On-Cloud Motherhood Clinic: A Healthcare Management Solution for Rural Communities in Developing Countries

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On-Cloud Motherhood Clinic: A Healthcare Management Solution for Rural Communities in Developing Countries

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Abstract

Background: *Modern telecommunication infrastructure enables bridging of the digital divide between rural and urban healthcare services, promoting the provision of suitable medical care and support. Thus far, there has been some positive impacts to applying mobile health (m-Health) solutions, but their full potential in relation to cloud computing has is yet to be realised. It is imperative to develop an innovative approach for addressing the digital divide in a context of developing country.*

Method: *Adopting a design science research approach (DSR), this study describes an innovative m-Health solution utilising cloud computing that enables healthcare professionals and women in rural areas to achieve comprehensive maternal healthcare support. We developed the solution framework through iterative prototyping with stakeholders' participation, and evaluated the design using focus groups.*

Results: *The cloud-based solution was positively evaluated as supporting healthcare professionals and service providers. It was perceived to help provide a virtual presence for evaluating and diagnosing expectant mothers' critical healthcare data, medical history, and in providing necessary service support in a virtual clinic environment.*

Conclusions: *The new application offers benefits to target stakeholders enabling a new practice-based paradigm applicable in other healthcare management. We demonstrated utilities to address target problems as well as the mechanism propositions for meeting the information exchange demand for better realisation of practical needs of the end users.*

Keywords: Rural Healthcare IT; Critical Maternity Management; m-Health; App Solution Design.

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Introduction

Women living in rural regions, particularly pregnant women, face a lot of challenges in receiving healthcare services. Many factors prevent them from receiving healthcare support during pregnancy and childbirth, including poverty, distance, lack of information, inadequate services, and cultural practices (World Health Organisation, 2018). As a result, women face a lifetime risk of maternal death of 1 in 160 in low and middle-income countries, compared to developed countries' rate of 1 in 3700 (Watterson et al., 2015).

Critical illness in obstetric patients are due to conditions unique to pregnancy and coincidental conditions (Plaat & Naik, 2011). Currently, almost all maternal deaths (99%) occur in developing countries (UNDP, 2015), with proportionately more in rural and poorer areas (WHO, 2018)[1]. More than half of these deaths occur in sub-Saharan Africa and almost one third occur in South Asia. Thus, it is a significant social issue that must be addressed (WHO, 2018).

Rural citizens in developing countries have been suffering from "digital divide" in healthcare support due to limited access to experts and mobile health (m-Health) information. Advanced information and communication technologies (ICT) have the potential to address these limitations within society by implementing mobile and cloud-based e-health solutions and enhancing self-management (Karim & Bajwa, 2011) and reducing travelling and medical expenditure (Brown et al., 2013) for these populations. There is rising international interest in using m-Health to improve the quality and safety of health care services; and reduce healthcare costs in developing countries (Brown et al., 2005; Manya et al., 2016) as access to mobile Internet services has increasingly grown in developing countries.

The study develops a conceptual solution framework using cloud computing[2] functionalities, adopting design science research (DSR) guidelines from Peffers et al. (2008) through a socio technical design paradigm defined in Carlsson et al. (2011). Regardless of privacy and security concerns in different specific cases (Nakayama and Chen, 2019), the cloud computing, in this study utilised is to facilitate the information solution (e.g. mobile app) to the end users over the telecommunication networks in a self-service fashion that is independent of platform or devices (Marston et al., 2011). Moreover, the proposed *"On-Cloud Motherhood Clinic"* offers opportunities of sharing all medical information exchange and suggested treatments/services of the expectant mothers to end users (women); and have access to information as appropriate for end users via cloud manager (e.g. can be a software agent) (Mell & Grance, 2011). Thus, the *motherhood clinic* is vital to adopt and support flexibility and all functions to fulfil a critical care demands of motherhood and it may be provided through an IS solution artefact (Hu & Bai, 2014) that is the central focus of this study reported in the paper.

