal care programme. Close coordination between multiple stakeholders and parties is hence required to ensure alignment in the project objectives. While the system is being developed, the fragmented information ecosystem remains a challenge for oversight. Within a geographical region, there are multiple entry-points for pregnancy registration - mothers need not necessarily go to the nearest healthcare facility and may visit family clinics, Union-level clinics or even those at the Upazila level.



[3] <https://www.ungm.org/Public/Notice/181557>

Prospects: AI could be used to improve the accuracy of the estimation of the number of new pregnancies in an area and streamline the search process conducted by CHWs within a geographical region. With the establishment of the OpenSys Individual Maternal and Immunisation Tracking System, AI could be used to automatically plan and schedule health check-ups and follow-up appointments for the mother. As indicated by South Korea's example, the automated provision of SMS reminders for check-ups could support pregnancy management adherence by mothers.

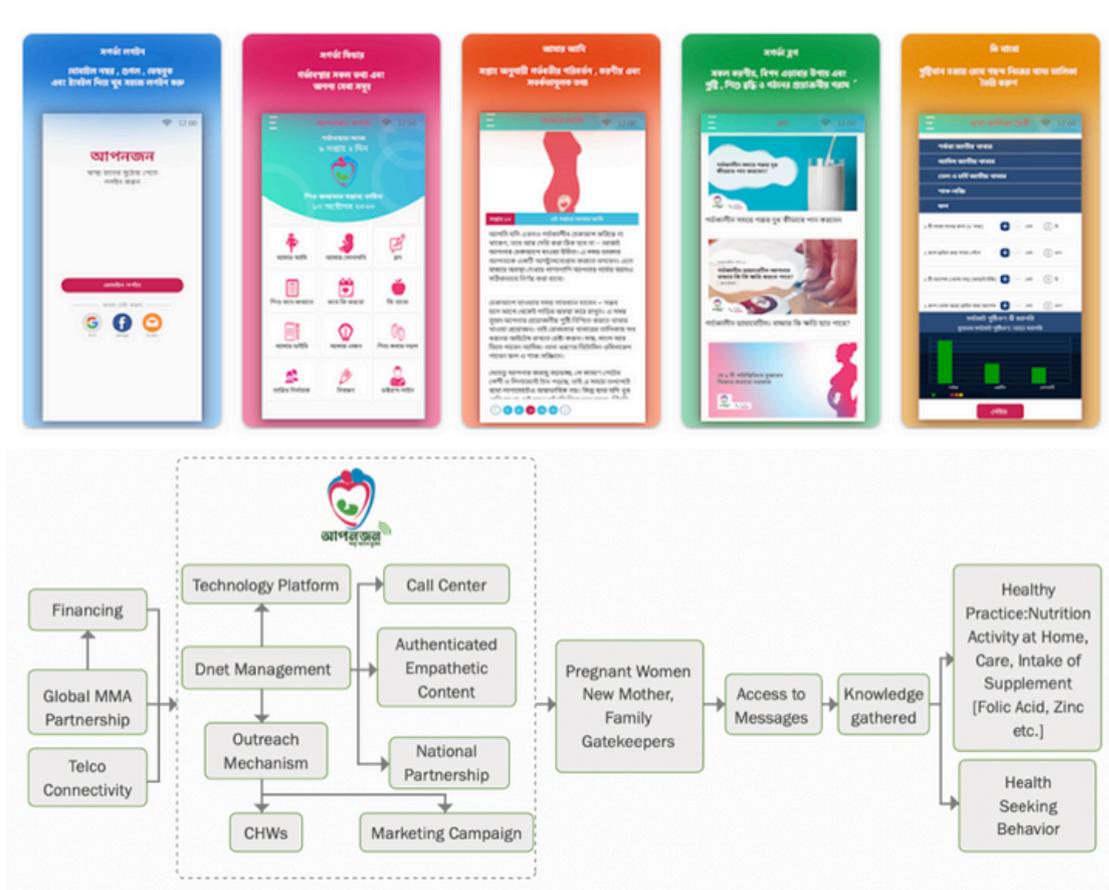
4.2 Information and communication to end users

4.2.1 Aponjon

Aponjon is a mHealth service programme for pregnant women, new mothers and family members. An information-based intervention, it aims to improve health outcomes through behavioural change - specifically increasing the number of antenatal check-ups and facility-based deliveries. This is achieved by disseminating gestational and age appropriate information to their audiences through mobile phone networks. The conceptual pathway to achieve health outcomes is illustrated in Figure 1.

Launched in 2012, the Aponjon initiative was part of a global mHealth effort, the Mobile Alliance for Maternal Action, funded by USAID and supported by the Bangladesh government. Implemented by Dnet, a social enterprise, the service provides regular text and voice messages to subscribers (mothers and family members) tailored to the stage of pregnancy, a mobile App (see Figure 1), chatbot, online resources and a call centre with counselling and an 'Ask a Doctor' service which allows subscribers to submit health-related inquiries. The pay per use model charges users for messages received and time spent on doctor's consultations. Initially, the fee could be discounted or waived depending on the socio-economic status of the subscriber. The App is free and the service is available on all national telecoms networks[4].

Figure 1: Aponjon App and pathway for achieving health outcomes
Sources: MAMA "Aponjon" Formative Research Report (2013); Googleplay store



[4] Raihan, A. 2016 "Aponjon" MHealth Compendium Special Edition 2016 Available at: https://lib.digitalsquare.io/bitstream/handle/123456789/77601/aponjon_se.pdf?sequence=1

Outcome: Aponjon acquired 100,000 subscribers by 2013[5] but the number of subscribers receiving text or voice messages subsequently declined and plateaued at 10,000 in 2022 (Key informant 11). Research conducted in the initial period of the initiative (2011–2012) found that majority of subscribers were low-SES women and their family members. At the end of 2022, approximately 70% of users were from rural areas, and it was estimated that 10% were from very low income, and 80% were from low and middle-income groups.

In early customer surveys, 94% of respondents reported they were satisfied with the service[6]. The Aponjon app has been downloaded more than 100,000 times but D-net estimates that the number of active users is much lower, at 4,000. The App has user-initiated functions such as a ‘Ask the Doctor’ telemedicine consultation service and the chatbot, and platform initiated functions such as message reminder services. The ‘Ask the Doctor’ telemedicine service is valued by users and the chatbot had low user demand. Users found the reminders (scheduling appointments, check-ups etc), information about danger signs, childcare tips and information on mental wellbeing most useful. A study conducted on the impact of Aponjon found a 30% increase in ANC visits and facility care. Informal feedback from users described some rural communities gathering in groups to listen to messages received by one subscriber, suggesting that the reach of the information is potentially much higher than the subscriber base.

Issues: According to Raihan (2021), “Aponjon has faced some vital challenges in the process of scaling up its operations. Lack of funding for above-the-line campaigns crippled the programme’s ability to sustain its brand communication efforts. In spite of co-branding efforts with products of high rural market penetration, the programme never overcame the need for launching above-the-line campaigns as the rate of self-registration was persistently low. Also, mostly due to the former, Aponjon had to heavily rely on customer acquisition led by community-based agencies that had to be paid more than some leading non-governmental organizations.” According to a key informant, the subscription decline is attributed to the lack of costly and resource-intensive marketing efforts. Overall, the technical platform performs well but connectivity of the end-user limits the range of services that they can access.

The integration of AI into the Aponjon platform has been considered. Block chain technologies are used to record payment of fees by users. Machine learning could in principle be used to personalize content. However, Key Informant 11 noted two major constraints: the lack of a suitable training dataset in Bangladesh; and the lack of digital medical records of individuals. Key Informant 13 also noted that the current data available were not collected or structured for the purposes of training predictive AI systems for antenatal conditions.

Prospects: The service continues to be offered by Dnet but it is not financially sustainable.

4.2.2 Smart bangle, Grameen-Intel

To encourage ANC take-up and use of facilities for delivery, Grameen-Intel developed a smart bangle which provides pre-recorded messages to expecting mothers based on the gestational period. The decorative wearable device was piloted and assessed in 2018–2020. A study involving 440 participants showed significant positive impact on ANC visits (from 11–25% pre-intervention to 40–74% during the intervention). Qualitative data suggested that participants viewed the device very positively “like a doctor at home”[7]. However, one key informant familiar with the intervention expressed doubt about the device’s potential for sustainable scalability.

[5] Ibid.

[6] Dnet and Johns Hopkins University, 2013, MAMA “APONJON” Formative Research Report, December 2013
https://www.researchgate.net/publication/304170339_MAMA_APONJON_Formative_Research_Report

[7] Rahman, Aminur et al, 2021, “Whether a pre-recorded electronic bangle can prompt ante natal care seeking behaviour or not? before and after covid-19” Available at:
https://apha.confex.com/apha/2021/meetingapi.cgi/Paper/494277?filename=2021_Abstract494277.html&template=Word

4.2.3 Changing behaviour through television, BBC Media Action[8]

In 2017, BBC Media Action produced a series of health dramas and health discussion shows to educate pregnant mothers. The programmes aimed to change behaviour around and improve knowledge about the importance of regular ANC check-ups, preparation for birth, and essential newborn care. They also sought to promote discussion, address the social norms that drive behaviours, and encourage pregnant women to: go for ANC check-ups with a skilled health worker, prepare for birth, and deliver with a skilled birth attendant.

An experiment was conducted to assess the effectiveness of coupling the two programmes together, and analysis was done to assess the effects of the different topics covered.

Outcome: It was found that the programmes increased viewers' knowledge and behavioural intent to practice health behaviours, and the effect was stronger when both programmes were watched. It was also found that the framing of topics covered is important. The discussion episode on pregnancy complications may have led viewers to associate ANC check-ups with ill health, hence having a counterproductive effect on behavioural intent.

Issues: Framing of the educational subject has an impact on audience receptiveness towards the subject. Due to cultural norms, ill health and negative outcomes are taboo and sensitive topics. Key Informant 1 explained that preventive actions such as saving money or going for health check-ups can be perceived as actions which "invite trouble". Households with this mentality believe that the act of preparing for bad situations will induce the occurrence of these events. There were even accounts of households turning aggressive against CHWs who spoke about potential pregnancy complications.

Television shows are watched by the whole family and interventions have to be targeted at the community, with particular consideration that elders with more decision-making power are often part of the group. Key informant 1 shared that in the development of TV programmes, sensitive topics such as sexually transmitted diseases had to be introduced indirectly so that it would not be deemed inappropriate by elders in the family. Elders have a big say and influence on the programmes viewed and they could support or impede its viewership.

Smartphones are mobile devices that are also typically owned by the males in the household. Mothers typically would only have access to these devices after working hours, when their husbands return from work.

Prospects: The use of television programmes as a medium for education is very effective and useful, particularly in the urban setting where there is more prevalent access to televisions. However, given the communal nature of television devices, the effectiveness of television programmes is largely contingent on the decisions made by key household members.

4.3 Information/ training for frontline healthcare providers

Interventions considered here include those directed towards CHWs, clinic staff and other frontline healthcare professionals. They include information on guidelines and procedures, checklists, risk flagging, and educational video content.

[8] <https://globalhealthstories.com/wp-content/uploads/2017/03/170321-RCT-briefing-final-web-file-for-UK.pdf>

4.3.1 Safe Delivery App

This app provides digital resources to health care providers. This includes written information, checklists and video tutorials. One key informant pointed to the value of the App for midwives who were able to receive guidance if faced with an unfamiliar situation during a delivery if needed. Another key informant expressed scepticism about the practicality and operational feasibility of using digital resources in the delivery room amidst a delivery, which is not only challenging but could also divert attention away from the patient. The Safe Delivery App has over 100,000 downloads in the Googleplay store.

Digital resources have also been developed for CHWs under a USAID-funded initiative. These include checklists and videos for use during community visits. A Key Informant explained the value of these resources:

- CHWs carry very heavy materials for their house visitations - books, leaflets, posters, and flash cards. The heavy baggage was particularly burdensome during the rainy season when they also had to carry umbrellas and prevent their materials from getting wet. The app consolidated these materials and made them accessible through a mobile device, to which most health workers had access.
- CHWs face challenges in providing advice to households as they are not viewed as a trusted source of medical information - they do not wear "aprons" or look like medical professionals. As community members trust doctors more, the app allowed CHWs to "bring the doctor to them". Videos of doctors delivering the message/attesting to the CHWs' credibility could be shown to the community to increase trust and change behaviours.
- The quality of the information shared by CHWs vary according to the health workers' familiarity of the topic. The use of video materials can raise the consistency and quality of health information shared by health workers. Access to these training and refresher materials also increases the confidence of health workers when they conduct their door-to-door visits.

