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MomConnect: an exemplar implementation of the Health Normative Standards Framework in South Africa

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In August 2014, the National Department of Health implemented MomConnect as a national digital maternal health program that implements the South African mobile health (mHealth) strategy and the National Health Normative Standards Framework for Interoperability in electronic health (eHealth). As the first digital health program communicating with people at scale, MomConnect enrolled more than half a million women from all regions of the country in the first year of operation, representing approximately half the number of pregnancies in the public health sector.

MomConnect uses a mobile phone application to support a pregnancy registration system in antenatal care facilities, allowing pregnant women to receive stage-based messages to help them improve their health and that of their babies. Women can self-subscribe or be subscribed by community health workers to receive a limited set of health-promotion messages. Registered users interact with the system by rating the service received, asking questions, and submitting compliments or complaints. The mobile system connects to a central health-information exchange that facilitates interoperability between digital health applications and includes data validation, a national pregnancy registry and a monitoring and reporting system.

Used throughout the health system at facility level, MomConnect has generated a national register of pregnant individuals and set up a national feedback system to clients. As such, it is an exemplar implementation of the Health Normative Standards Framework enabling national-level innovation as a model for future health system strengthening, enabling interoperability between digital health applications, and achieving universal health coverage.

MomConnect has drawn global attention due to its innovative features and its avoidance of many of the common pitfalls when implementing digital health projects at scale in low-resource settings. This chapter focuses on the design and development of the technical infrastructure supporting MomConnect.

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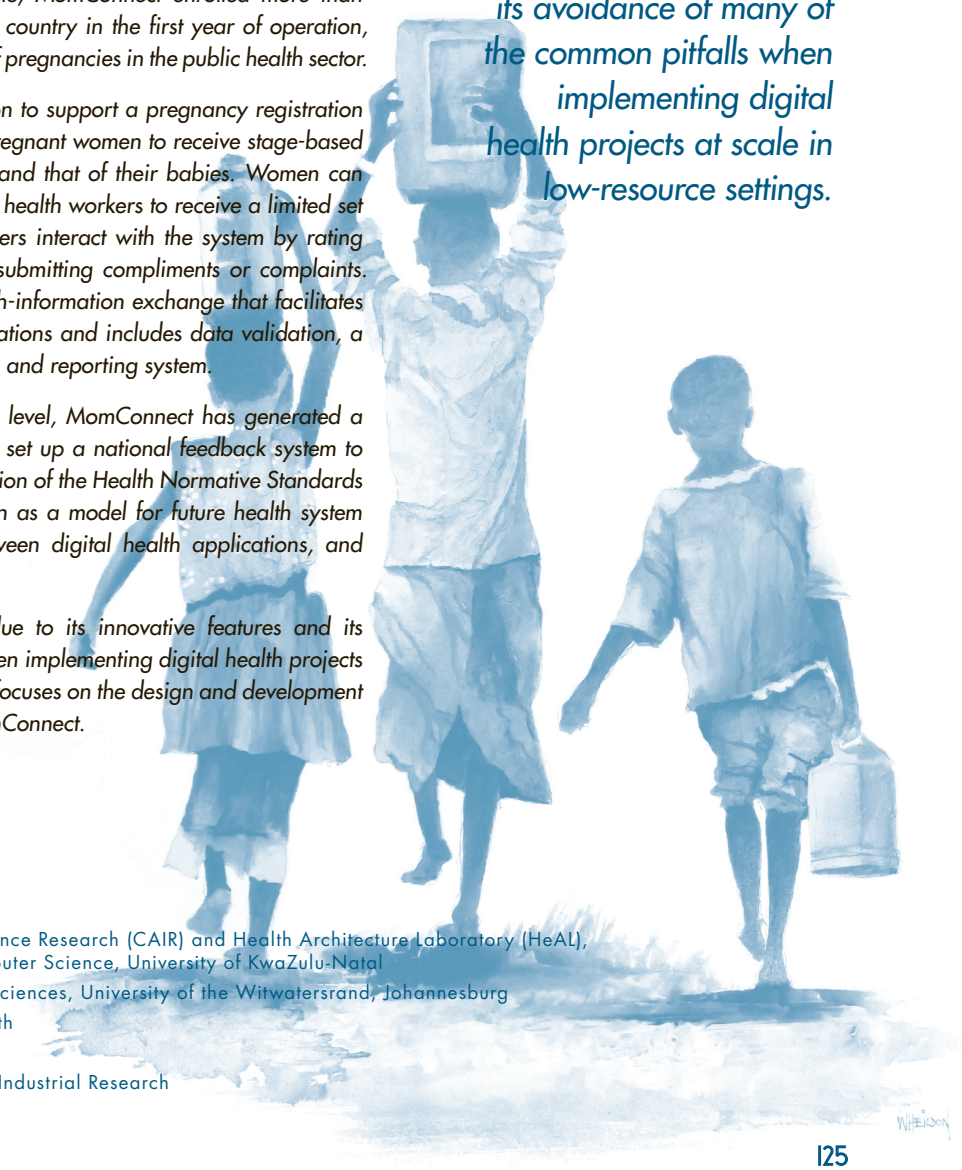