DSR intends to generate prescriptive knowledge that relates to many forms of IS (information systems) artefact designs, such as software applications, methods, models, and concepts (Hevner et al., 2004; Gregor & Hevner, 2013; vom Brocke et al., 2019). The aim of DSR is to build on existing design knowledge and create new design knowledge so that researchers can obtain benefits from the new IS artefact design (vom Brocke et al., 2019). The solution artefact presented in this paper is showcasing to contribute (using a theoretical lens of Carlsson et al., 2011) to both the theory and practice of solving a real-world complex problem. The problem is centred to critical maternal health issues in which most of the outdated approaches are related to traditional diagnosis and consultation procedure. Critical illness in the obstetric

[1] Source: http://www.who.int/news-room/fact-sheets/detail/maternal-mortality

[2] Cloud-based computing is an ICT service model where computing services including both hardware and software are delivered on demand to customers over a network in a self-service fashion, independent of device and location (Marston et al., 2011). Cloud computing is a model for organizing shared computing resources such that automatic, on-demand access to these resources is possible, irrespective of who owns them and whether they are located "on or off premises" (Mell & Grance, 2011). Cloud computing adopts and supports the functionalities of an integrated m-health system as a number of interoperable services (Hu & Bai, 2014).

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patient are due to conditions unique to pregnancy, conditions exacerbated by pregnancy and coincidental conditions (Platt & Naik, 2011). Critical illness in pregnant women may result from deteriorating pre-existing illnesses, diseases that are co-incidental to pregnancy, or pregnancy-specific conditions (Pandya & Mangalampally, 2018), which can result in high mortality rates. For example, major obstetric haemorrhages are the leading cause of maternal mortality worldwide and is the most frequent indication for ICU admission during pregnancy (Hazelgrove et al., 2001; Sriram & Robertson, 2008; Tang et al., 1997). Similarly, cardiac arrest during late pregnancy, can also result in maternal death (Campbell & Sanson, 2009). Thus, given the severity of these health issues, it is crucial to address this problem.

Going beyond the traditional direct and web-based support systems, considering the increasing digitalization in almost all sectors of society, an innovative cloud-based solution artefact is designed to enable both healthcare professionals and patients to enhance interoperability, collaboration, data storage and processing, saving time for organised visits, and one-on-one consultations. It further enables patients to avoid inconvenience of travelling from remote locations to big cities for basic health management; as well as immediate support for critical maternal illness management. The solution artefact as instantiation[3] (as a proof of conceptual solution framework) is designed to meet the new contextually formulated problem details. This artefact brings all medical information and data to geographically dispersed health professionals, manages consultation outcomes and services via locally based doctors/health workers. More importantly, it offers a more effective and responsive model for managing critical maternal health care services to remote locations elsewhere in developing countries. Our immediate research context is Bangladesh, which despite progress in reducing its maternal mortality rates, still ranks highly for maternal mortality, and is comparable with many South Asian and African countries (WHO, 2018).

Research Scope and Research Question

Previous studies indicated that mobile or e-health based solutions for various critical health services are limited to simply online based technologies. For example, studies such as for child immunization (Uddin et al., 2012), diabetes (Islam & Tabassum, 2015); and basic routine information on reproductive health issues (Alam et al., 2017) were based on inflexible options such as lack of collaboration and interoperability. For instance, most of the health care organisations are in practice of reducing paper-based records, therefore it became of a paramount option for healthcare professionals to interact with electronic health records that are easily stored in cloud server and enable collaboration for continuous and real-time updating and monitoring. Also, it is important to streamline the information delivery process ensuring patient's access through mobile devices. The cloud based information such as personal health records are relatively quicker and easier for professionals to assess or share with patients or other parties for ensuring remote and quick critical care services. No existing studies of cloud-based computing within m-health service space focused on maternal critical health care issues via mobility care. It is, thus imperative to develop and evaluate an innovative practical concept using a cloud-based approach to provide health care services to the expectant mothers with critical maternal health issues. Outlining the scope as vital design motivation, we develop the research question: "How a maternal information support solution could be developed to address critical maternal healthcare management of the rural communities in Bangladesh?"

[3] March and Smith (1995) classified the IS artefacts as method, model, construct and instantiation. The instantiation is defined as *"the realization of an artifact"* in its problem domain, being instantiated out of necessity, and using intuition and technical practice (March and Smith, 1995; Genemo et al. 2015).

Background of the study

Bangladesh is a small country with a huge population. 162.95 million people living in an area of 130,170 km square. Overall, the health care facilities are poor, with three (3) hospital beds per 10,000 inhabitants, five (5) physicians per 10,000 as of 2016 (World Development Indicators, 2017). The majority of the population (115 million) live in rural areas without access to modern health care services and specialised hospitals with 75% of qualified physicians practicing in urban areas (Hasan, 2012). As a result, the access to public health systems in the rural areas are extremely limited, and severely affect the quality of health services received by rural populations. Currently, the practice of treatment and diagnosis are heavily dependent on in person communication, e.g. making appointment with the GP (general practitioners) and specialised doctor and visiting doctors in person each time. Moreover, as mentioned earlier, there is not enough specialised doctors and hospitals in the rural areas. Thus, the access to specialised doctors, hospitals and support services are harder for the rural patients as it is time consuming and expensive.