A formal evaluation of the App was not available but the key informant expressed the view that the App had met the needs expressed by CHWs. Three limitations were noted. First, there is a wide age range among the frontline community health workers. The workers in their 40-50s are not familiar with smart phones and find it challenging to adopt these apps. Second, smart phones and data plans are not provided to CHWs as part of their role so access to the App depends on the CHW personally having a suitable device and ability to connect. Third, both workers and the families they visit are time-constrained. Workers may not have time to show short videos of 3 - 5mins in their entirety and instead just show 1 - 2 minutes of key points. As a result, some useful information may not reach end-users during CHW visits.



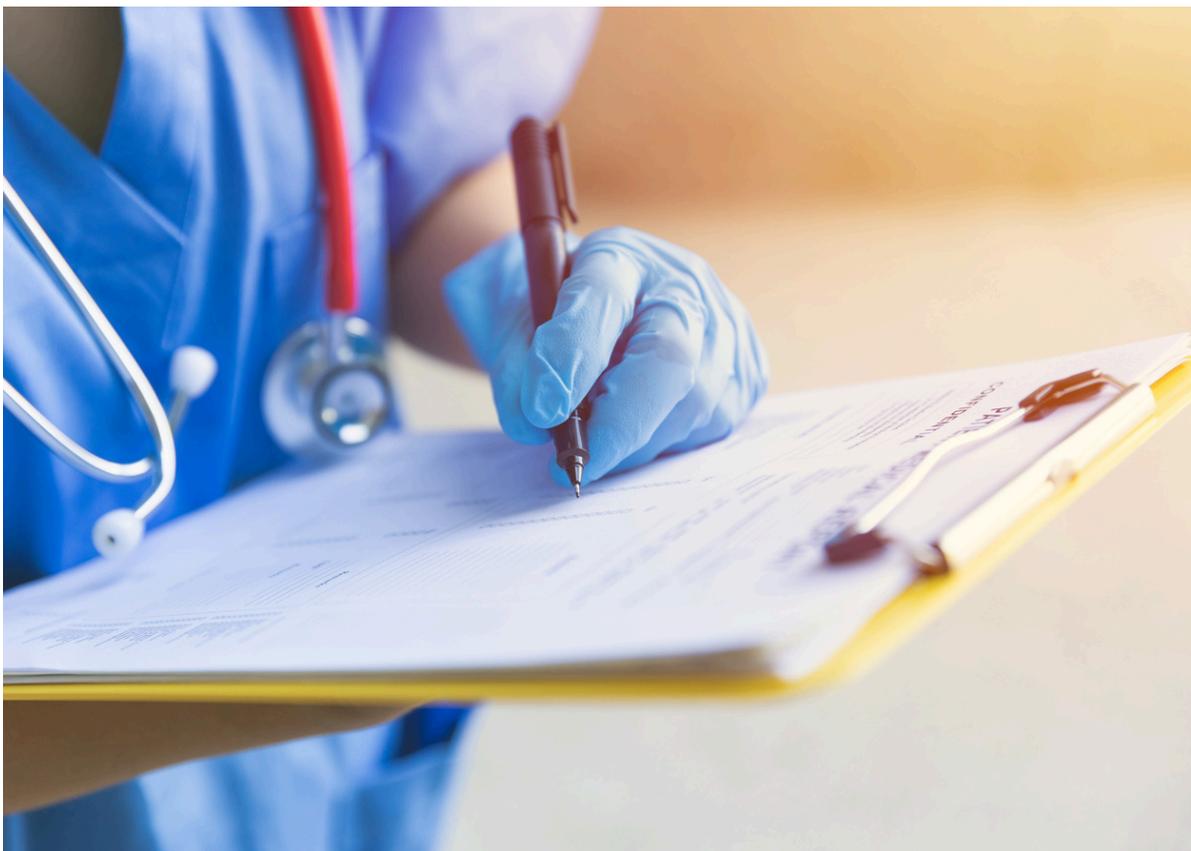
4.4 Interviews: Cross-cutting themes

Informants raised a number of general challenges for interventions centred around digitalization of record-keeping:

- Digital data input creates an additional burden for already heavily-burdened health workers when it runs in parallel to paper-based systems, when additional information is required in the digital system, or when the digital system mandates complete entries. A key informant responsible for managing a health facility noted that they had to appoint a member of staff to enter data into national databases. In some settings, doctors may see up to 300 patients in a day. Key informant 11 noted that a doctor might take just one minute to complete a paper data entry, and up to two minutes for a digital data entry. In this context, any increase in the administrative burden arising from digital data input reduces the ability of the health care provider to meet the priority objective of seeing patients. This disadvantage needs to be weighed against better information management in the digital system.
- Information management on ANC has greatly improved through digitalization. However, there are now several government and non-government information systems in use which are not interoperable. DGHS and DGFP have separate systems which do not 'speak' to each other. Furthermore, private facilities are not bound [MOU] to provide information on ANC or births. This results in large information gaps which make it more difficult to use the eMIS data for analytical purposes. Beyond information gaps, the existing data has not been collected or formatted for the purposes of training AI. This presents in operational challenges where the data has to be cleaned before they can be used and issues of validity as the data may not be representative for the issues they are being used to tackle.
- Use of data by supervisors/managers. Managers may not know how or when to use data dashboards. Organisational culture may take time to change so that dashboards are used effectively for monitoring. Key informant 7 also indicated that even with sophisticated levels of data, the majority of administrators are not data science trained and would not be able to draw meaningful conclusions effectively – AI could fill this capability gap for predictive and prescriptive analytics.

In relation to services for CHWs, cross-cutting challenges raised by key informants included:

- Resource constraints. In rural areas, CHWs may have large geographical coverage areas, leading to long travel times and may be continually over-burdened (Key informants 1, 4, 5).
- Lack of support from supervisors, managers and the health system.



Regarding services for end-users, key informants pointed to the need for certain enabling conditions to be met, notably:

- **Technical:** access to phone, mobile devices, tracking devices, remote measurement tools. While most households have access to a mobile phone, including low income and rural households, an expecting mother may not receive a call or message because the phone is with the husband or other family members, or because the pre-paid amount has been used up and the phone is switched off (Key Informant 3). Beyond mobile access, access to basic healthcare services remains a challenge for some in rural areas, particularly nomadic or displaced populations. For these groups, the provisions of a phone or informational service will fall short in the face of emergencies as they are simply unable to access the medical support needed (Key Informant 14).
- **Social:** young women have no decision-making power within the household; customs, traditional beliefs play a strong role. Key informant 1 provided a number of examples of social factors which affect take-up of mobile-based information services: families may discourage or prevent young women from using the internet as they are thought to be at risk of speaking to strangers; young women were found to be shy and embarrassed to speak about their physiological conditions to non-female healthcare workers (Key Informant 14); knowledge and care during pregnancy is often seen as the responsibility of a mother-in-law or grandmother, rather than the pregnant woman herself; some families are not open to information about danger signs or risk factors because they believe that hearing about dangers during pregnancy would invite misfortune.
- **Organisational:** many women do not have ID cards, although these are increasingly required for accessing some government services and assistance from NGOs. This makes it impossible to track women who use multiple health care providers during the course of their pregnancies (Key informant 3). In medical facilities, organisational processes may be so complex that it is challenging to digitize them (Key informant 11).



5.0 Documentary review: AI in ANC

There are several applications of AI in the health care context. Current AI-based software is narrow and limited to performing specific tasks such as diagnosing specific conditions or processing natural language to provide an appropriate response in the form of chatbots or self-service frequently asked questions (FAQ) navigation platform. At this time, AI is not being used to perform complex, general tasks such as making clinical decisions or providing treatment plans, which require the consideration of multiple factors and types of information. Broadly, AI applications in healthcare fall into three categories: (1) clinical- decision support tools, (2) patient-decision support tools and (3) healthcare administration.

In Nigeria and the Philippines, in-built diagnostic apps have been developed to classify patients and escalate them for further consultation. In Vietnam, AI has been used to provide treatment and follow-up recommendations to doctors to facilitate their decision-making.

Carter et al. (2019)[12] reviewed 13 papers related to the development of mobile apps pertaining to clinical decision support for pregnancies. Most papers report early-stage development of the mobile app, and feasibility or acceptability studies designed to inform further development. Due to the lack of implementation at scale, these papers often discuss the benefits of adoption and barriers to implementation, but there do not appear to be any studies yet which provide a full evaluation of the use of AI apps, their acceptability to clinicians, patients or regulators, or their impacts on clinical decisions or maternal health outcomes.

5.1 Clinical-decision support tools

AI is used in diagnostic imaging, predicting the onset of medical conditions, predicting 20 treatment outcomes, remote monitoring of patients, and robotics in surgery. These tools, devices and applications support clinical practitioners in the delivery of their work.

In the context of ANC, AI has been used to improve the diagnosis and detection of birth defects and adverse perinatal outcomes. These conditions include gestational diabetes, gestational hypertension, prenatal depression, preeclampsia, foetal pathologies, birth weight and pre-term birth. However, its implementation remains relatively nascent worldwide. In a recent literature review on the use of AI to predict perinatal health, Ramakrishnan et al. (2021) [9] reported that the use of real time electronic health medical records and predictive modelling has found early success in foetal monitoring and monitoring of women with gestational diabetes in low resource settings. In Saudi Arabia, AI has been used to predict the mode of delivery which facilitates early referrals to escalated medical care as required (Ullah et al., 2021)[10].

AI systems and interfaces have also been used to conduct baseline monitoring of vital signs and flag out abnormalities which warrant further medical attention. While this enables a wider coverage of care and facilitates the allocation of time and resources, access to basic measurement equipment or tools are still required for these apps to function. In China, apps have been developed to monitor fetal heart rates, blood glucose and weight remotely (Shu et al., 2021)[11].

5.2 Patient-decision support tools

Medical devices and applications can also provide information and recommendations directly to expecting and new mothers and their families. These patient-decision support tools come in the form of mobile apps providing tailored information by gestational period, apps for data entry and tracking, chatbots, online tools to support identification of danger signs during pregnancy and signs of labour, and lifestyle applications such as fitness trackers.

Educational apps for expecting mothers have been deployed in a number of high-income countries including the US, Spain and South Korea. In relation to technology acceptance and adoption, the user-friendliness of the application was found to be a major factor supporting sustained use (Gance-Cleveland et al., 2019)[13]. A study in Spain showed that users felt more confident and trusted the system more when the app explained the system's decisions and recommendations (Oprescu et al., 2022)[14]. In terms of outcomes, apps in the US were found to support patient adherence to treatment and pregnancy management plans. Beyond education, apps deployed in South Korea helped mothers to monitor and manage their treatment and ante-natal appointments (Kim et al. 2022) [15]. In Italy, an app targeted at improving mental wellness among pregnant women was found to improve users' sense of autonomy and greater self-acceptance after childbirth (Carissoli et al., 2022).

[9] Ramakrishnan R, Rao S, He J-R. Perinatal health predictors using artificial intelligence: A review. *Women's Health*. 2021;17. doi:10.1177/17455065211046132

[10] Ullah Z, Saleem F, Jamjoom M, Fakhie B. Reliable Prediction Models Based on Enriched Data for Identifying the Mode of Childbirth by Using Machine Learning Methods: Development Study. *J Med Internet Res* 2021;23(6):e28856. DOI: 10.2196/28856

[11] Chang Shu, Shumei Han, Linli Li, Peng Xu, Yule Bai, "The Clinical Application and Prospect of Smart Prenatal Care and Postpartum Recovery"; *Journal of Healthcare Engineering*, vol. 2021, Article ID 3279714, 8 pages, 2021. <https://doi.org/10.1155/2021/3279714>

[12] Carter, J., Sandall, J., Shennan, A.H. et al. Mobile phone apps for clinical decision support in pregnancy: a scoping review. *BMC Med Inform Decis Mak* 19, 219 (2019). <https://doi.org/10.1186/s12911-019-0954-1>

[13] Gance-Cleveland, B., Leiferman, J., Aldrich, H., Nodine, P., Anderson, J., Nacht, A., Martin, J., Carrington, S. and Ozkaynak, M. (2019), Using the Technology Acceptance Model to Develop StartSmart: mHealth for Screening, Brief Intervention, and Referral for Risk and Protective Factors in Pregnancy. *Journal of Midwifery & Women's Health*, 64: 630-640. <https://doi.org/10.1111/jmwh.13009>

[14] A.M. Oprescu, G. Miró-Amarante, L. García-Díaz, V.E. Rey, A. Chimenea-Toscano, R. Martínez-Martínez, M.C. Romero-Ternero (2022), Towards a data collection methodology for Responsible Artificial Intelligence in health: A prospective and qualitative study in pregnancy. *Information Fusion*, Volumes 83-84, Pages 53-78. ISSN 1566-2535, <https://doi.org/10.1016/j.inffus.2022.03.011>.