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Introduction

Reduction in maternal and child mortality is a global health priority that featured prominently in the Millennium Development Goals as Goals 4 and 5, with targets given to each country.[1] Like many other middle- and low-income countries, South Africa is implementing various programmes to improve maternal health.[2–4] In 2014, the Minister of Health, Dr Aaron Motsoaledi, launched an initiative to use mobile phone technology as part of a suite of interventions (e.g. increased access to contraception, improved coverage of breastfeeding) to address the relatively high maternal mortality ratio (MMR), child mortality rate and perinatal mortality rate (PNMR) in South Africa.[5,6] The Medical Research Council estimated the MMR in South Africa to be 155 deaths per 100 000 live births in 2013,[7] down from 281 deaths per 100 000 live births in 2008. South Africa is targeting 100 deaths (or less) per 100 000 live births by 2020.[8]

Mobile health (mHealth) is recognised as having significant potential to address health issues in developing countries, notably maternal and child health.[9–13]

This chapter describes the development of the technical infrastructure for the MomConnect system, and the alignment of its information-management component with the Health Normative Standards Framework for Interoperability in electronic health (eHealth) in South Africa (HNSF).[14] The emphasis in this chapter is on describing the processes followed to implement a technical infrastructure using the HNSF model, and its construction in a modular manner in order to facilitate ongoing alignment with the evolving National Department of Health (NDoH) technical infrastructure. This initiative builds on previous work conducted by South Africa's NDoH and reported on in the *South African Health Review* in respect of the eHealth reference implementation.[15–17]

Understanding the technical infrastructure of the MomConnect program is critical in achieving national scale, and it is an exemplar implementation of the HNSF that is relevant for digital health solution developers in South Africa and in other countries in low-resource settings.

In developing this chapter we have been guided by the recently published guidelines for reporting health interventions using mobile phones.[18]

Development of MomConnect

The rationale for the MomConnect program was to capitalise on the high mobile-phone coverage in South Africa in order to strengthen antenatal care (ANC) services in the country. In particular, MomConnect was designed to offer voluntary health-promotion messaging to encourage pregnant women to attend an ANC facility within the first trimester of pregnancy and to complete all recommended ANC visits in a timely manner. MomConnect provides the following basic services:[a,4]

- registration of pregnant women in public health ANC facilities and enrolment into a national register of pregnant individuals;
- subscription to limited weekly messages essentially telling pregnant women to attend a health facility via public or Community Health Worker (CHW) enrolment;
- subscription to stage-appropriate SMS messaging from the date of registration, through delivery, until the baby's first birthday;
- a virtual help-desk allowing pregnant women to ask additional questions, and submit compliments and complaints; and
- a service to allow mothers to rate the quality of care received at the facility.

Despite the existence of a number of mobile health applications including websites, mobi-sites, social networks and smartphone applications, these services were for the most part small in scale, clustered mainly in urban areas, and required the use of smart phones and internet access. This limited the usefulness of the technology in rural areas and in poorer communities, which were among the target populations identified by the NDoH in addressing maternal and child health.

Policy framework

In 2014, the NDoH published the HNSF,[14] which augments previous South African government policies dealing with interoperability, enterprise architecture and standards.[19,20] The framework was designed to address some of the issues and initiatives identified in the National eHealth Strategy[17,21] and sub-outcome 10 of the Medium-term Strategic Framework 2014–2019 (under Outcome 2: "A long and healthy life for all South Africans").[22] Additionally, the South African mHealth Strategy[23] was published in 2015 and complemented the eHealth Strategy published in 2012,[21] which is a roadmap for achieving a well-functioning, patient-centred electronic national health information system. Processing of personally identifiable information is governed by the Protection of Personal Information Act 4 of 2013.[24]

Preliminary processes and consultations

A mobile maternal health (mMH) task team comprising representatives from the NDoH, parastatal organisations, universities, non-governmental organisations and private sector organisations was convened under the auspices of the NDoH. This task team subsequently developed a concept proposal for using mobile technology to address some of the factors contributing to maternal mortality in South Africa.[3,5] Central elements of the proposal included providing information and knowledge to pregnant women by providing them with health-promotion messaging and enabling them to interact with the system and provide feedback to health providers on service quality.

Details of the MomConnect project in the context of other NDoH projects have been published elsewhere.[4,25,26]

System design considerations

In designing a technical solution for MomConnect, a number of considerations were taken into account, including maximum coverage and reach to all areas of South Africa, including rural settings. A South African National Identifier (SAID), or the mobile phone number of the user in the case of the former not being available, was chosen as the patient identifier. In order to ensure the widest network coverage and mobile handset compatibility

a http://www.southafrica.info/services/health/momconnect.htm#.VsR-aBji7EE

for maximum access, Unstructured Supplementary Service Data[b] (USSD) and Short Message Service (SMS) systems were chosen as the protocols because they do not require sophisticated phones to be operational, and every cell-phone in South Africa has the capacity to support these two services.