In comparison, the telecommunication infrastructure condition is surprisingly good in Bangladesh. The mobile-broadband subscriptions have grown more than 20% annually in the last five years and have reached 4.3 billion globally by end 2017 (ITU, 2017). In Bangladesh, the total number of Mobile Phone subscribers has reached 150.945 Million; and the total number of Mobile Internet subscribers is 82.024 Million at the end of June 2018 (BTRC, 2018). Moreover, the Bangladesh *Telecommunication Regulatory Commission (BTRC),* encourages use of mobile applications; and they are readily accessible for all people in Bangladesh (BTRC, 2018). Given these circumstances, m-Health Innovation solutions provides a promising solution for rural populations.

With the continuing improvement of mobile broadband services, quite a few effective eHealth interventions have been introduced in Bangladesh such as *CMED health, Doctorola Ltd, Aponjon, DIMS, Tonic, Maya Apa,* and *Bhalo Achi*. Table 1 shows the key e-Health interventions in Bangladesh.

Table 1 - e-Health interventions in Bangladesh

Intervention Name	Technology/tools/system used	Source
Bhalo Achi	DSS (decision support systems) for public use	http://www.bhaloachi.com
CMED Health	Cloud based smart health monitoring system (Hardware based) for patients	https://cmed.com.bd
Doctorola Ltd.	Appointments booking system for patients	https://doctorola.com
Aponjon	DSS 2. SMS notification for new mothers	http://www.aponjon.com.bd
DIMS	Static information dissemination system for doctors	http://dimsbd.com
Tonic	Appointments booking system	http://www.mytonic.com/en
Maya Apa	DSS	https://www.maya.com.bd

Within this context, Information and Communication technologies, cloud-based ICT services; and mobile devices (m-Health) can contribute significantly to the improvement of health care systems and services in developing countries (Alam et al., 2017). Previous research has examined the effectiveness or usefulness of mobile devices, and specific applications such as child immunization coverage in rural Bangladesh (Uddin et al., 2012), or other health care services, such as for diabetes management (Islam & Tabassum, 2015). Only one initiative

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(Aponjon) targeted the rural population to use mobile phones for reproductive health services and found that these services were not very widely used due to lack of integration with public health care systems (Ahmed et al., 2014); Furthermore, Aponjon only provided basic routine information on reproductive health issues rather than a personalised health-care approach (Alam et al., 2017).

Existing studies which focus on a cloud-based e-Health solution via mobile devices for maternal health care issues is limited. Our research aims to develop and evaluate and innovative personalised and practical mechanism to better maternal health by using a cloud-based eHealth approach to provide health care services to the expectant mothers with critical maternal health issues. This approach will not provide any service to expectant mother with general maternal health issues or to other patients.

Recent e-Health and m-Health research suggests three dominant purposes of cloud-based approaches in delivering speedy and real-time health care support. These are: for health monitoring, e.g. with smart phones (Hossain, 2015); for health awareness, such as online social discussion groups for people with common health problems (West, 2013); and for disease diagnosis (Al Mamun et al., 2017). Such approaches support patient empowerment for example, in terms of providing access to their personal health records, as well as leveraging real time and scalable features, which generate key motivations of designing a new solution for maternal critical healthcare.

Cloud computing based healthcare systems have been proliferated for various purposes. Appendix A illustrates the major studies in the area, which have explored these purposes. A cloud-based e-Health system for diagnosing various health conditions of patients living in a rural area of India, was proposed by Parekh & Saleena (2015). Using data mining techniques, the system produces outcomes by relating entered symptoms to diseases and by analysing historical data maintained by the system. Their proposal involved the patient logging into their mobile application, and entering all symptoms related to their health issues including his/her location. The system then analysis the symptoms for the users and displayed the nearest specialized doctors and hospitals for which s/he can receive specific treatment according to their location.