[15] Kim, B., Moon, J.Y., Shin, J.Y. et al. Effect of smartphone app-based health care intervention for health management of high-risk mothers: a study protocol for a randomized controlled trial. *Trials* 23, 486 (2022). <https://doi.org/10.1186/s13063-022-06425-3>

In a systematic review of experimental studies of decision-support tools for expecting mothers, Ngo et al (2020) [16] found consistently positive attitudes of mothers towards the tools and a range of positive impacts from the user's perspective. Support tools focusing on genetic screening reduced decisional conflict for mothers and increased their knowledge about the process. Tools to track blood glucose through self-testing and reporting led to more readings, and made mothers feel more satisfied and in control of their health. A similar type of tool relating to blood pressure led to mothers providing more readings, and were more willing to share and discuss the information with their healthcare providers. They felt they had better control of their symptoms and higher quality of life. An app providing gestationally-appropriate information about wellbeing led to mothers having lower levels of anxiety and greater confidence. Overall, the study noted that the mothers involved in these studies tended to be drawn from higher socio-economic groups than the general population, and that those with higher education levels were more positively disposed towards the technologies, understood information better and benefited more from their use.

A number of studies focus on patient-focused apps developed and used in middle and lower-income countries. In Malaysia, an evaluation was conducted on the Amila Pregnancy app to assess if users are able to navigate the app and use its various functions. With over 500,000 downloads worldwide, the app helps mothers monitor their pregnancy, week by week, by providing information on fetal development, and allowing users to input data on current weight and log instances of "baby kicks". The evaluation found the interface of the app could be improved through bigger icons better menu categorisation for sustained adoption. Despite its relatively poor interface, the app can be a suitable medium to provide expert advice and provide support to pregnant woman who value information (Hussain et al., 2017)[17]. In Sri Lanka, an educational app, "MumCare" featured a chatbot which communicates and guides the mother in a way that creates the illusion as if they are talking to their unborn child. As a proof of concept, the AI based chatbot seems to be valued by users (Maduwantha & Vithana, 2021)[18].

In Italy, an app targeted at improving mental wellness was developed and it was found that the app improved users' sense of autonomy and greater self-acceptance after childbirth (Carissoli et al., 2022)[19].

A 2019 study in Uganda utilised the Technology Acceptance Model to identify five factors contributing to the use of eHealth systems for routine antenatal care amongst mothers – performance expectancy, effort expectancy, social influence, facilitating conditions and behavioural intention (Namatovu et al., 2021)[20]. It was found that facilitating conditions including digital literacy, cost, access to the applications and technical infrastructure had the largest effect on adoption. Participants also cited the lack of user involvement during the development of mHealth technologies which result in the inclusion of functions which are not valued by users. In terms of effort expectancy, usability and prior training on how to use the technologies stood out as participants indicated that they would be quickly discouraged if they could not use the app easily, but prior training could mitigate this problem.

In a controlled quasi-experimental study in Tanzania, Masoi and Kibusi (2019)[21] found that an interactive SMS system improved mothers' knowledge of danger signs and their birth preparedness compared to the control, with large and significant effect sizes (an 85% increase in knowledge of danger signs and and 90% increase in birth preparedness). Similar to other studies, the effects were stronger among the more educated participants, possibly indicating their greater ability to understand and interpret the messages received. The system sent health education messages to mothers and fathers appropriate to gestation period and users were also able to send and receive individualized responses as needed. Messages were free of charge. The majority of participants used the query service and feedback was positive, although the study did not report detailed findings on use or perceptions of the service among users.

[16] Ngo, E., Truong, M. B. T., & Nordeng, H. (2020). Use of decision support tools to empower pregnant women: systematic review. *Journal of Medical Internet Research*, 22(9), e19436.

[17] Azham Hussain, Emmanuel O. C. Mkpogogu, Najdawatil Mohd Fadzil, and Norhasizasuriati Mohd Hassan, "The UX of amila pregnancy on mobile device", AIP Conference Proceedings 1891, 020061 (2017) <https://doi.org/10.1063/1.5005394>

[18] Maduwantha, M. C. ., & Vithana, V. (2021). "MumCare": An Artificial Intelligence Based Assistant. *International Journal of Electrical and Computer Engineering Research*, 1(1), 21–28. <https://doi.org/10.53375/ijecer.2021.25>

[19] Claudia Carissoli, Deborah Gasparri, Giuseppe Riva & Daniela Villani (2022) Mobile well-being in pregnancy: suggestions from a quasi-experimental controlled study, *Behaviour & Information Technology*, 41:8, 1639– 1651, DOI: 10.1080/0144929X.2021.1894484

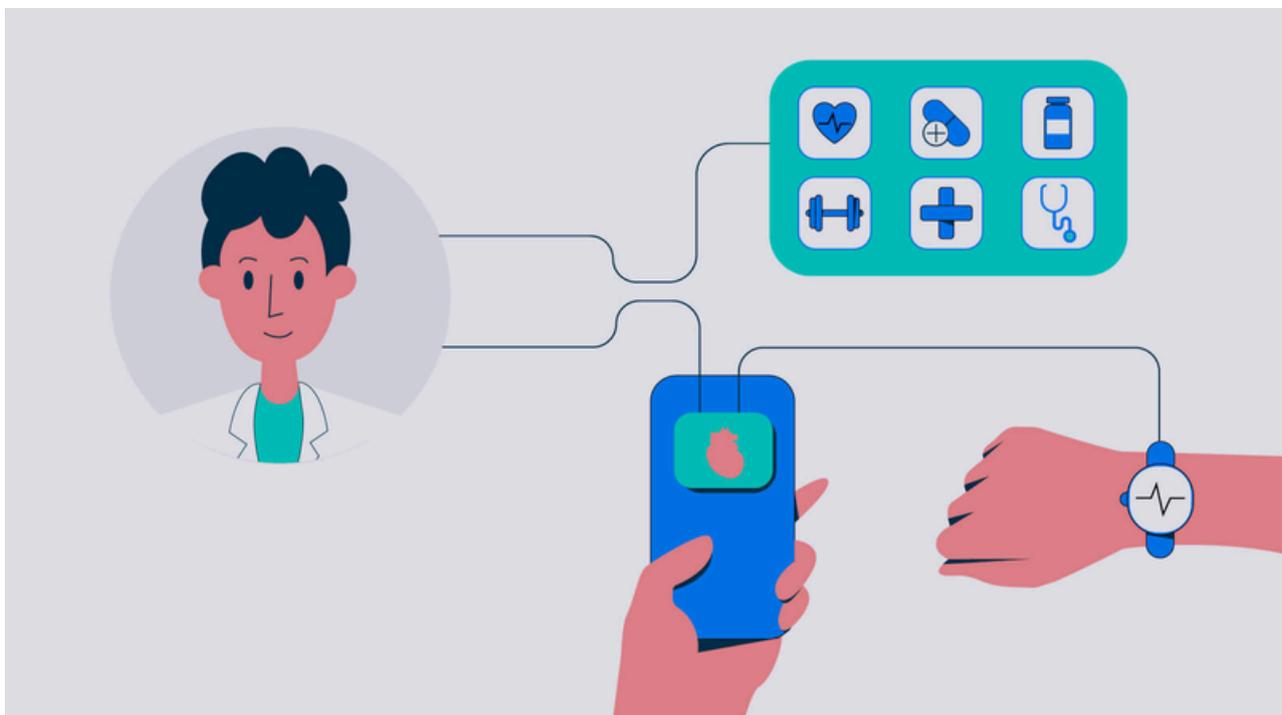
[20] Namatovu HK, Oyana TJ, Sol HG. Barriers to eHealth adoption in routine antenatal care practices: Perspectives of expectant mothers in Uganda – A qualitative study using the unified theory of acceptance and use of technology model. *DIGITAL HEALTH*. 2021;7. doi:10.1177/20552076211064406

21] Masoi, T. J., & Kibusi, S. M. (2019). Improving pregnant women's knowledge on danger signs and birth preparedness practices using an interactive mobile messaging alert system in Dodoma region, Tanzania: a controlled quasi experimental study. *Reproductive health*, 16, 1–10.

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[20] Namatovu HK, Oyana TJ, Sol HG. Barriers to eHealth adoption in routine antenatal care practices: Perspectives of expectant mothers in Uganda – A qualitative study using the unified theory of acceptance and use of technology model. DIGITAL HEALTH. 2021;7. doi:10.1177/20552076211064406



Puspitasari et al (2022)[22] report on user involvement in the development of a chatbot for expecting mothers and midwives in Indonesia providing health information. In focus group discussions, participants expressed the need for information on discomfort in pregnancy, recognising danger signs and signs of labour, psychological issues, health behaviours (nutrition and nutritional supplements, rest, personal hygiene, clothing and physical activity, sex during pregnancy) and information about the availability and costs of ANC and national health insurance schemes. The development of this chatbot through exploratory qualitative data collection is consistent with previous research showing the value of a user-centred approach to health technology interventions and provides a model for design and development in other contexts.

For successful implementation, strategies such as co-development, training end-users, garnering support at the national and hospital levels should be advocated to improve user acceptance of technology and magnify the positive impacts demonstrated in these studies.

[22] Puspitasari, I. W., Rinawan, F. R., Purnama, W. G., Susiarno, H., & Susanti, A. I. (2022, October). Development of a Chatbot for Pregnant Women on a Posyandu Application in Indonesia: From Qualitative Approach to Decision Tree Method. In *Informatics* (Vol. 9, No. 4, p. 88). MDPI.

5.3 Healthcare administration

AI is also used in healthcare administration and the better provision of services. These tools are used by organisations to facilitate resource allocation, cost reduction, process optimisation and automation of processes such as dispensing medication.

In Vietnam, AI has been used to facilitate patient appointment scheduling with doctors, provide reminders and recommendations for follow-up actions (Le Nguyen & Do, 2019)[23] . Coupled with remote monitoring, AI has also been widely used in resource scarce localities to flag out and escalate patients with higher risk factors for attention.

5.4 Factors related to data collection

Data used for AI analysis can be collected through the use of dedicated devices such as blood pressure measurement tools and thermometers, remote sensors and wearables, or direct input provided by users. The usability of these data inputs vary widely based on the precision of the tool utilised for recording, the user proficiency of the tool, the amount of data collected and factuality/precision/accuracy of data entered.

In the implementation of remote monitoring and data collection through wearable devices, ancillary factors which influence the continued usage of these devices must be considered. In a qualitative study on the usage of self-tracking applications conducted by Nathaniel Tan (2020), it was found that operational factors often impede the successful collection of data for analysis. For example, as users need to wear these devices continually for comprehensive data collection, the physical comfort of these wearables become a very pertinent concern. Other operational factors include battery life, memory space and convenience of usage (e.g., actions required to record and transfer the data).

AI in ANC is still largely nascent in its development, particularly in its application of most maternal health outcome prediction tools where there are only preliminary results. While the early-stage outcomes may show promise for adoption in Bangladesh, users must be aware that these applications were built with different population data sets which may not be representative of the Bangladesh population. Further assessment must be made on the accuracy of the prediction tool before wholesale adoption in the Bangladesh context.

In terms of educational platforms and FAQ systems, the adoption of such tools has found to be heavily influenced by the cost of adoption and usability of the system. In particular, the navigability of applications would have an impact on the continued usage of the application. These user interface learnings should be taken into consideration when developing different applications.

Thirdly, the use of reminder systems will promote the adherence of health management behaviours. Currently, the Aponjon system and the envisioned OpenSys Individual Maternal and Immunisation Tracking System developed by UNICEF has or will have these functionalities.

In terms of service delivery, Bangladesh is facing a shortage of CHWs and these resource constraints could be alleviated through the use of AI in optimising schedules and route planning. There are robust studies and international experiences in supply chain optimisation or study of the “Chinese postman problem” where shortest delivery routes are identified to minimise resource usage. Such resource optimisation solutions from other non- ANC related fields could minimise the number of CHWs required to serve a region and improve service delivery.

6.0 AI Adoption Readiness Assessment

In this section, we assess the current conditions for AI adoption in Bangladesh in three areas: digital and physical communications infrastructure, social and demographic conditions, and economic conditions.