Data elements

Table 1 provides a list of the data collected as part of the MomConnect registration process at facilities as well as through self-subscriptions and CHW enrolments. These data elements are collected for each transaction; each mother can conduct multiple transactions of each type and the system can capture a subset of these 16 elements per transaction. Some transactions can be activated only once within a specified period (to avoid duplicate entries for the same transaction), while others can be activated a number of times.

These core data elements were later supplemented with additional data elements relating to service ratings, a help-desk, and a system for feedback on services received (compliments and complaints). A separate but complementary program, NurseConnect, collects data elements from nurses in order to provide them with support and clinical updates, and to facilitate interaction with managers.

System architecture

The technical architecture of MomConnect was designed around the HNSF health information exchange (HIE) framework that connects consumer applications and edge devices[c] (through an interoperability layer) to demographic registries and clinical repositories complemented with security and audit services.[14]

System components

Edge devices

In the case of MomConnect, mobile phone handsets are used as the edge devices. A constraint on the system is that it had to be compatible with the majority of handsets, namely basic, low-end handsets with support for only voice, USSD and SMS services. The initial registration process in public health ANC facilities uses either the client's handset or a handset provided by the clinic.

Consumer application

For the purpose of the initial project, a single mobile health application was selected to serve as the consumer application. The application is an open-source, custom-made mobile messaging platform, programmed to interact with individual mobile phone handsets using USSD and to send messages via SMS. The USSD application supports the collection of data from handsets using data-collection screens as well as the messages sent back to the handsets by SMS. The same toll-free USSD short-codes are made available on all four mobile networks in South Africa.[27] SMS messages to the central system for opt-outs and help-desk questions are reverse-billed to the NDoH-funded MomConnect project. The cost was subsidised by all four mobile network operators in South Africa (Cell C, MTN, Telkom Mobile and Vodacom). A separate system was integrated with the consumer application to provide help-desk functionality.

Health information exchange

An open-source software application was used for the HIE component. It was programmed to validate and orchestrate messages received in a standard format, as specified by the HNSF,[14] also making it a reference implementation of the interoperability layer component as prescribed by the HNSF, which promotes use of open standards to achieve interoperability for health.

Table 1: Core data elements collected by MomConnect

	Description	Function
1	Mobile health application ID	Unique identifier specifying the application provider. In the current version of MomConnect, there is only one Application ID.
2	Software type ID	Unique identifier specifying the application software type. In the current version of MomConnect, there are two types: (SMS) and (USSD).
3	Device telephone number	Unique number of the SIM card interacting with the server by USSD or SMS
4	Client telephone number	Unique mobile phone number of the client to which SMS messages will be sent
5	Client identifier	Unique client identifier – this is the South African National ID Number, if available; alternatively the client mobile phone number is used.
6	Message type	Unique code specifying the source of the data, viz. a public subscription, identification by a community health worker, a clinic registration, an opt-out message, a message of baby loss, service-rating data, help-desk data
7	Language	Unique two-digit code indicating the preferred language for message correspondence in one of the 11 official languages in South Africa
8	Event date	Date of the event
9	Facility code	Unique six-digit facility code
10	Date of birth	Date of birth of the client (optional)
11	Opt-out reason code	Unique code specifying the reason for opting out of the MomConnect service: Miscarriage, Stillborn, Baby Loss, Not useful, Other, Unknown
12	Estimated due date	The date of estimated delivery of the baby, validated by a nurse
13	Question-answer pairs	Data containing the service rating and help-desk questions and answers
14	Reply date	Date of the reply to the help-desk message
15	Class of help desk interaction	Compliment, complaint or question
16	Help desk operator ID	Unique code assigned to operators of the help-desk service

b USSD is used to send text between a mobile phone and an application program in the network, much the same as requesting an air-time balance, and is therefore largely familiar to users.

c An edge device typically exists at the edge of a health information network where it is used by a human user to collect or display information.

Demographic Registry and Clinical Repository

The Demographic Registry and Clinical Repository used by MomConnect is a module of the open-source District Health Information System (DHIS) – the official routine information system used to monitor the performance of various health programmes in the national health systems. It serves three main functions:

- The tracker module stores individual records in the form of a national pregnancy registry and acts as a patient registry and shared health record (SHR).
- The data warehousing capability facilitates aggregation and therefore reports core indicators aggregated from the individual records.
- The module stores an organisation unit hierarchy and thereby maintains the list of unique facility codes, acting as a master facility list and registry in the HNSF implementation.