Miah et al. (2017) recently developed and evaluated an on-cloud consultancy system through cloud computing utilizing a socio-technical approach of *ensemble* artefact design[4]. That e-Health solution enabled health professionals and healthcare workers to identify and treat non-communicable diseases (e.g. Diabetes) successfully in rural and remote communities in Bangladesh. The evaluation of their research found a positive attitude towards the on-cloud solution design artefact approach. Moreover, the research found that the role of intermediator health professionals (e.g. an individual or part of local community clinic) is important to implement the design solution appropriately. The research findings also suggest that the practical feasibility of the solution is sufficient to the further develop and implement the system effectively. Earlier to that, Sailunaz et al. (2016) proposed framework named Cloud-based MEDical System (CMED) as a setup considering both healthcare centre and a portable healthcare service with a Community Health Worker (CHW) setting. The system sorts the patients into three categories; healthy, alarming and emergency suggests a specialised doctor after diagnosing the problem of the patients.

Song et al. (2015) described a cloud-based personal health record system that provides patients or guardians the ability to constantly monitor and control their personal health records. Their system allows constant monitoring capability by supporting dynamic creation of clinical

[4] Ensemble artifact is a view of DSR solution that supports dynamic interactions of human with technologies for achieving wider systems of use (Miah, 2008 & 2009; Miah & Gammack, 2014; Miah & Genemo, 2016; Miah, Gammack & McKay, 2019)

document architecture (CAD) documents from a mobile device. The CDA data ensure the meaningful use of data from the clinicians.

To acquire voice and electroencephalogram signals in a scalable, real-time and efficient manner, Hossain (2015) proposed a "cloud-based cyber-physical localization system" for monitoring patients using smart-phones. The approach uses Gaussain mixture modelling for localization and is shown to outperform other similar methods in terms of error estimation.

Hossain & Muhammad (2014) reported a cloud-based system for providing combined media services through collaboration. Utilising Extensive Messaging and Presence Protocol (XMPP) and the identifying ability of smartphones' microphones, the cloud-based system primarily facilitates effective collaboration between health professionals, caregiver and patients. The system allows all users to access the voice pathology assessment scenarios through smartphones microphones.

For diagnosis of chronic illness such as diabetes, Kaur & Chan (2014) designed a cloud-based smart healthcare service to monitor user health data. In their design system, the body sensor mechanisms are utilised for recording and uploading user data to cloud storage; where analysis and classification are done in cloud-based storage repositories. Table 2 summarises the key features from a few major studies related to cloud-based healthcare solutions relevant particularly to patients and professionals in developing countries.

Table 2 - Major works on Cloud-based eHealth solution in developing countries

Author/s	Cloud-based solution purposes/classes	Techniques/Procedures used	Target beneficiaries
Sailunaz et al. (2016)	Health monitoring system for several diseases	Cloud-based MEDical System (CMED) involving healthcare centre and a portable healthcare service with a Community Health Worker (CHW)	Rural and under privileged people
Al Mamun et al. (2016)	System for diagnosis neurological diseases such as Parkinson's Disease	Support vector machine was used for classifying text or image	Patients and healthcare professionals
Hossain (2015)	Elderly health monitoring/remote care	Speech and face recognition framework, support vector mechanism	Healthcare professionals
Hossain & Muhammad (2014)	Monitoring system for effective collaboration between healthcare professionals and care givers	Extensive Messaging and Presence Protocol (XMPP)	Healthcare professionals and care givers
Rana & Bajpayee (2015)	Diagnosis system for analysing patients EMR for professionals for their further study and process improvement	Integrated and inter-operable solution technology	Healthcare professionals
Song et al. (2015)	Health monitoring system to provide health records to patients/guardians for further monitoring and controlling the records	Clinical documents architecture for assessing current health against major diseases	Patients and Guardians
Parekh & Saleena (2015)	Diagnosis system for analysing healthcare data using data mining	Clustering technique	Healthcare professionals, patients and government

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Muhammad (2015)	A framework for speech-enable remote healthcare	Interlaced derivative pattern for automatic speech recognition	Healthcare professionals and patients
Kaur & Chan (2014)	Intelligent system to monitor user health data for diagnosing chronic illness e.g. Diabetes	AI techniques for real-time monitoring of patients' data	Healthcare professionals