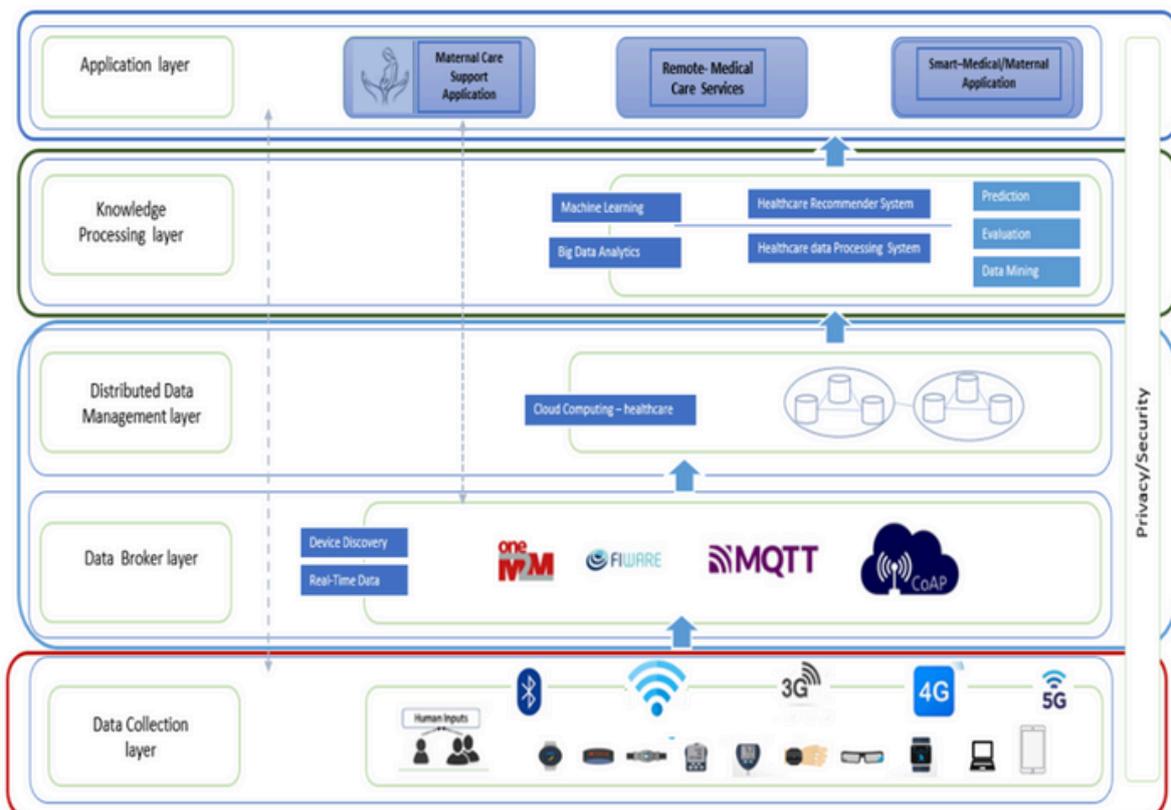
6.1 As-Is: Digital and physical infrastructure

These can be defined as factors that point to the capability of the existing infrastructure ecosystem to support the development, adoption, and use of AI technologies in maternal healthcare. Such legacy factors include:

- Access to meaningful broadband connectivity, defined as having access to a fast internet connection (powered by 4G connectivity), an appropriate device, enough data, and regular internet use (UNESCAP, 2021).
- Access to appropriate devices by expecting mothers and healthcare providers. Such devices may include but are not limited to smartphones, wearables, mobile ultrasounds powered by AI and 4G capabilities, etc.
- Access to a reliable power supply on both ends of maternal service consumers and providers.
- Availability of healthcare facilities that can support maternal health needs.
- User identification, which is fundamental to patient data collection. Without this, it is hard to collect meaningful data that can power AI applications in healthcare.

Figure 2 illustrates the different layers that are required for the development of an AI- powered mobile healthcare platform for continuous pregnancy monitoring. The model can help stakeholders understand and evaluate the required and as-is digital and physical infrastructure conditions, the different state-of-the-art technologies, data standards, and platforms, and the different data acquisition and processing layers involved in a robust AI system.

Figure 2: Conceptual Model of the Digital Infrastructure Ecosystem
Source: Authors' elaboration

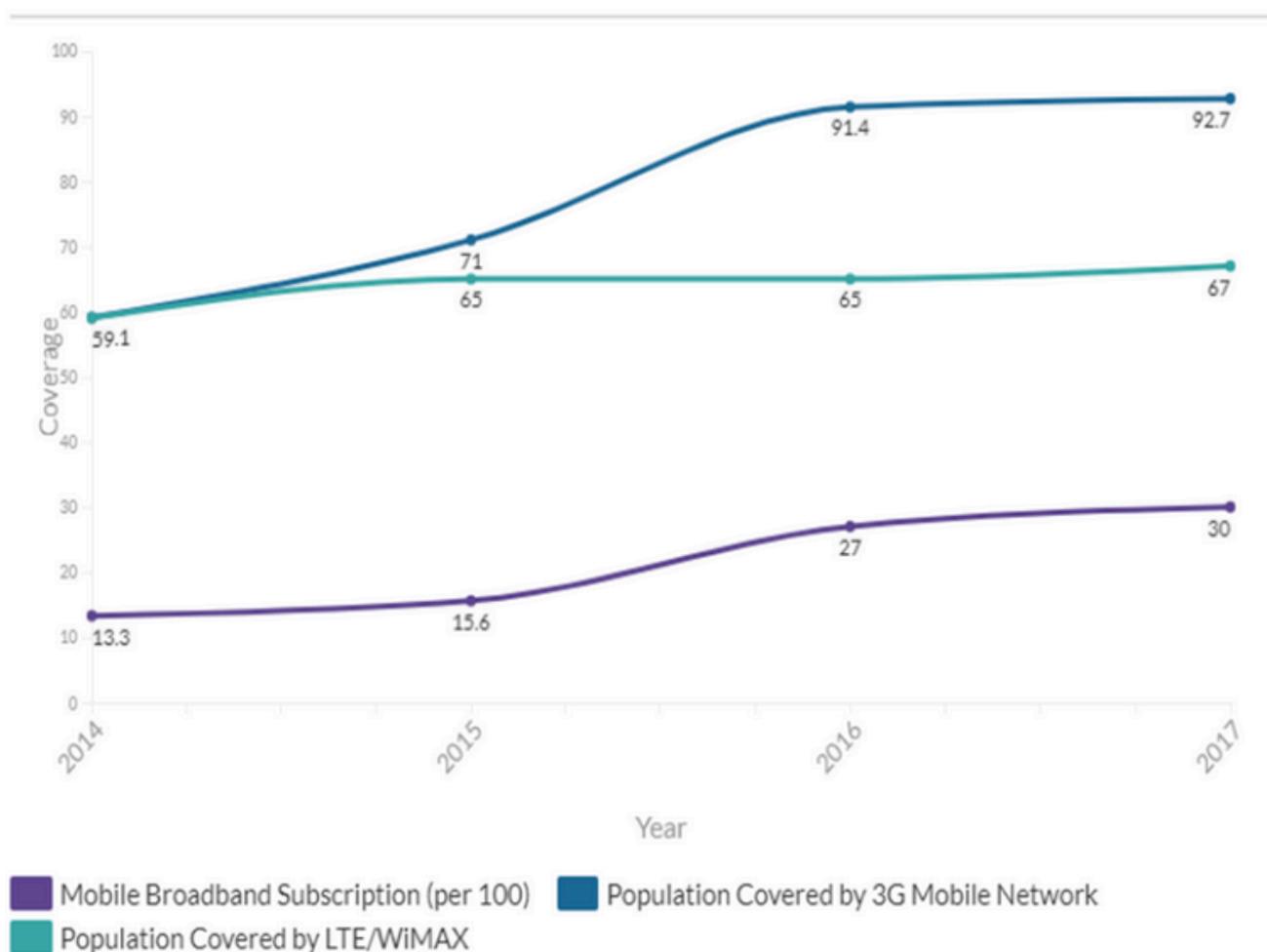


The fundamental data collection layer is the pre-requisite for any technology deployment. It is where devices and sensors (such as mobile and smartphones, mobile ultrasounds, healthcare wearables that can help with maternal monitoring, etc), and a network of trained users (doctors, nurses, community healthcare workers, birth attendants, and expectant mothers) to provide human input, are interfaced with data broker layer through broadband and internet networks.

On the network component of the data collection layer, the data in Figure 3 indicate that Bangladesh is making tremendous progress in upgrading its broadband infrastructure. As at 2017, more than 67 % of the population is covered by a 4G LTE/WiMAX network, 92.7 percent of the population is covered by a 3G network, and 30% of the Bangladesh population are mobile broadband subscribers. The number of mobile cellular subscribers stood at over 184 million subscribers and about 103 users per 100 inhabitants in 2019[24].

Official data obtained from ITU and the World Bank indicate that about 87% of households have access to a mobile telephone, and 46% of households can access the internet. These impressive data suggest that Bangladesh is a “mobile first” country that can now support some versions of mobile and e-health services including maternal healthcare, particularly healthcare information-sharing services at the application layer.

Figure 3: Mobile Broadband Infrastructure Coverage in Bangladesh
 Source: Authors’ based on ITU[25] and World Bank Data[26].



[24] “Mobile Phone subscribers”, <http://old.btrc.gov.bd/content/mobile-phone-subscribers-bangladesh-november-2021>

[25] ITU Time Series ICT data for the World: https://www.itu.int/en/ITU-D/Statistics/Documents/facts/ITU_regional_global_Key_ICT_indicator_aggregates_rev2_Sept_2022.xlsx

[26] World Bank World Development Indicators: <https://databank.worldbank.org/source/world-development-indicators>. Data downloaded Nov 2022.

The progress in Bangladesh's digital infrastructure as indicated by the data above however masks some critical important factors that are required in the actual implementation of mobile and AI-powered services in maternal healthcare. For example, wide 4G/LTE/WiMAX coverage does not translate to actual connection and usage. In the analysis, the results show that Bangladesh has low online connection rates.

Figure 4 shows that about 24% of the population have actual access to the internet. The numbers for fixed broadband (users with access to cable modems, digital subscriber line (DSL) internet, fibre-to-the-home, building subscriptions, and terrestrial fixed wireless subscriptions) are even lower at 6% of the population.

These infrastructure barriers limit the range of services that the healthcare system can support. With the existing fixed and mobile broadband infrastructure, limited mobile healthcare and e-healthcare services could be supported. For example, the widespread adoption of mobile phones enables the design of, services at the application layer through these devices.

Figure 4: Percentage of Internet Users and Fixed Broadband Users in Bangladesh

Source: Authors' elaboration based on ITU[27] and World Bank Data[28].