In the early stages of the project, additional components, such as a dedicated client registry with master patient index (MPI) and a shared health record (SHR) were tested and although these were technically successful, they were removed because a significant portion of records did not have personal identifier data (see Table 2) and maintaining a separate system that was not serving a practical function introduced additional and unnecessary overheads. In addition, the client registry system's patient-matching algorithms were not utilised, as the dataset captured would have been too small to de-duplicate client entries reliably. Finally, a substantial amount of non-clinical event data were also collected, which could not be stored directly in the client registry. However, it is possible to reinstate these components in the future if required.

Table 2: Identifier data captured in MomConnect (N,%)

Identity type	Number	Percentage
None	134 535	22%
SA national identifier	454 545	75%
Other identification	16 748	3%

Source: South African National Department of Health, MomConnect Data, 19 February 2016.

Security and auditing

All data transmission between various components is encrypted and located in a secure data centre in South Africa and servers are secured by firewalls and protected from unauthorised access. The interoperability layer has a secure web-based console and alerting system that is used to monitor the flow of transactions and ensures that problems are identified and addressed timeously.

System application and implementation

Technical implementation of the MomConnect infrastructure

One of the important requirements for MomConnect was to adhere to the principles and architecture elaborated in the HNSF. The technical implementation team was able to meet this requirement using existing software tools combined with the standards and profiles listed in the HNSF specification.

The initial infrastructure was developed and deployed within the first few months and then evolved iteratively over the course of the project. Changes to the infrastructure were implemented without any breaks in service.

Standards and profiles

As specified in the HNSF, the connection between layers in the health information exchange should be implemented using one or more interoperability standards. The main interaction considered for standardisation was that occurring between the consumer application and the HIE.

The MomConnect implementation team initially chose the Clinical Document Architecture[d] (CDA) as the content standard. The Mobile Access to Health Document[e] (MHD) profile was implemented from the consumer application to the HIE for further processing. At the same time, non-clinical data were captured in JavaScript Object Notation[f] (a text-based data exchange format) (JSON). Due to the limited clinical content captured in MomConnect and in the interests of simplification, the JSON document became the primary source for transaction data populating the pregnancy registry. In future, the team plans to replace the JSON document with a document formatted using Fast Healthcare Interoperability Resources[g] (FHIR), a relatively new lightweight Health Level Seven (HL7) standard. FIHR is not mentioned explicitly in the HNSF as it did not exist at the time of writing the HNSF, but it is an emerging standard that is expected to be incorporated in future.

The selection, customisation and implementation of standards prescribed by the HNSF is complex but achievable by a team with knowledge of interoperability and international standards. In future, the governance structures described in the HNSF, including the appointment of an eHealth Standards Board under the leadership of NDoH, plan to facilitate the process of standardisation and localisation.

Sequence of events

A typical sequence of events in MomConnect is as follows:

- A user, alternatively a nurse or CHW, enters the client's data, on her behalf, into the MomConnect USSD application.
- During the USSD session, if a facility code is entered it is validated against the central Facility Registry.
- These data are then sent through to the mobile platform, which triggers the stage-based SMS message suite for the mother and sends the data through to the HIE.
- The interoperability mediator validates the message and if valid, places it into a queue.
- The message is then sent asynchronously to the generic DHIS2 tracker mediator that populates the MomConnect program data in DHIS2 (the client registry and the tracker events, of which the SHR is a subset).

Figure 1 shows a summarised sequence of events for capturing a MomConnect registration.

The number of MomConnect registrations and subscriptions has grown steadily over the 17-month period of the MomConnect project, as shown in Figure 2.