Most of the cloud computing based solutions have been introduced for monitoring of patients' health conditions. Generally, this type of systems produces outcomes by relating entered symptoms to diseases and by analysing historical data maintained by the system. The patient can login into their mobile application for entering all symptoms related to their health issues including his/her location. The system then analyses the symptoms for the users and displays results with support service information. A recent study (Miah et al., 2017) introduced a cloud computing solution for an on-cloud consultancy system that enables health professionals and healthcare workers to identify and treat non-communicable diseases (e.g. diabetes) successfully in rural and remote communities in Bangladesh. The evaluation of their research found a very positive attitude towards the on-cloud solution approaches when they are designed through the DSR principles and guidance. "DSR projects must provide both intellectual merit in creative designs and broader impacts to the application domain via original problem solutions" (vom Brocke et al., 2019, p. 2). For this, a socio technical design may provide appropriate lens to view the problem and solution spaces (such as enhancing impact using latest technology such as IoT (de Vass et al. 2018)) as the DSR must produce a design knowledge that is about "means-end relationships between problem and solution spaces" (vom Brocke et al., 2019; Venable, 2006).This implies that when designing a socio technological solution for the purpose of maternal critical healthcare a DSR approach would provide the best opportunity to demonstrate the rigor and relevance of the solution design.

Study methodology

We adopt a socio-technical approach to artefact design view (Carlsson et al., 2011) of design science research (DSR) for designing and evaluating the proposed artefact called On-Cloud Motherhood Clinic. Our aim is to conduct the design research developing socio-technical design knowledge in that such knowledge could be reusable to support practitioners and end users. The knowledge support will be mainly with a new combined technological approach that may lead to their desired context-oriented outcome. Carlsson et al. (2011) proposed a socio technical DSR framework that consists of five components: such as design propositions (e.g. which mechanism would lead to beneficial outcome such as an effective care support), problem situation (e.g. maternal support and treatment demand), context (e.g. exchanging information in between healthcare professionals and rural expectant mothers), mechanism (e.g. innovative mechanism such as cloud computing technique that is used to address problems); and outcome (an effective artefact design and solution understanding). According to Carlsson et al. (2011)'s framework, design propositions should therefore, aim to address contextual constraints; for example, in our case, requirements of common vocabulary for effective information exchange among all users, although the purpose of the design is to generate general and abstract knowledge rather than enabling specific techniques for addressing the problem.

Furthermore, IS design science research should develop practical design knowledge and theory to be used to solve particular problems (Gregor & Hevner, 2013). It is possible to take contextual variables into account, such as media use in groups of different sizes, but it is not possible to give guidance for every specific context. Instead, practitioners should base their design on experience, the specific problem situation and context, and on the knowledge of the design propositions (Carlsson et al., 2011; van Aken, 2005). Accordingly, our research focuses

on the 'Beneficial' comes to the expectant mothers as end users, as a result of solution artefact. Figure 1 shows the 'Guiding "Beneficial" outcomes' of our research.