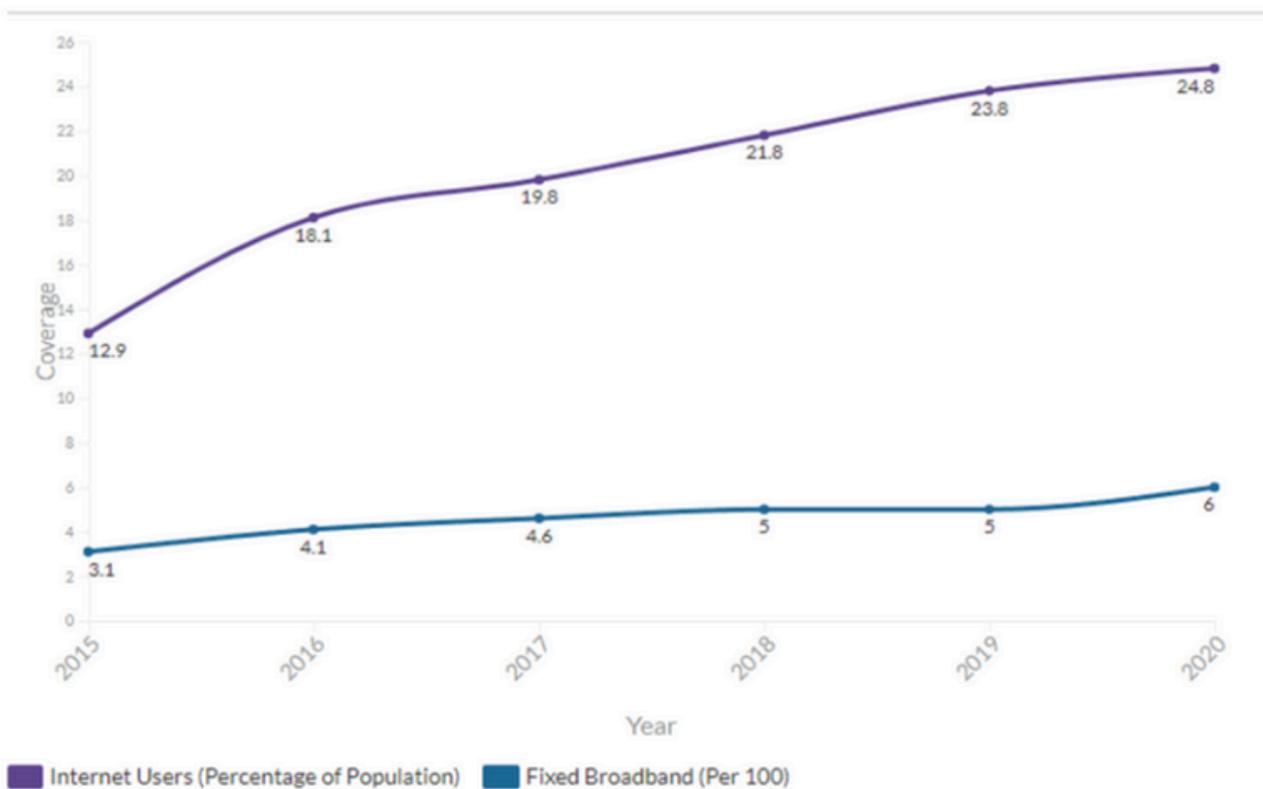


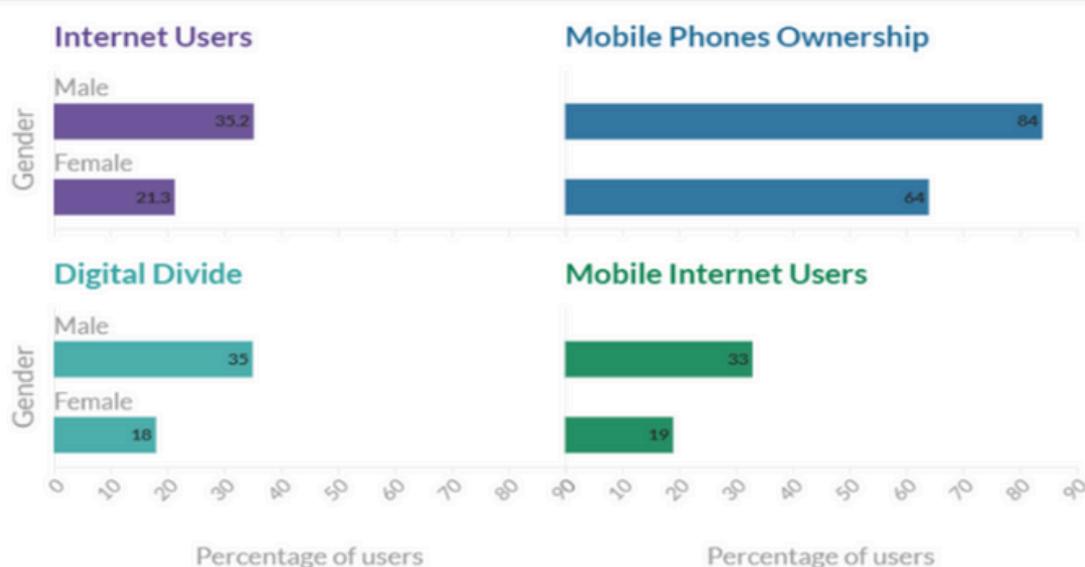
Figure 5 shows that there are important differences in access and use of mobile phones and the internet by gender. According to data obtained from the Bangladesh Bureau of Statistics, ITU, and the World Bank, 21.3% of internet users in Bangladesh are women compared to 35.2% men. When it comes to mobile phone ownership, 60% of women have access to mobile phones while about 86% of men have access to mobile phones.

[27] ITU, *ibid*

[28] World Bank, *ibid*.

Figure 5: Percentage of Internet Users and mobile Phone Users in Bangladesh by Gender
 Source: Authors' based on Bangladesh's Bureau of Statistics[29], GSMA[30], and ITU[31] data.

Mobile and Internet Use by Gender in Bangladesh

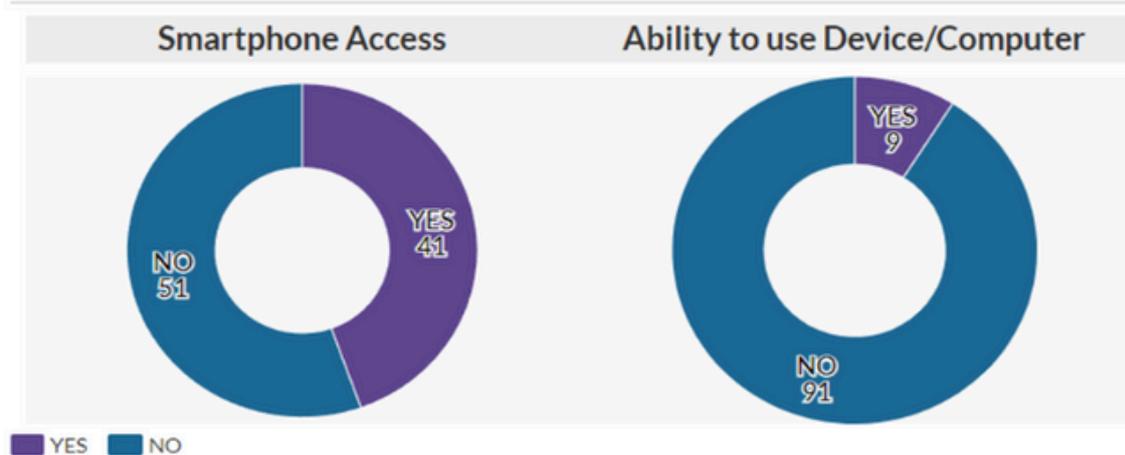


The gender disparities in internet and mobile usage[32] in Bangladesh pose challenges for access. In many cases, expecting mothers may depend on their husband's mobile phone for access to the internet, SMS or voice messages etc which husbands may be unwilling or unable (if working away from home, for example) to provide.

Figure 6 indicates that mobile devices is the main platform used by many, including women in rural areas and underserved communities, for accessing the internet.

Figure 6: State of access to appropriate devices for using digital healthcare in Bangladesh[33].

Smart phone access and ability to use in Bangladesh



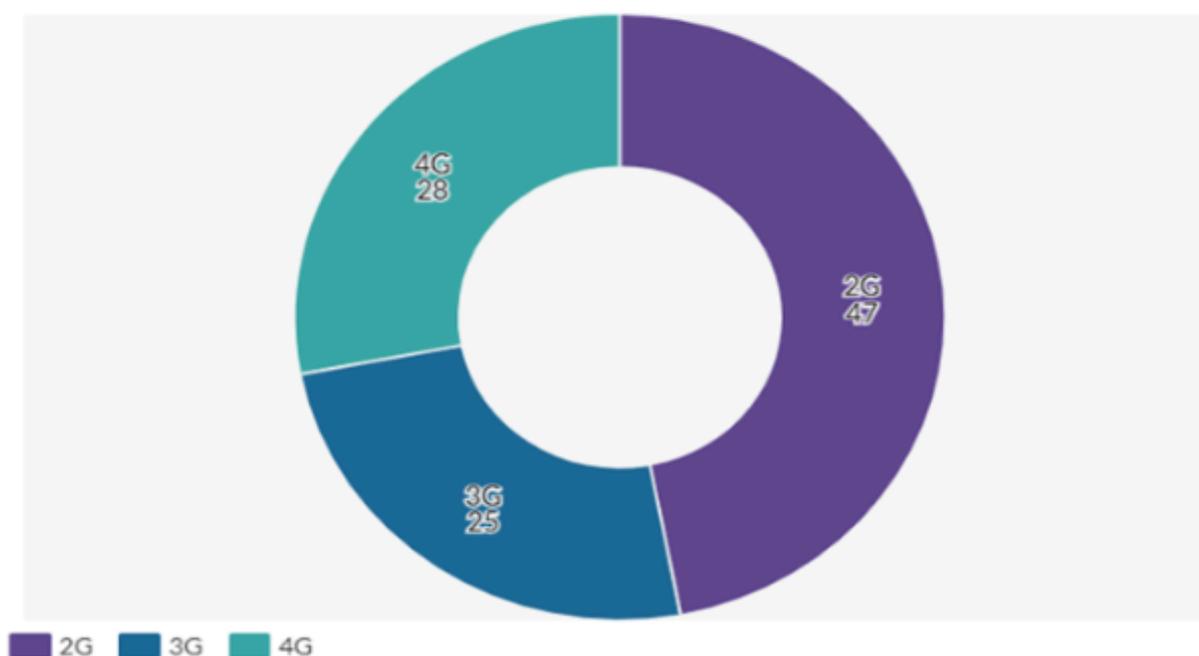
Source: Authors' compilation based on Brac 2019 survey on Digital Literacy

[29] "ICT Use and Access by Individuals and Households 2013," Bangladesh Bureau of Statistics.
<http://203.112.218.65:8008/WebTestApplication/userfiles/Image/LatestReports/ICTUseAccessSurvey2013.pdf>
 [30] "GSMA Country Overview: Bangladesh." <https://data.gsmaintelligence.com/api-web/v2/research-file-download?id=30933394&file=Country%20overview%20Bangladesh.pdf>
 [31] ITU, *ibid*.
 [32] "Bangladesh's mobile internet usage gender gap widest in 10 LMICs", <https://www.tbsnews.net/bangladesh/bangladeshs-mobile-internet-usage-gender-gap-widest-10-lmics-447786>
 [33] "Digital literacy survey", https://bigd.bracu.ac.bd/wp-content/uploads/2020/10/Policy-Brief_Digital-Literacy-in-Rural-Bangladesh.pdf

Figure 7 shows that 47% or majority of mobile phone users rely on 2G connectivity. While 2G has baseline capabilities which can support one-way information transfer, enabling users to access vital information and facilitating communication with service providers, it is unable to support advanced web-based applications. The development of AI powered services requires connectivity which can support two-way exchange of information, and this can only be implemented with 3G and above connections. Hence, the successful deployment of AI solutions for pregnancy monitoring will be partly contingent on the onboarding of citizens on the 3G or 4G network coverage and their actual usage of the improved connectivity – while the 3G and 4G network (covers over 67% of the population (see Figure 3), the actual connectivity and use remains at only 28% (see Figure 7).

Figure 7: Mobile technology as percentage of total internet connections
Source: Authors' elaboration based on GSMA data (GSMA, 2021)[34]

Mobile technology as a percentage of total connections in Bangladesh



The data process to the knowledge processing layer is fragmented and incomplete in Bangladesh. Although there is a National ID card system in Bangladesh, it is not universal, and is not required to access ANC from non-government health care providers. An ID is the basic requirement that health service providers use to create a patient profile in their Electronic Records database(s). It is central to ensuring a continuum of care for an individual and to the collection and analysis of data on care quality and health outcomes at the aggregate level.

Similarly, there is a need to consider the machine readability of the collected data (critical in AI applications development), and this is largely influenced by existing systems of data collection, including the use of mobile devices, wearables, advanced patient records databases (Electronic Health Reports, obstetric reports and lab results). While there are some records present, these need to be converted and standardised in machine readable formats.

[34] "Achieving mobile enabled digital inclusion in Bangladesh" report by GSMA 2021, <https://www.gsma.com/mobilefordevelopment/wp-content/uploads/2021/03/Achieving-mobile-enabled-digital-inclusion-in-Bangladesh.pdf>

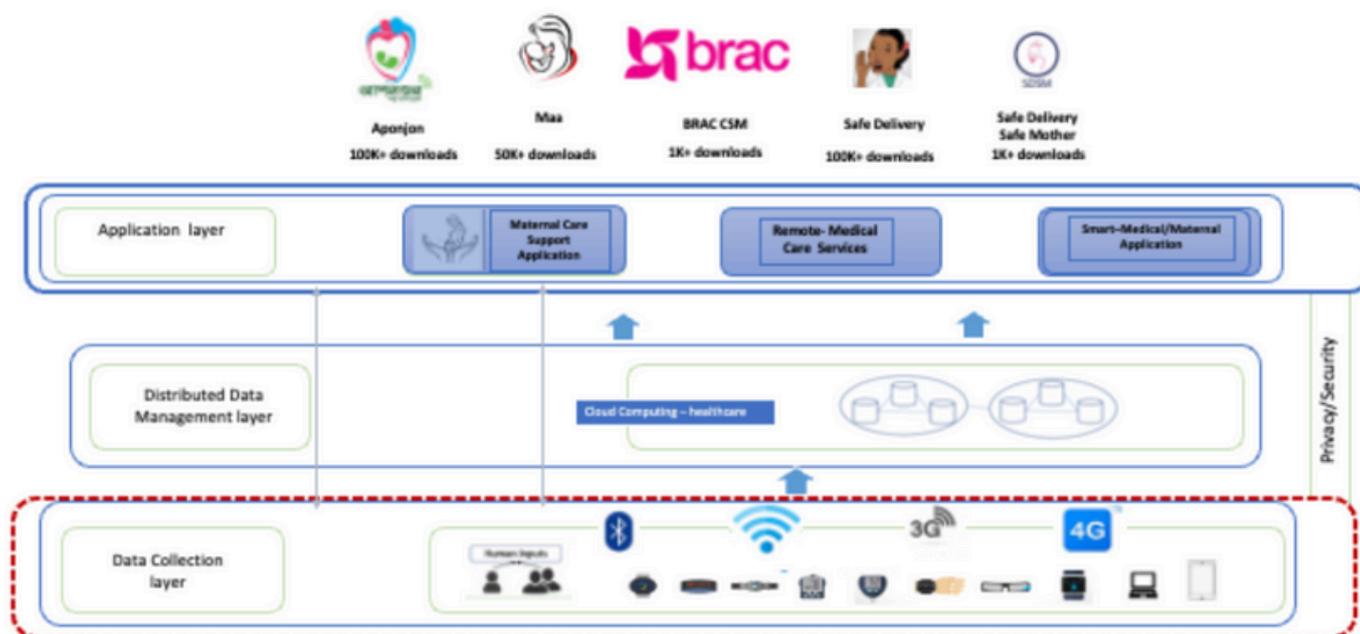
Maternal health data are collected through the DHIS Software[35] and in rural Bangladesh, this data is collected by CHWs using paper cards. While the data collected by CHWs is shared from community level up to tertiary hospital level, it is underutilised because of its poor quality. Efforts are ongoing to roll out digital-record keeping.