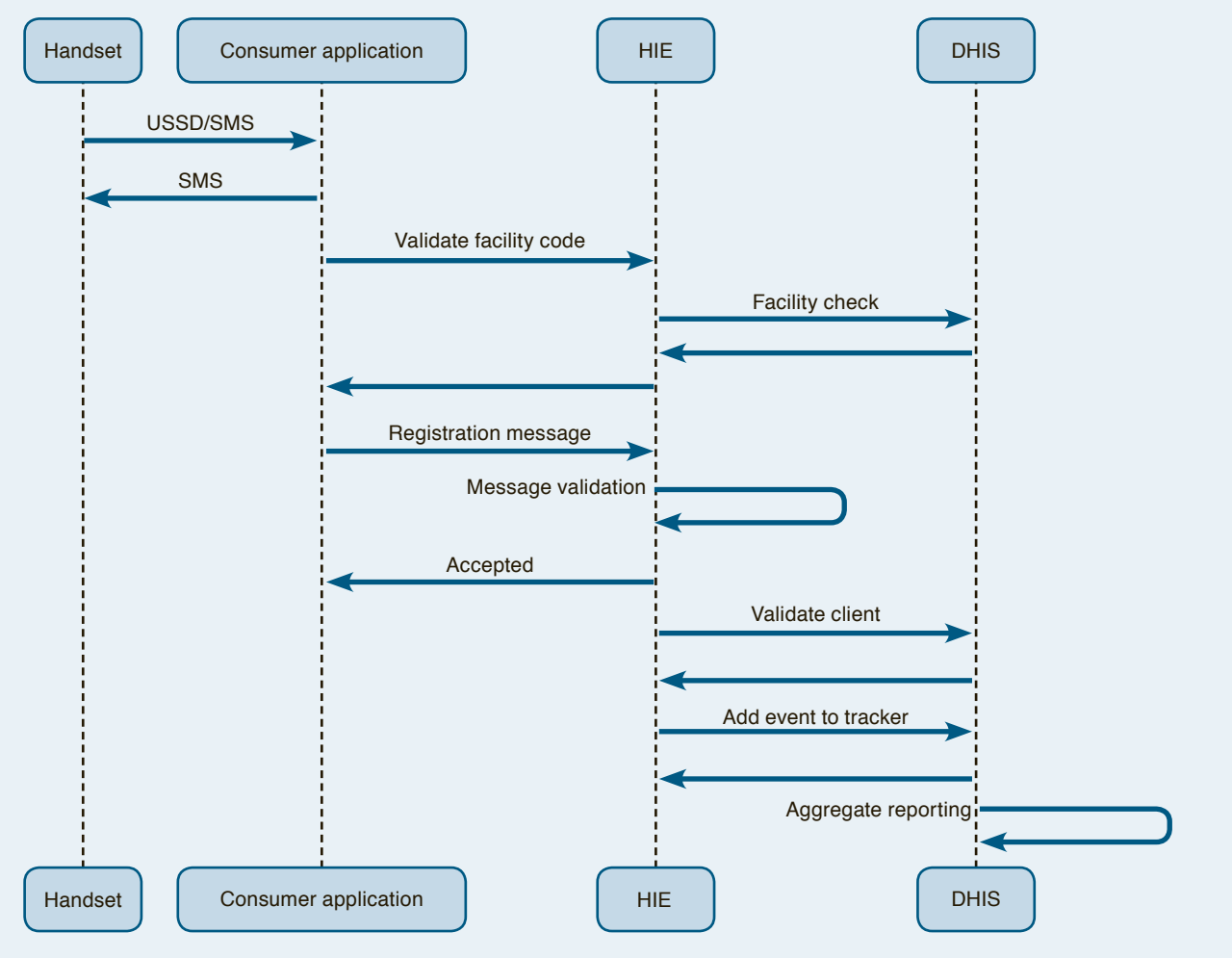
d http://www.hl7.org/implement/standards/product_brief.cfm?product_id=7

e http://wiki.ihe.net/index.php/Mobile_access_to_Health_Documents_%28MHD%29

f JavaScript Object Notation is a lightweight data-interchange format that is easy for humans to read and write.

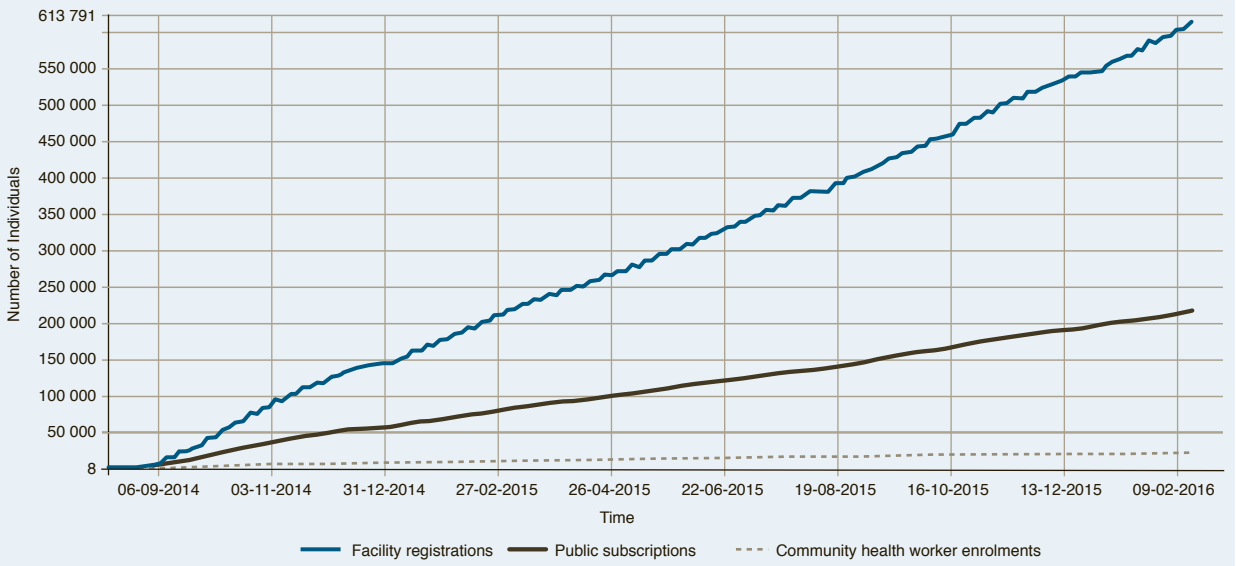
g https://www.hl7.org/fhir/overview.html

Figure 1: MomConnect registration: sequence of events



Key: USSD – Unstructured Supplementary Service Data
SMS –Short Message Service
HIE – Health Information Exchange
DHIS – District Health Information System

Figure 2: Cumulative total MomConnect registrations, subscriptions and enrolments (N)



As a successful national mobile health application, MomConnect is one of only a few known standards-based implementations in Africa and serves as positive proof that South Africa can succeed in implementing the HNSF and make health applications interoperable.