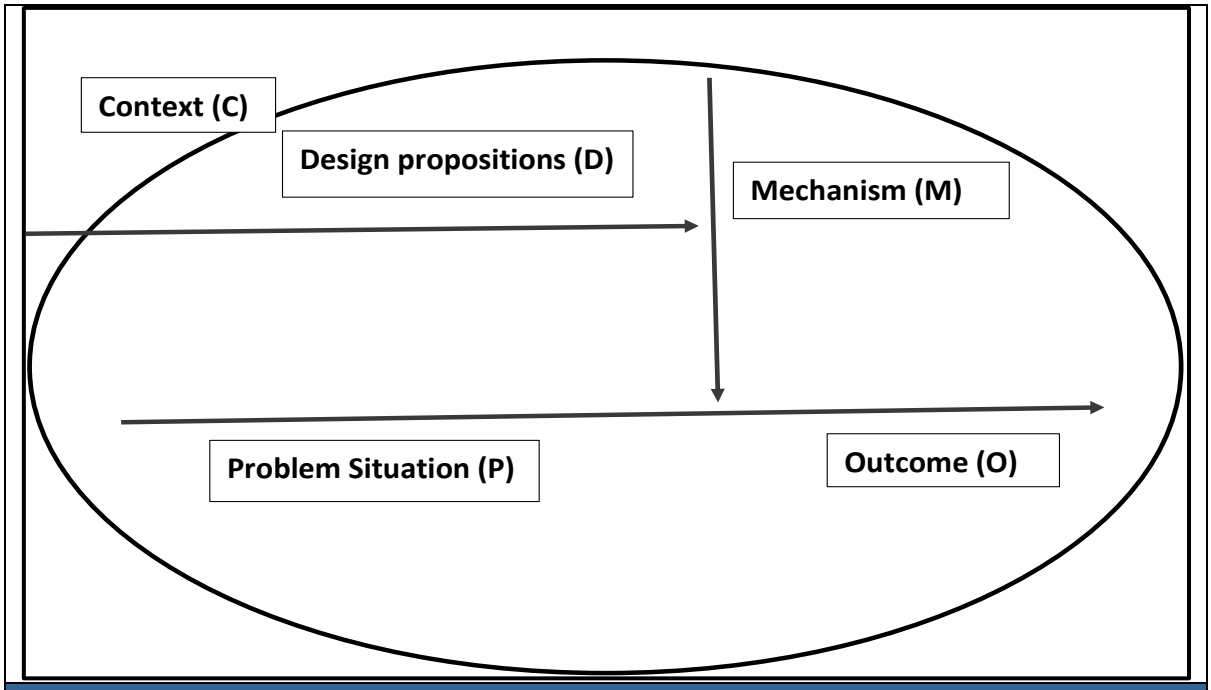

Figure 1 - Guiding "Beneficial" outcomes (Adapted from Carlsson et al. 2011)

(For our research, as Figure 1 shows, Design propositions D = e.g. which mechanism would lead to beneficial outcome such as an effective care support provisions; Problem situation P = e.g. maternal support and treatment demand; Context C = e.g. rural area where hospital supports are rare and options for exchanging information in between healthcare professionals and rural women should be based on electronic media; Mechanism M= e.g. innovative mechanism such as cloud computing technique that is used to address problems; and Outcome O = e.g. an effective artefact design and solution understanding).

Moreover, DSR has become a major paradigm for IS solution design, gaining enormous attention by IS researchers in recent years, but the knowledge growth in socio technical realm of design research is relatively limited, concerning the integration or interactions of people, process and technology. One reason for DSR being a popular design methodology is it promotes creation of innovative solution that reflect both practical context and professional relevance (Gregor & Hevner, 2013). Baskerville et al. (2015) summarised DSR as building and evaluating an IT solution as an outcome of a research project; producing new knowledge from the practices of design, development and/or evaluation activities, and communicating research by effectively reporting on it. Figure 2 represents the adopted procedure for conducting our design study.

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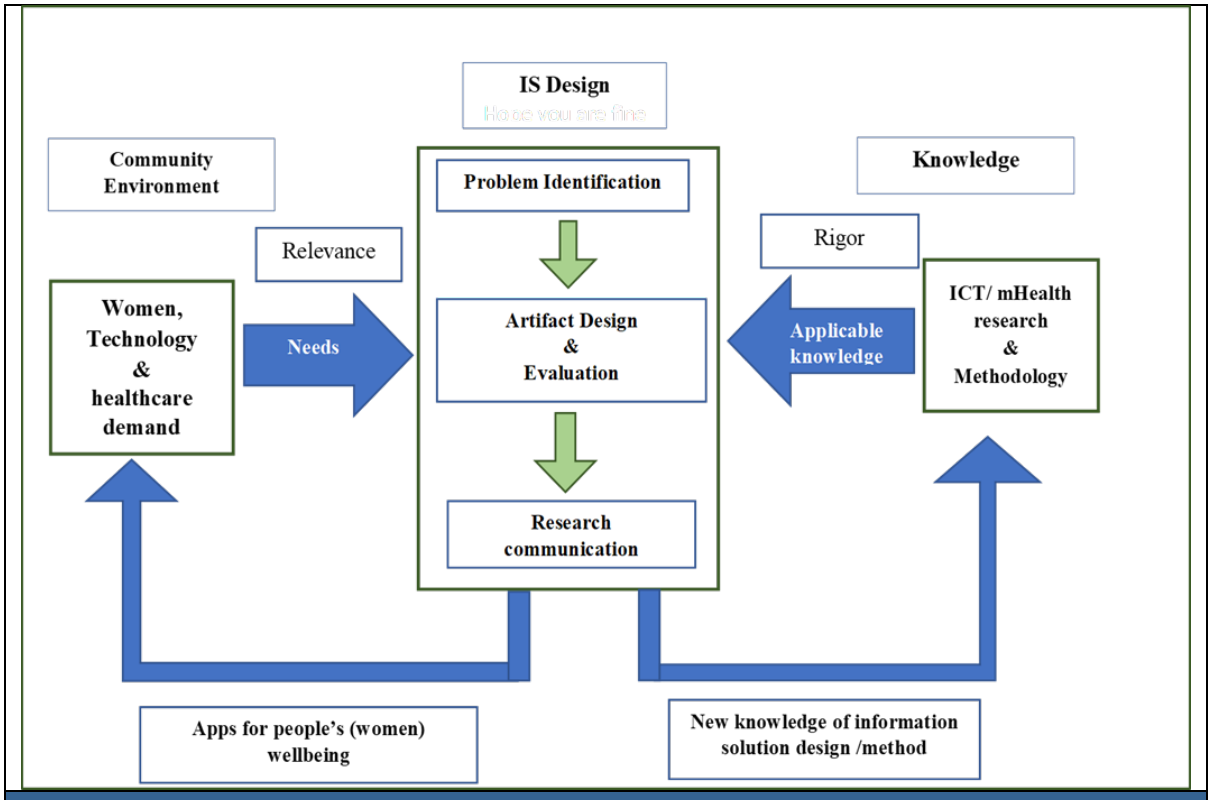