Further, according to one of the Key informants, there is no mechanism for integration and interoperability of data systems in Bangladesh’s maternal healthcare sector. Each service provider has their own Electronic Records systems and there is no integration between them. Such a data ecosystem raises critical constraints in the development of AI- powered applications in maternal healthcare, since these applications are largely based on well structured, standardised and machine-readable data.

The National Data Center Bangladesh has introduced cloud computing services that are accessible to government and non-government organisations. These could be leveraged for mobile and AI-powered digital healthcare, enabling distributed data management protocols. These can potentially include a host of cloud-native services for maternal and continuous monitoring apps through platform as a service (PaaS) and Software as a Service (SaaS). The Tier 3 existing infrastructure could also be leveraged for web hosting of maternal- information services and hosting applications that provide maternal and expectant mothers with pregnancy-related information. Furthermore, the supercomputing capabilities can be optimised to implement large-scale data analysis within the healthcare sectors. While this capacity exists in Bangladesh, we were not able to find information on the use of this capacity in the healthcare sector.

Figure 8 illustrates the current digital ecosystem in Bangladesh which only supports basic feature applications for maternal healthcare based on the 2G and 3G network.

Figure 8: Current applications in Bangladesh healthcare & existing ecosystem



[35] "Using DHIS Software to Collect Health Data in Bangladesh", <http://rpcc.dghs.gov.bd/rpcc/?wpdmpo=using-dhis-software-to-collect-health-data-in-bangladesh>

6.2 As-Is: Social and Demographic Conditions

Social and demographic factors have proven to have a significant influence on the adoption and usage of digital services (Yu et al., 2017)[36]. Digital services for general healthcare and maternal healthcare are particularly influenced by such factors. These factors include:

- Digital literacy challenges in the adoption use of mobile healthcare services affect all layers of data collection to the application layer (answers to human input);
- Language barriers and challenges in the adoption of mobile/AI healthcare services;
- General mistrust of technologies and public healthcare providers (rural prefer local birth attendants and local knowledge compared to urban);
- Exclusive trust in doctors for health-related advice, resulting in mistrust in technologies and other service providers;
- Reluctance to discuss physiological conditions with persons who are not of the same gender;
- Gender and religious barriers and cultural perspectives around the use of technology (security and safety concerns);
- Lack of local software and applications (in local languages for maternal healthcare
- Digital safety and security concerns; and
- Decision-making authority generally lies with males and mother-in-law. This is accentuated in households with adolescent or young mothers.

Of these factors, low digital literacy appears to be a key barrier to uptake of digital and AI- powered healthcare in the country. Without digital literacy, users would not be able to receive and utilise information disseminated through digital platforms. In 2019, the BRAC Institute of Governance conducted a large-scale survey on digital literacy in Bangladesh[37].

The survey measured: communication skills (ability to communicate in digital environments, interact with, and participate in communities and networks, etc.); information skills (identifying, locating, and retrieving information; judging its relevance and purpose); and problem-solving skills (identifying digital needs and resources, making informed decisions about appropriate digital tools according to the purpose or need, etc.).

In the communication skills domain, Figures 9 and 10 show that most households have no ability to use devices and computers (91%), no ability to use video calling apps (85%), 68% of households cannot read or send an SMS. The majority of the households also have limited ability to search for information (73%). While some can access information, the majority find it very difficult to obtain and understand digital content that may be publicly available.

[36] Yu, Tai-Kuei, Mei-Lan Lin, and Ying-Kai Liao. "Understanding factors influencing information communication technology adoption behavior: The moderators of information literacy and digital skills." *Computers in Human Behavior* 71 (2017): 196-208.

[37] "Understanding the Digital Gender Divide in Rural Bangladesh: How Wide It Is and Why", https://bigd.bracu.ac.bd/wp-content/uploads/2021/04/Policy-Brief_Digital_gender_Divide_BIGD_2021.pdf

Figure 9: Digital Literacy in Bangladesh[38]

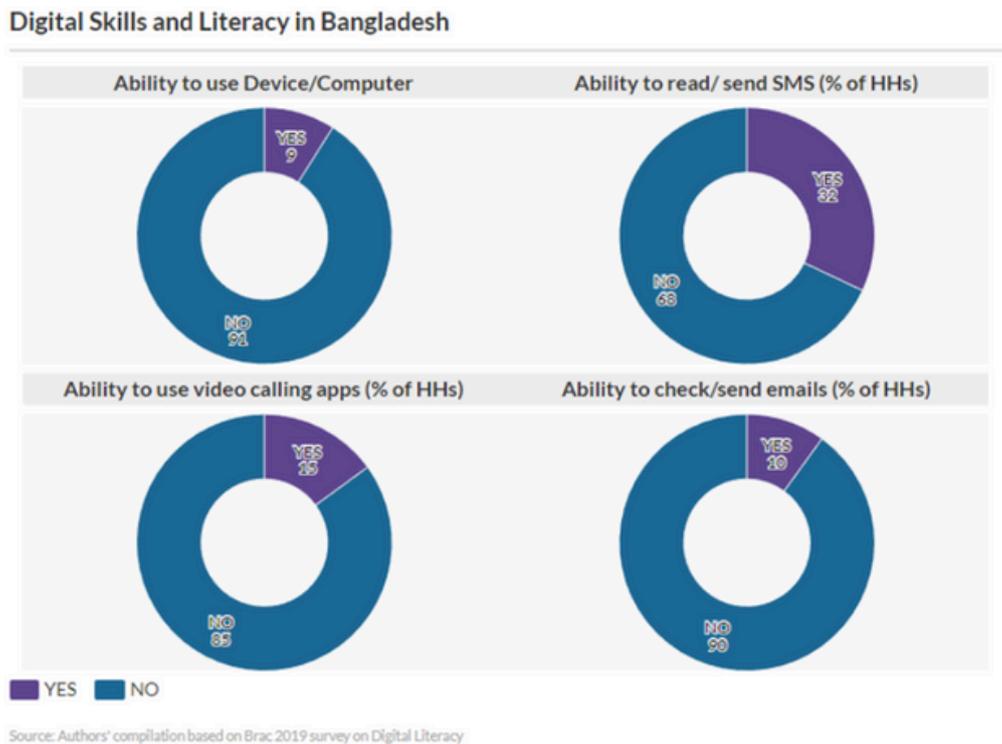
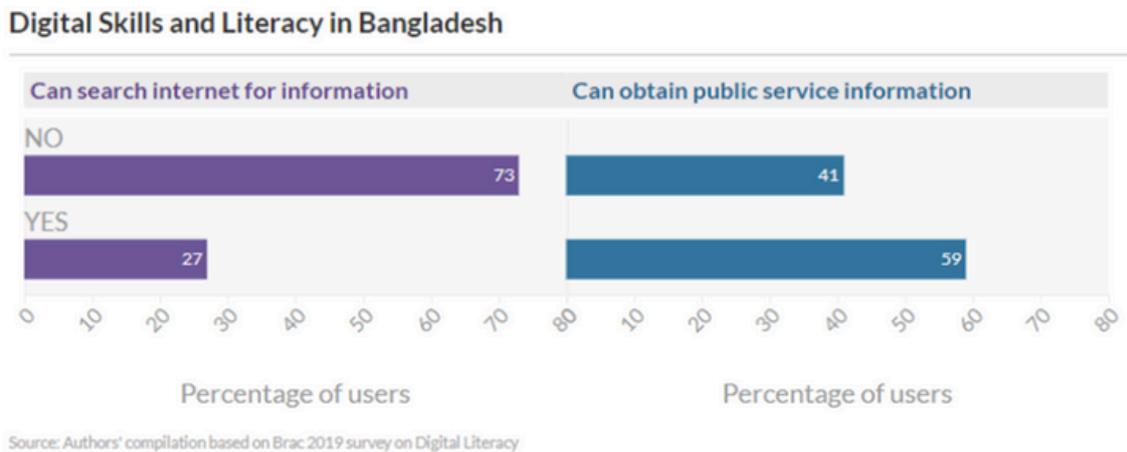


Figure 10: Digital Skills in Bangladesh



Even though these findings are at a household rather than individual level and thus do not shed light on gender disparities, they still provide insight into the broader challenges of implementing digital healthcare tools in population where most have difficulty understanding and using online tools. It also points to the limits on the usefulness of digital healthcare tools in the context of low digital illiteracy.

Relatedly, low literacy levels pose significant challenges to the adoption and use of digital services in healthcare. In the case of Aponjon, this has been addressed through the provision of healthcare information via voice messages, but low literacy levels limit the usefulness of other digital resources for key target groups.

[38] "Digital literacy survey in Bangladesh", https://bigd.bracu.ac.bd/wp-content/uploads/2020/10/Policy-Brief_Digital-Literacy-in-Rural-Bangladesh.pdf

6.3 Economic and Financial Conditions

The economic and financial barriers are focused on digital and healthcare service affordability and related challenges that expectant mothers experience during pregnancy. Figure 11 illustrates the affordability of broadband internet in Bangladesh. 1GB of mobile internet is unaffordable for nearly 40 % of the country because it costs more than 2% of their stated incomes. The affordability situation is even worse for women as Figure 12 shows that only 23% can afford digital services, and only 11% as of 2018 were registered with digital financial services. These disparities play very critical roles in the development, adoption, and use of digital services in healthcare, and pose significant limits to using such services.