Discussion

In view of the operational success of the MomConnect technical implementation, and ongoing challenges faced when attempting to mainstream digital health technical solutions, it is useful to align some of the key features of the technical architecture with factors that have been found by others to be important to success. In this section, we consider the MomConnect infrastructure in the context of two digital health systems frameworks. The recently published guidelines for reporting health interventions[18] were also useful for guiding both the content of this chapter and the recommendations for future work.

The MomConnect program and its technical features are reviewed from four health system dimensions as recommended by Leon et al.[28]

Government stewardship

- Strategic leadership: This is arguably the single most important criterion for success, and the MomConnect infrastructure scores highly in this dimension in that it was launched and supported by the Minister of Health and led by senior officials in the NDoH. The project was personally launched by the Minister in every province in South Africa, ensuring buy-in at the level where implementation occurs. The technical infrastructure itself is closely aligned with government policy as an instantiation of the NDoH HNSF architecture and implementation roadmap.
- Learning environment: A more formal evaluation of the impact of the MomConnect program is currently being conducted by the NDoH. Learnings from the infrastructure component have contributed significantly to our understanding of the implementation of systems at scale and the larger task of implementing the HNSF. These learnings are iteratively built into incremental improvements to the system.

Organisational systems

- Capacity for implementation: The MomConnect infrastructure development was undertaken by the NDoH in collaboration with private sector partners mobilised through the mMH Task Team. This proved to be an effective mechanism for ensuring that the MomConnect infrastructure contributes directly to the development of the public health system, while leveraging some of the innovation and implementation skills available in the private and academic sectors.
- Culture of information use: The MomConnect infrastructure was designed to integrate directly with the DHIS, which is used for monitoring and evaluation (M&E) of the various NDoH programmes. Integration of the registry system with the M&E platform ensures that MomConnect data are readily available to NDoH officials in near-real time. In this way, the data can be used effectively to monitor and intervene as necessary.

Technological systems

- Usability: The MomConnect technology platform was designed to maximise usability at several levels. At an end-user level, phones made use of simple USSD functionality that is familiar to end-users and ubiquitously available across cell-phone types throughout the country. The backend infrastructure was optimised to use the fewest possible components and simplest possible standards, and user-friendly administration tools were developed to assist with long-term maintenance.
- Interoperability: MomConnect's technical infrastructure makes use of the architecture provided by the HNSF, which implements interoperability standards and profiles across different applications that may also be extended to support additional health services.
- Privacy and security: The MomConnect technical infrastructure makes use of industry-standard methods for ensuring privacy and implementing security.

Financial systems

- Sustainable funding: The MomConnect technical infrastructure uses entirely open-source systems and software that minimises licensing and support costs and is consistent with South African government policy.[29] As such, it is relatively more sustainable and less reliant on ongoing funding than other commercial systems. The system is being improved continuously and the operating costs are being made more economical, e.g. by integrating with other established government systems and developing data-driven alternatives that have lower line costs.
- Cost-effectiveness: This criterion can only be evaluated fully once the impact of MomConnect has been assessed; however, early indications are that the infrastructure component is as low-cost as it can be, with the exception of line costs that are still being optimised. Based on initial results from a similar intervention in Bangladesh,[30] we anticipate that MomConnect will be found to be cost-effective for such a public health intervention. Additionally, improvements in cost-effectiveness may be realised if the USSD and SMS services are supplemented with data services.

Another framework for evaluating the MomConnect technical architecture is the Principles for Digital Development (PDD),[31] generally considered by many donors and implementing partners to represent best practice in the development of digital health solutions. Evaluation of the MomConnect technical implementation against the PDD is detailed in Table 3.

Table 3: Evaluation of MomConnect technical implementation against the Principles for Digital Development (PDD) framework