Figure 2 - DSR research procedure (based on Peffers et al., 2008)

As illustrated in Figure 2, our aim is to produce a new understanding of a problem based solution that would meet the specific population's demands. For problem identification we conducted prototyping, involving 10 domain experts to ensure better management of critical illness for expectant mothers. The experts are mainly healthcare professionals and specialised doctors in this field. We, as design team confirmed that the artefact offers provisions for end users e.g. the expectant mothers, GP, gynaecologist, specialised doctors, support service providers and hospitals especially the ICU (intensive care unit) under a collaborative process in the system to ensure better treatment and management of critical illness of expectant mothers. The primary challenge was associated with the information exchange among all stakeholders including expectant mothers, doctors, healthcare workers and support service providers. It was a vital requirement for all of these stakeholders to engage and provide effective electronic information exchange services useful in practice, via structures, easy vocabulary and location as context for general users. Using the socio technical framework for achieving "Beneficial" outcomes, the problem domain is structured for elaborations that is a foundation for the new solution design.

These are also to address the limitations of the existing technologies and enhance supportability. Technologically, proposed solution enabled efficient analytical method using data mining to leverage cloud computing features (combining software as service (SaS) and platform as service (PaS) modules together for addressing existing limitations), which can be seen as innovative features enabling better collaboration among healthcare professionals and patients (women); better interoperability and storage for effective critical and remote patient care support. Most of the existing approaches are incapable of producing such insightful approach for meeting the target critical purpose.

In terms of the Peffers et al. (2008)'s six activities map, our research process included realizing a problem situation (activity 1), analysing published literature for similar methods (activity 2), developing a prototype of the 'On-Cloud Motherhood Clinic' and testing its functionality in practice through focus groups study (activity 3). A proof-of-concept of the proposed artefact

was demonstrated later to obtain quality feedback from knowledgeable professionals and to explore the fidelity of the design work (activity 4). Descriptive evaluation occurred via seminars with participant feedback (activity 5). A total system was then dispersed to a practical audience (activity 6). To meet the requirements of ensemble artefact design, we combined the six activities into three phases that was suitable to the design study, particularly around capturing the needs of patients, doctors and healthcare workers of remote locations.

Table 3 - Different phases of the project

Phases	***DSR design activities***	***Our proposed artefact design***
Identifying business problems and artefact types	**Activity 1 and 2**	There is a need to develop appropriate and efficient analytical methods to offer flexible, collaborative and interoperable option for information exchange. Most current approaches are incapable of producing a powerful context-sensitive approach for this purpose. This is the essence of the research gap addressed by our DSR study. The study has produced an analytics method designed to generate activities of people traveling and gathering in locations.
Artefact creation and evaluation	**Activity 3 and 5**	Data mining methods employed in other domains were adapted for use in this study. The design process was iterative in order to cope with much of the uncertainty inherent in the problem space. The artefact was constructed using established data mining technique called clustering for outcome generation through a standard API (application programming interface) by analysing historical data maintained by the system and evaluated using fundamental and commonly accepted research methods namely focus groups study. To demonstrate artefact efficiency, effectiveness and utility, focus groups study were conducted including end users; e.g. expectant mothers, local GP (doctors), specialised doctors and pathological clinics. The findings of focus groups further evaluated with academics and medical practitioners through a seminar to gather more feedback.
Research contributions of the artefact and communication of results	**Activity 4 and 6**	The method that is theoretically informed through the *On-Cloud Healthcare Clinic* a framework of Miah et al. (2017). We applied the principles for inventing a new method and the experimental outcomes have shown a clear effectiveness. As a part of prototyping of solution, the artefact has been presented to medical professionals, and academic professionals who evaluated it for usability and efficacy in a focus group setting. The academic report is intended for publication following recommended practice and schema.