Figure 11: Affordability of internet data [39]

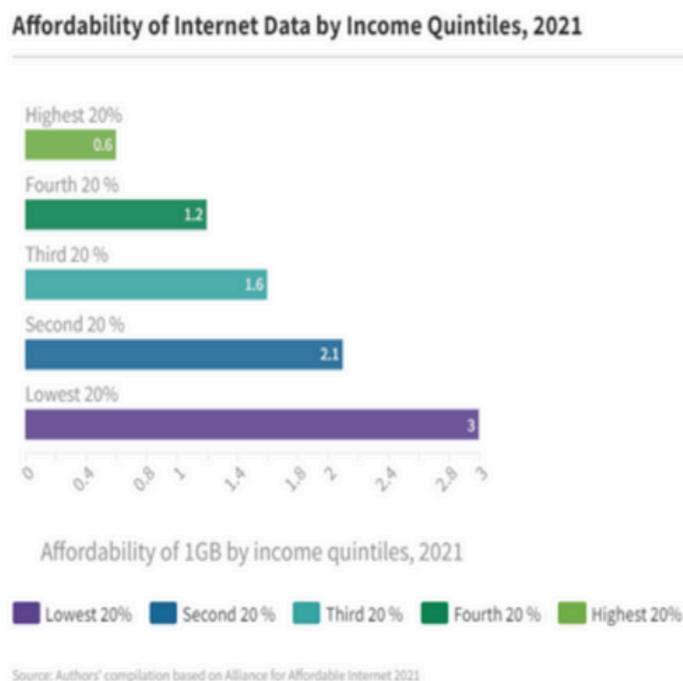
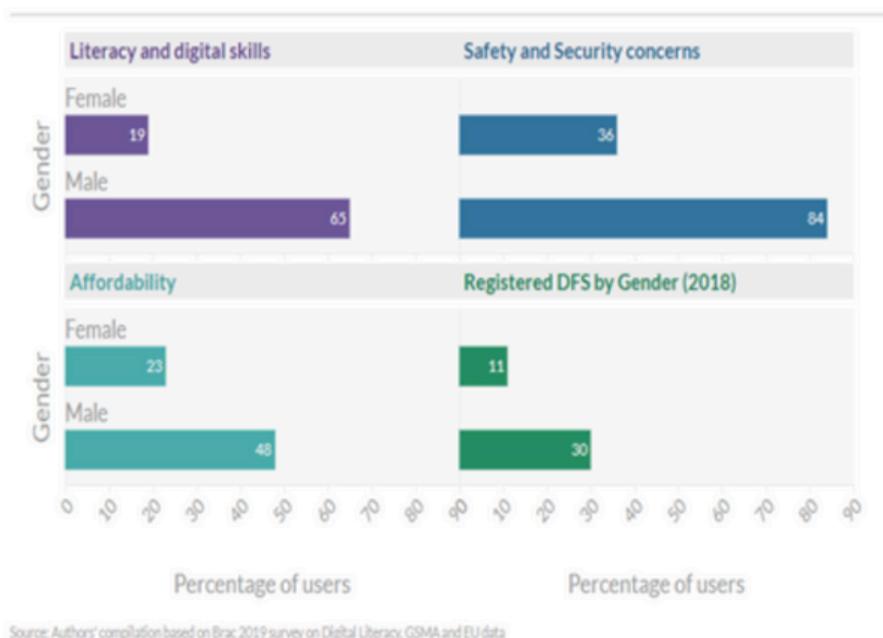


Figure 12: Affordability and registration of digital financial services by gender



[39] "Realising affordable internet in Bangladesh: A case study", http://a4ai.org/wp-content/uploads/2016/06/A4AI-Bangladesh-Case-Study_June-2016.pdf

7.0 Evaluation of AI & digital applications by target user

Artificial Intelligence and digital healthcare tools are often touted as a potential technological solution to gaps in healthcare delivery. What typically misses in these studies is the context-specific variables that can influence the adoption and use of AI in healthcare. Moreover, AI applications in specialised healthcare areas such as maternal healthcare are still in the early stages of development and require very advanced digital ecosystems for success, development, adoption, and use. The paper aims to assess Technological Readiness and whether current AI applications can be implemented in an environment with a still developing digital ecosystem in Bangladesh. More specifically, what are the technological requirements in terms of the digital ecosystem that Bangladesh would need to meet to employ AI in the continuous pregnancy monitoring system? What is the back-end infrastructure required for implementation?

7.1 Target User 1: Expectant mother and family members.

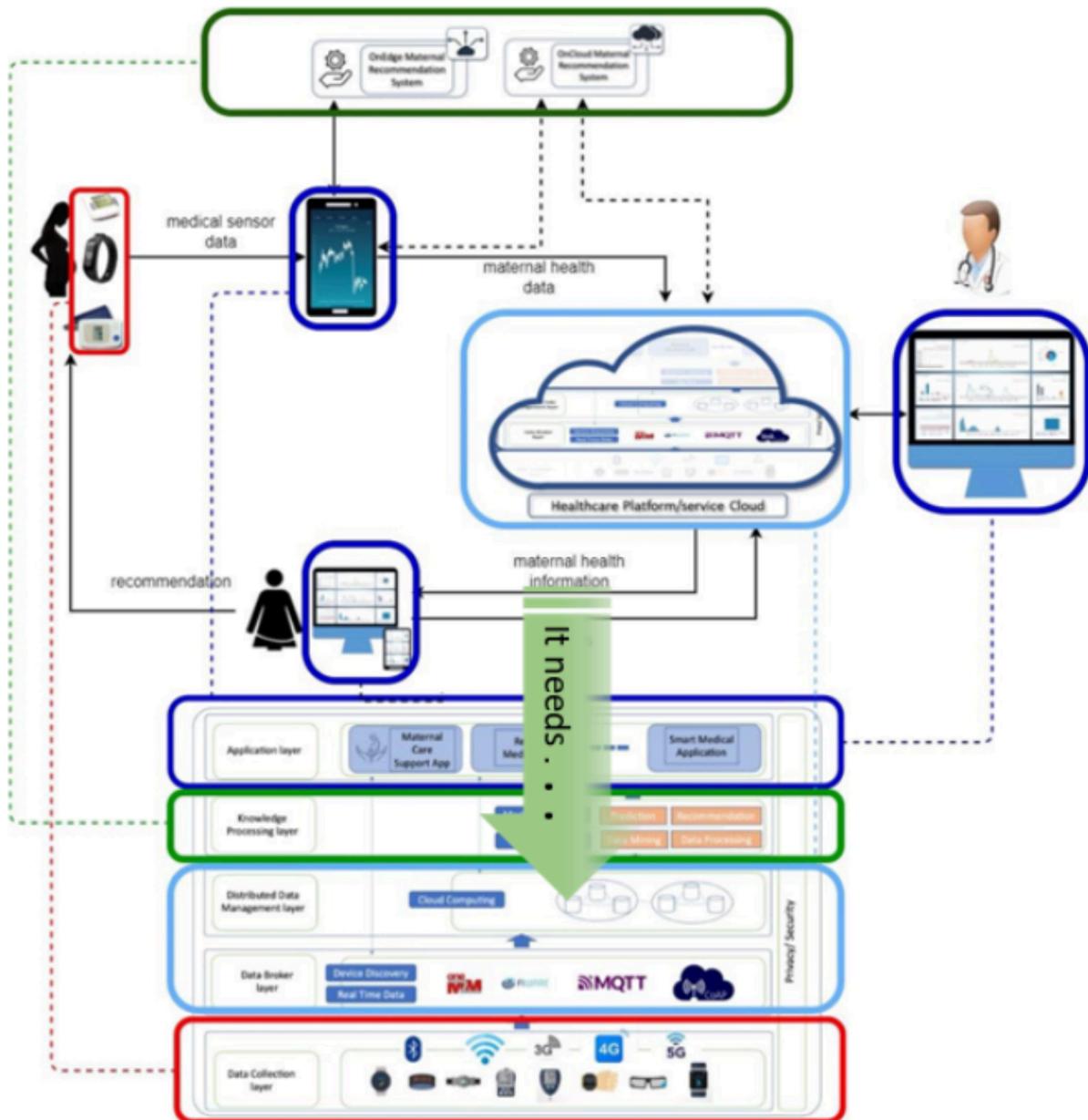
Functions: Education, timely provision of information, scheduling reminders, provision of data for decision-making.

For this category, interventions could be introduced to help expectant mothers adopt behaviours which would improve maternal health outcomes. The level of sophistication of the intervention is largely restricted by the functionality of the devices held by expectant mothers. Additionally, the success of these interventions is also dependent on the capacity and ability of the information recipients to act on the information - these are largely influenced by non-technological factors and would not be discussed in this section.

For example, AI systems could be used to send scheduling or health management reminders. It could also send personalised educational material, depending on sophistication of the data input health monitor tool interfaces. Ideally, such tools require the development of applications with the following attributes:

- An end-to-end application that supports maternal care enabling easily accessible and more effective services;
- Remote and real-time maternal health-related data collection;
- Included in the app are clinical and other gynaecologist related recommendations;
- The service provider, caregiver and specialist should be connected to the patient.;
- Collection of maternal care-related data and knowledge base that can further be used to enhance the services; and
- Everyday care related data can be used for further research.

Figure 13: Conceptual model for AI-powered Mobile/digital services for Target User 1
 Source: Author's elaboration



In this model, different state-of-the-art technologies, standards, and platforms in different data acquisition and processing layers are used to properly design and develop healthcare platforms for continuous pregnancy monitoring in Bangladesh. Although developing the platform is beyond the scope of this paper, we have focused on understanding the perception/reception gaps of such a platform as above. Briefly, the technologies and standards involved in each layer of AI and IoT platforms (as shown in Figure 13), were evaluated based on the existing digital ecosystem in Bangladesh as detailed earlier.

The conceptualisation of the technological challenges was based on literature review, and detailed data collection and as-is analysis.

In the general architecture, the lower layer is the data collection layer where the sensors read data and publish it to the data broker layer. The broker layer provides device recovery and real-time data delivery services to the upper layers. The Distributed Data Management layer serves as a repository for historical data. Based on the collected data, the knowledge processing layer operates big data and machine learning algorithms to generate knowledge from the raw data. The last layer, the applications layer, uses real-time data, historical data, and/or processed data to provide the service.

AI-powered tools require robust systems at every level, and this may only be available to a small proportion of the wealthy Bangladesh population who already have access to good infrastructure and resources. For this small percentage of the population, they would be able to access remote sensing devices which could capture vital signs and health data. Through an end-to-end integrated system, these health data could be used for remote monitoring and early detection of conditions, and the appropriate information or required follow-up action could be relayed back to the patient. These additional services would likely only make incremental differences to the already good access to healthcare this population group would already have, and are complementary in nature.

7.2 Target User 2: Maternal healthcare professionals (doctor/midwife)

Functions: Monitor patient health, deliver remote services (telemedicine), diagnostics and prediction tools, data collection tools. AI-Powered applications and services to continuously monitor their patients using AI-powered tools.

For this target user, the service provider may develop and implement scalable solutions (used by different patients in different accessibility stratas - rural vs urban, etc.) to enable the following:

- An end-to-end connection to provide easily accessible and remote services to maternal and expectant mothers;
- Provide real-time information and maternal healthcare services to patients;
- Real time data collection that can be used to enhance the services provided to the patients;
- Automated vital sign measurements, diagnosis and recommendations; and
- Automated development of electronic partograph/partograms

Similar to the first category of users, the conduct of remote services is largely dependent on the patient's access to devices which can capture and relate vital health information for further decisions, and an interface which allows two-way patient- doctor communication. This requires the same technical infrastructure, and this would likely only be accessible by better resourced populations.

Within the hospital or clinic context, AI powered diagnostic tools could also be used to help healthcare professionals deliver better standards of care by improving the accuracy of vital sign measurement, diagnosis and detection and prediction of conditions. With the right infrastructure in place, such systems would complement existing clinical processes to improve efficiencies, facilitate the digitisation of records and improve patient care.

7.3 Target User 3: Community healthcare workers

Functions: Education, remote measurements, data entry and planning.

CHWs in Bangladesh play an important role in locating and registering mothers, conducting visits and checks, and providing educational guidance. AI-powered digital tools can be developed and implemented to support critical information and maternal services support (e.g., providing recommendations for gynaecology referrals).

Recent developments of AI-powered, low-cost, portable ultrasound devices can enable the conduct of remote ultrasound scans. Coupled with a smartphone and training, CHWs can be delegated the role of performing remote ultrasound scans and automated referrals can be made for patients who require further attention. Additionally, such tools can be automated to support data entry and planning engagements with expectant mothers.

AI-powered chatbots could also be used to facilitate the search and navigation process for educational materials currently accessed by CHWs via apps. On top of Bengali, natural language processing could be deployed to include different Bengali dialects.

For this target user, the service provider may develop solutions to enable the following:

- Provide real-time consultation connection to the community healthcare worker;
- Provide real-time information and referral services based on a number of variables including data and vital signs collected from expectant mothers.;
- Automated data capture and entry with CHW in the loop;
 - Registration and identification number, geolocation, household details.
 - Depending on the access to miniature measurement devices, various expectant mother indicators could be captured, including checking for anomalies, foetal size, foetal heart rate, ectopic pregnancy, placental medication safety, gestational disease, and maternal health statistics (weight, nutrition intake, BP, anaemia).
- Providing real time data and statistics to maternal healthcare service providers (gynaecology hospitals/clinics) and health administrators;
- Recommend personalised educational materials for mothers based on data collected; and
- Provide personalised training resources and refresher courses to CHWs for upskilling/reskilling.