Design with the user	• This was adapted using the input of local experts to make it compatible with the local South African context, ensuring that the system was accessible to and equitable for marginalised populations where the need is greatest (rather than where technical access is easiest). The South African Mobile Alliance for Maternal Action[h] (MAMA) project had extensively tested the system used by MomConnect and its initial messages with South African women. • The messaging system used has been found to be effective in other low-resource settings. • The task team comprised people with varied backgrounds and experience, from which the project benefited. • Technical infrastructure made use of general, pre-developed eHealth and mHealth system components that had been successfully implemented in low-resource settings and shown to be effective and reliable. This meant that the focus could be on satisfying the end-user's requirements. The task of developing the MomConnect infrastructure was largely one of configuring the systems for the mobile maternal use case and integrating the working systems using the NDoH standards-based framework, rather than attempting to develop new systems.
Understand the ecosystem	• The process followed in the development of the technical infrastructure was initiated and led at the highest level by the NDoH and made use of an mMH Task team that included experienced private sector mHealth practitioners. • A survey of all mHealth services and projects was conducted at the start of the initiative, and all active partners were invited to the first meeting that led to the establishment of the Task Team. • Technical implementation was aligned with technological, legal and regulatory policies, both in South Africa and internationally.
Design for scale	• A systems approach was followed in the development of the technical infrastructure to ensure that the system fitted into the wider NDoH architecture. • Open standards were selected and implemented to ensure that the application could be scaled to include other mHealth applications and extended to include additional services. • The system was designed to be used in thousands of facilities, with training and support designed accordingly.
Build for sustainability	• The technical infrastructure was designed around considerations of long-term sustainability, including the use of open-source software and alignment with NDoH systems. • Use of the program has been institutionalised through the operating practices of clinical staff, ensuring a level of organisational sustainability. • MomConnect was designed to be a zero-cost service for the client.
Be data-driven	• Technical infrastructure was largely developed to manage data, including the data for registering and subscribing clients, messages sent to clients to promote antenatal care, and data for monitoring and evaluating the program. • A simpler minimal solution would have been merely to register women and provide messages. However, the technical backend infrastructure provides much more data for effective management of the program. • Usage data from MomConnect are collated weekly and circulated to the MomConnect Task Team and other stakeholders ensuring that management decisions are informed by data on the development of the system.
Use open data, open standards, open source and open innovation.	• Technical infrastructure has a number of features illustrating the principles of an open mHealth architecture[32] and open eHealth architectures in general: - Open data: The principles of making data open are relative in this context and the use of personally identifiable data cannot be made open. However, the de-identified, aggregate reporting data are made available within the NDoH and used for routine monitoring and evaluation of the program and to compare outcomes with performance indicators, such as the expected rate of enrolment based on previous maternal booking rates. - Open standards: By adopting the HNSF architecture and design, the MomConnect technical infrastructure implements open standards. Both the IHE profiles and the HL7 CDA specification used by the MomConnect technical infrastructure are openly available to users from low- and middle-income countries. The standards were also adapted to the specific requirements of MomConnect. The standards will be used to define a common means of connecting mHealth consumer applications to the HIE. - Open source: All applications used by the MomConnect technical infrastructure are open source. - Open innovation: Development of the technical infrastructure was conducted in an open environment and with transparency, allowing open innovation to occur.
Re-use and improve	• The NDoH and mMH Task Team elected to use open-source software that had already been implemented in South Africa and other countries. In this way, the MomConnect technical infrastructure was built based on existing initiatives, and its development has benefited from the considerable software development effort and investment that has generated existing software tools and standards. This has certainly lowered the costs and risk associated with software systems development. In addition, by using existing tools, MomConnect has contributed to the continued growth and development of these tools as a global good of open architecture health informatics tools that can be deployed in other low-resource settings.[33] • The message structure and the content of many of the messages were adapted from the MAMA South Africa project. While the NDoH took full ownership of the MomConnect project, the existing building blocks were used rather than re-invented. • The South African MomConnect technical infrastructure has now become a model for other initiatives, such as FamilyConnect in Uganda.
Address privacy and security	• MomConnect is one of the first projects in South Africa collecting individual-level data using a unique patient identifier. Privacy and security are of primary concern. The MomConnect HIE and monitoring systems protect client data at several levels, including physical access to the hardware, encryption of data and the use of certificates. A security policy has been developed and implemented by the NDoH
Be collaborative	• The MomConnect technical infrastructure project has been collaborative on several different levels. The mMH Task Team was initiated as a collaborative forum with representatives from a range of South African organisations. As the system develops, additional partners may be included to contribute to the integrated system. The development of the technical architecture was a productive collaboration between public health professionals and software engineers. The use of open-source software components and communities has the potential to contribute to the notion of a "broader commons of resource, action and knowledge" through the development of similar projects and initiative in Africa.[33,34]

Key: MAMA – Mobile Alliance for Maternal Action
mMH – mobile Maternal Health
NDoH – National Department of Health
HNSF – Health Normative Standards Framework
IHE – Integrating the Healthcare Enterprise
HL7 – Health Level Seven
CDA – Clinical Document Architecture
HIE – health information exchange

h MAMA South Africa provides access to information on pregnancy using different channels and a variety of formats and protocols (see http://www.askmama.co.za/)

Conclusion

Aligning MomConnect with international best practices resulted in a number of conclusions:

- Ensure government stewardship: Government stewardship is the most fundamental precondition for building health information technology infrastructure at national level. MomConnect has also shown that projects with strong government leadership can effectively leverage private sector innovation to best advantage and have the strongest chance of creating systems that are sustainable beyond the initial development phase.
- Adopt an open architecture approach: The open architecture approach adopted in the HNSF[14] has significant advantages for large-scale systems development, allowing multiple applications to be integrated into a single system through loosely coupled components. Open standards and open application programming interfaces (APIs) are fundamental enablers of the open architecture approach. Combining a flexible front-end consumer application with a standardised platform proved to be a powerful platform for MomConnect.
- Adopt the Principles for Digital Development:[31] These principles can assist system developers in avoiding common pitfalls and help them to develop systems that contribute to strengthening public health systems rather than consuming scarce resources with limited outcome.
- Re-use and integrate: Software and system development is expensive and risky, with a high failure rate. Within this context many working components can be re-used and integrated into a working system. This effectively lowers the cost and risk associated with system development. However, it is necessary to avoid the hazards of fitting the requirement to a particular software tool.
- Design a roadmap: Restricting scope and creating a roadmap for implementation are critical to the success of system development projects. It is important to understand which functionality is important at which stage of development of the project. In the case of MomConnect, it was possible to limit functionality, e.g. the number of data elements, in order to focus on the elements essential to its success.

Recommendations and future directions

Based on our experience in implementing the technical infrastructure for MomConnect, we offer the following recommendations for the future development of the MomConnect technical infrastructure and related projects as part of the HNSF implementation, several of which are already being investigated or developed by the NDoH:

- Include data options: Despite generous discounts afforded by Mobile Network Operators (MNOs), USSD and SMS are expensive protocols to implement. Significant cost savings could be achieved by supplementing MomConnect with applications that use data services while retaining the reach afforded by USSD and SMS. Interaction with the HPRS application could also help to reduce the cost of collecting MomConnect data in facilities where it has been implemented.
- Extend to other health services: An opportunity exists to extend the MomConnect implementation to other health services where digital data are collected. The NDoH plans to expand the program to include additional maternal, newborn and child health (MNCH) services and mobile health applications. The application currently being considered is the mobile health application implemented by CHWs as part of the primary health care stream of Ward-based Outreach Teams (WBOTs). MomConnect can be developed to include and integrate with other services, such as child health and immunisation programmes supporting a continuum of care through pregnancy and early childhood and linking to the requirements for universal health coverage.[35]
- Include other mobile health applications: A particular advantage of the HNSF architecture is that it enables interoperability between different applications using the same interoperability standard. This opens up the possibility of leveraging digital health applications used in other programmes to contribute to data collection and potentially interact with MomConnect to create more extended data sets. The ability to facilitate interoperability between different mHealth applications will solve the vexing problem of the proliferation of small pilot projects ('pilotitis') in mHealth that has plagued many low- and middle-income countries, including South Africa, struggling to use information and communication technologies (ICTs) to improve efficiencies.[13,36] The NDoH is already working with other mobile health application providers to explore such incorporation into the MomConnect technical infrastructure.
- Extend the national architecture based on the HNSF: The South African HNSF is an advanced legislative framework for digital health that can be used effectively to realise digital health benefits such as interoperability, standardisation and re-use of existing infrastructure. The architecture itself could be used effectively by the NDoH to guide the implementation of other digital health programs in South Africa in the interests of strengthening the public health information system more generally. There are many advantages in integrating MomConnect into the eHealth reference implementation project, including integration with the HPRS to reduce duplicate registration and unnecessary data capture. As the application and data integration occurs, additional opportunities will open up for integrated data to support public health services in South Africa.
- Assess the effectiveness of the MomConnect messages: The MomConnect interoperability architecture is a powerful platform for data integration. In future, triangulation of data from within MomConnect and other programs collecting maternal health data could be used to test the delivery of messages and their effectiveness in improving ANC attendance. The NDoH has already initiated an action to integrate related applications, which can catalyse integration of data elements and enable more powerful analyses. This will also serve as a model for other health services within the HNSRF implementation project.

Acknowledgments

The authors acknowledge the leadership of the South African Minister of Health who initiated and leads the MomConnect project, as well as the direction and contribution of the South African National Department of Health, especially Dr Yogan Pillay who convened and led the mMH Task Team, and the MomConnect project managers. The mobile phone and mobile health application components were implemented and managed by a group from Praekelt Foundation. The interoperability components were implemented and managed by a group from Jembi Health Systems. The registry and data warehouse components were implemented and managed by a group from the Health Information Systems Programme, South Africa (HISP-SA). Additional inputs for the technical design and implementation of MomConnect were provided by the Council for Scientific and Industrial Research (CSIR) Meraka Institute and Inner City Fund (ICF) International. Regular inputs and feedback were provided by all members of the mMH Task Team. Local and international funders, including the United States President's Emergency Plan for AIDS Relief (PEPFAR), the Johnson & Johnson Foundation and Elma Philanthropies, support MomConnect. The mobile operators in South Africa – Cell C, MTN, Telkom Mobile and Vodacom – afforded generous discounts on the commercial cost of SMS messages.

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