7.4 Target Use 4: Health administrators, government

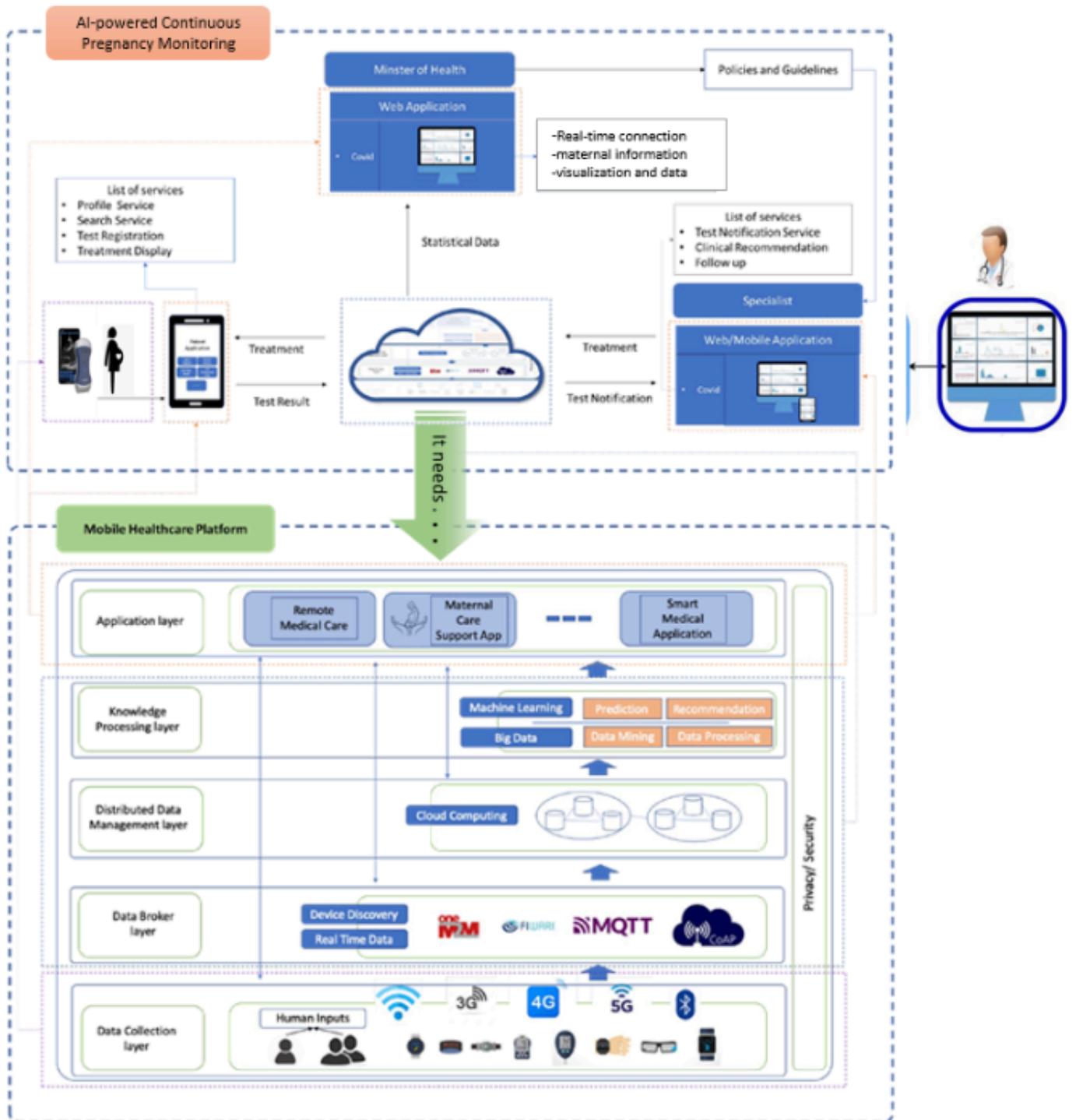
Functions: monitoring, performance analysis, resource allocation.

For healthcare administrators, their work priorities revolve around resource planning and policy evaluation. For these users, digital tools and applications that can capture and leverage “small” and big data can be developed to support these users in discharging their responsibilities. For example, AI has been used in accounting to conduct audits and governance checks to improve data quality and manage performance. AI could also be used to improve resource planning and allocation.

In the context of management of CHWs, AI could be used to optimise visitation routes and improve work efficiencies to reduce the amount of manpower required to serve a geographical region. Advancements in digital technologies enable capabilities such as:

- Real-time and near-time monitoring of Maternal Mortality in Bangladesh;
- Monitoring of post-delivery outcomes;
- Recording pregnancy-related maternal mortality;
- Better estimation of number of mothers in a geographical region;
- Detection of data entry discrepancies for performance management; and
- Monitoring of human resource provisions (e.g., doctor or healthworker to patient ratios)

Figure 14: Conceptual model for AI-powered Mobile/digital services for Target Users 2,3,4



7.5 Assessment

Many of the enabling conditions required for the implementation of AI technologies are not yet in place in Bangladesh. This limits the range of technologies that can be adopted, adapted or developed in Bangladesh at present. Considering the different user needs and use cases, even though it is technically possible to develop such advanced AI technologies to improve maternal healthcare outcomes, it would only benefit a small, well-resourced population and would not benefit much from it.

In terms of technical feasibility and usability, it is possible to leverage the existing infrastructure to develop AI-powered digital maternal services for a small percentage of users. These users are typically high-income, which means that they have access to advanced digital infrastructure at par with what is typically found in more advanced 42 countries. Such infrastructure includes advanced 4G connectivity, access to appropriate devices and the users are highly educated and can afford services that are enabled by AI-powered applications.

For this sub-group of end-users, health service providers can offer advanced digital tools and applications with AI components such as chatbots, telemedicine, wearable devices, and remote pregnancy monitoring apps to provide additional channels and greater convenience. These patients already have access to relatively high-quality maternal healthcare services (typically by private service providers) in Bangladesh, and digital tools may be perceived as complementary but not prerequisites to receiving quality maternal healthcare in Bangladesh. Indeed a number of service providers have already started providing such services targeted at wealthy patients in urban Bangladesh.

Figure 15: Emerging Mobile and Digital Healthcare services in Bangladesh
Source: futurestartup.com

A comparison of startups in the health-tech space

		Doctorola.com	Digital Health	PRAAVA HEALTH	Maya	BanglaMeds	Olwel NRB PARENT CARE
Appointment Booking	Video Consultation	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	In-person / Home Visit	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>
Medical Advice	SMS and Chat	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	Hotline/Calls	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Medicine Delivery	Over the counter Drugs	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
	Prescription Drugs	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
Ambulance Service	On-demand Ambulance	<input type="checkbox"/>	<input checked="" type="checkbox"/>				
Testing Facilities	Sample collection and Testing	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>
Insurance	Micro Health Insurance	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

However, accessibility and affordability conditions are not yet met to enable AI-based services for a typical Target User 1 (expecting mothers and their families). In particular, the gap between broadband network coverage and actual use rates would need to be reduced.

In summary, these are the enabling conditions that need to be met for the deployment of AI-powered digital tools:

- **Digital infrastructure conditions**
 - Access to meaningful broadband connectivity
 - Access to appropriate devices for data input
 - Access to appropriate devices for data reception
 - User access to interoperable identity cards
 - Availability of digitally connected-physical maternal health facility
 - Access to electricity
 - Digitised records for development of AI
 - Navigability and usability of application or tool
- **Social and demographic conditions**
 - Ability to use digital products (digital literacy level)
 - Ability to utilise data to inform decision-making (data literacy level) 43
 - Comfort in using devices
 - Ability and power to act on decisions
 - Trust in emerging and digital technologies
 - Trust in service provider
 - Digital safety and privacy concerns
- **Financial and economic**
 - Affordable digital healthcare services
 - Affordable smart devices
 - Affordable healthcare services
 - Affordable data and internet services

This section provides an evaluation of applications of digital technologies and AI by the target user group. The applications are evaluated against two priority criteria: usefulness and feasibility.

For Target User 2 (Maternal Healthcare Professionals-doctors and Midwives) and Target User 3 (Community healthcare workers), the existing digital infrastructure and ecosystem offers them opportunities to develop and implement AI-powered digital health services to connect to small percentages expectant mothers (wealthy patients and neighbourhoods). Like Target User 1, massive efforts should aim at upgrading their communication infrastructure, training, employing and retaining of human resources for maternal health, and availing them with software and digital platforms to their work.

There have been improvements in development, adoption and use of Electronic health records systems in Bangladesh. However, many technical challenges in relation to how data related to maternal health is collected from expectant mothers.

One of the basic requirements to unlock AI-powered digital applications for Target users 2, 3 and 4 (given they have to interface with expectant mothers) is scaling of access and use to reliable national Identity (NID) cards.

he feasibility criteria is based on the existing technical, social and economic conditions and whether they meet the required levels for the AI application. For example, a simple appointment scheduling and reminder system can be implemented using SMS functions and this would be assessed as high feasibility. Comparatively, remote monitoring requires access to sensing devices and network capabilities and this would be assessed as low feasibility.

The usefulness criteria is assessed by who the application is intended to benefit, how they benefit and whether the service is desired or usable by the target audience. For example, the provision of remote monitoring services and health information to the everyday mother may not be useful as most would not know how to use this information. Culturally, they also do not welcome bad news about the child and would not welcome such information. The usefulness for such an application would hence be low.

Table 1 summarizes the different AI applications by target user groups.

Table 1: Evaluation of Applications by Target User

Target User	Applications	Usefulness	Feasibility
1. Expecting mothers and families	Remote monitoring and personal health information	Low	Low
	Chatbot	Low	Mid
	Educational materials (health management information)	Mid	Mid
	Automated scheduling, visit and health reminders	High	High
2. Maternal Healthcare professionals	Remote monitoring and health information of patients	High	Low
	Digital partograms	High	Mid
	Automated patient appointment scheduling and reminder system	High	High
	Digitisation of patient data input and tracking	High	High
	Automated patient data input and tracking	High	Mid
3. Community Healthcare worker	Chatbot	Low	Mid
	Patient visitation route planning	High	High
	Remote diagnostics	Low	Low
	Digitisation of patient data input and tracking	High	High
	Education materials (health management information)	High	Mid
	Training and refresher materials	High	Mid
	Automated patient appointment scheduling and reminder system	High	High
4. Healthcare administrator in healthcare agencies for maternal health	Dashboards	Low	Mid
	Automated report generation	Low	Mid
	Auditing functions to flag up data discrepancies and abnormalities	High	Mid
	Estimation of number of new mothers in a region	High	High
	Tracking and optimisation of CHW visitation route and schedule	High	High

8.0 Recommendations

On the basis of the evaluation, the most promising short-term digital interventions are to: complete the digitalization of standard data entry for antenatal care within the public health system; and to universalize a mobile-based system of reminders for ANC direct to end-users and CHWs. The feasibility and value of these interventions has already been well demonstrated but additional commitment and resources are needed to achieve nationwide coverage. While neither of these interventions employs AI, they are necessary steps to move towards AI-enabled services in the future. When digitalization of public health records for expecting mothers and newborns is complete, capacity and incentives to monitor service quality will be strengthened, and machine learning can be used to spot data anomalies, gradually improving the quality of the data through use. Digital data can be analysed statistically to produce more accurate estimates of the number of pregnancies in a 45 geographical area, and forecasts can be compared with field data as an additional form of validation.

Universal coverage of a mobile-based reminder service could be expanded to incorporate the information-provision functions of Aponjon, with information tailored to the gestational period. As 3G and 4G becomes more widely available in Bangladesh, data exchange can become more sophisticated, allowing for the personalisation of information for mothers and families tailored to their age, health, capacities and concerns. Integrated data systems with clinics and hospitals can also facilitate automated appointment scheduling and even prioritisation of appointments based on maternal health risk factors.

In the near term, another AI-powered intervention with strong potential is to use geolocation data on CHWs and pregnant women to set optimal household visitation routes for CHWs. This could improve scheduling efficiency, reduce burdens on CHWs and make tracking and monitoring easier. AI applications of this kind have been widely and successfully deployed for tracking and transport optimisation outside the health field but to our knowledge have not yet been applied to community health services.

A strong digital infrastructure is a prerequisite for successful and sustainable use of AI applications, and ultimately to achieve better and more equitable health outcomes for expecting mothers. The benefits of greater digital access will be seen across social and economic sectors. Investment in this should therefore be a high priority, covering last mile broadband connectivity; affordability of internet and data services; increasing access to affordable smartphones and wearable devices; scaling digital literacy training to millions of expectant mothers and their families; and supporting the innovators to develop locally relevant applications. Once the basic foundations are in place, then it will be possible to develop end-to-end mobile and digital healthcare applications that can leverage AI for continuous pregnancy monitoring for all.

Annex: Key Informants

Informant Number	Organisation	Interview Date
1	BBC Media Action	6 June 2022
2	Quicksand	12 July 2022
3	LAMB Hospital	4 August 2022
4	BRAC	5 September 2022
5	UNFPA	3 November 2022
6	Save The Children	3 November 2022
7	IPAS Bangladesh	4 November 2022
8	MoHFW	8 November 2022
9	UNICEF Bangladesh	15 November 2022
10	ICDDR,B	1 December 2022
11	Dnet	18 December 2022
12	Aspire to Innovate	15 February 2023
13	DGHS	23 February 2023
14	Aspire to Innovate	15 March 2023