Artefact Description

The On-Cloud Motherhood Clinic enables information exchange among all stakeholders including expectant mothers, GP, specialised doctors, healthcare workers and support service providers. Utilising cloud computing for healthcare information service delivery, the module of software-as-a-service (SaaS) [5] and Platform-As-A-Service (PaaS) are utilised as many opportunities for developing nations are available. The SaaS is increasingly deployed in various electronic services including healthcare with the main reasons given including cost

[5] Software-As-A-Service (SaaS) is an important resource on the cloud computing environment. Without installing any software locally, service user can use software as a utility; and enjoy the benefits of SaaS model (Yang & Tate, 2012). Same way, Platform-As-A-Service (PaaS) offers a flexible platform that enables collaborations and mobility.

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savings, deployment speed, and overcoming lack of qualified staff and medical professionals on premises. Our SaaS enabled artefact aims to provide effective IT services useful in practice, via structures and easy vocabulary relatable by all end users. Designed specifically to ensure better management of critical illness of expectant mothers, the artefact offers provisions for end users e.g. the expectant mothers, GP, gynaecologist, specialised doctors, support service providers and hospitals especially the ICU (intensive care unit) under a collaborative process in the system to ensure better treatment and management of critical illness of expectant mothers. This artefact is particularly useful in the rural and remote areas where access to GP, specialised doctors, support services and hospitals are hard to reach.

Figure 3 illustrates the architecture of the artefact. There are several parts to the ensemble design that include (a) access process, (b) role of intermediaries, (c) role of service providers (d) service delivery process, (e) management process, (f) privacy management. The steps are described below:

(a) ***Access process:*** Registration through 'Log in' is the first point for all end users and service providers to access the *Motherhood Clinic* service including the expectant mothers as service receivers. 'Log in Info' menu provides an easy description of the access process. Doctors including general practitioners (GP), gynaecologists, and critical illness related specialised doctors; along with support service providers (e.g. blood bank, ambulance services, ICU department of hospitals) are key stakeholders as service providers. They are to register with their expertise and availability details. Like the doctors and support services, the health care workers details are to register for coverage of areas.

(b) ***Role of Intermediaries:*** Local general practitioner (GP) (an MBBS doctor) and healthcare workers are considered as intermediaries for this *Motherhood Clinic*. An expectant mother with a critical illness (e.g. pregnancy related unique illness or pre-existing illness) is to be initially introduced either with a local GP, or a gynaecologist through a local community health worker or individually. The system then sets up an appointment either with a GP/gynaecologist, or a specialised doctor as appropriate; and all relevant end users are then to informed immediately with a notification.

(c) ***Role of service providers:*** Either a GP or a gynaecologist is initially responsible for the primary consultation, and then for referring the patient to an illness specific specialised doctor (e.g. to an endocrinologist in case of Diabetes). The specialised doctor is then responsible for providing immediate medical support or advice e.g. either by prescription of medication or via referral for further diagnostic assessment (if necessary). The support services (e.g. ambulance services, pathology clinic/radiology clinic) and hospitals are responsible for providing services to the patients after getting a referral from the specialised doctors through a notification on their system.

(d) ***Service delivery process:*** As part of delivering services, doctors including GPs, gynaecologists, other specialised doctors; and support service providers (e.g. pathology clinic, blood bank, ambulance service) are to connect through the system. Pharmaceutical prescriptions for medication or other treatment requirements (e.g. further testing/admission to ICU) guidance can be provided and followed up from time to time via *Motherhood Clinic's* cloud system[6]. Load balancing allocations can be logically handled in the cloud, and thus the system is completely accessible, and it appears seamless to the patients and the healthcare workers.

[6] For the purpose of evaluation, the app is available at https://snappy.appypie.com/index/app-download/appId/d9d6cc345b90.

(e) ***Management Process:*** A cloud manager controls all the actions, which occur on the cloud. It is responsible for managing and controlling all operations between the *Motherhood Clinic* and the cloud. A few main features of the cloud manager are: 1. Stakeholders and expectant mothers' registration, 2. Context management, e.g. managing and storing all information and data; 3. Communication management, e.g. communicating between cloud and the end users.

(f) ***Privacy management:*** Considering the privacy issues (Rana & Bajpayee, 2015; Sailunaz et al., 2016) and security issues in terms of data security (Masrom & Rahimly, 2015; Kotz et al., 2015) of the mobile and cloud-based healthcare solutions, the *Motherhood Clinic* is designed with password protected access mode for all users.

Other features: Several features are incorporated in the *Motherhood Clinic* artefact solution e.g. notification, rating of each services providers, teleconference, Google map and GPS services.

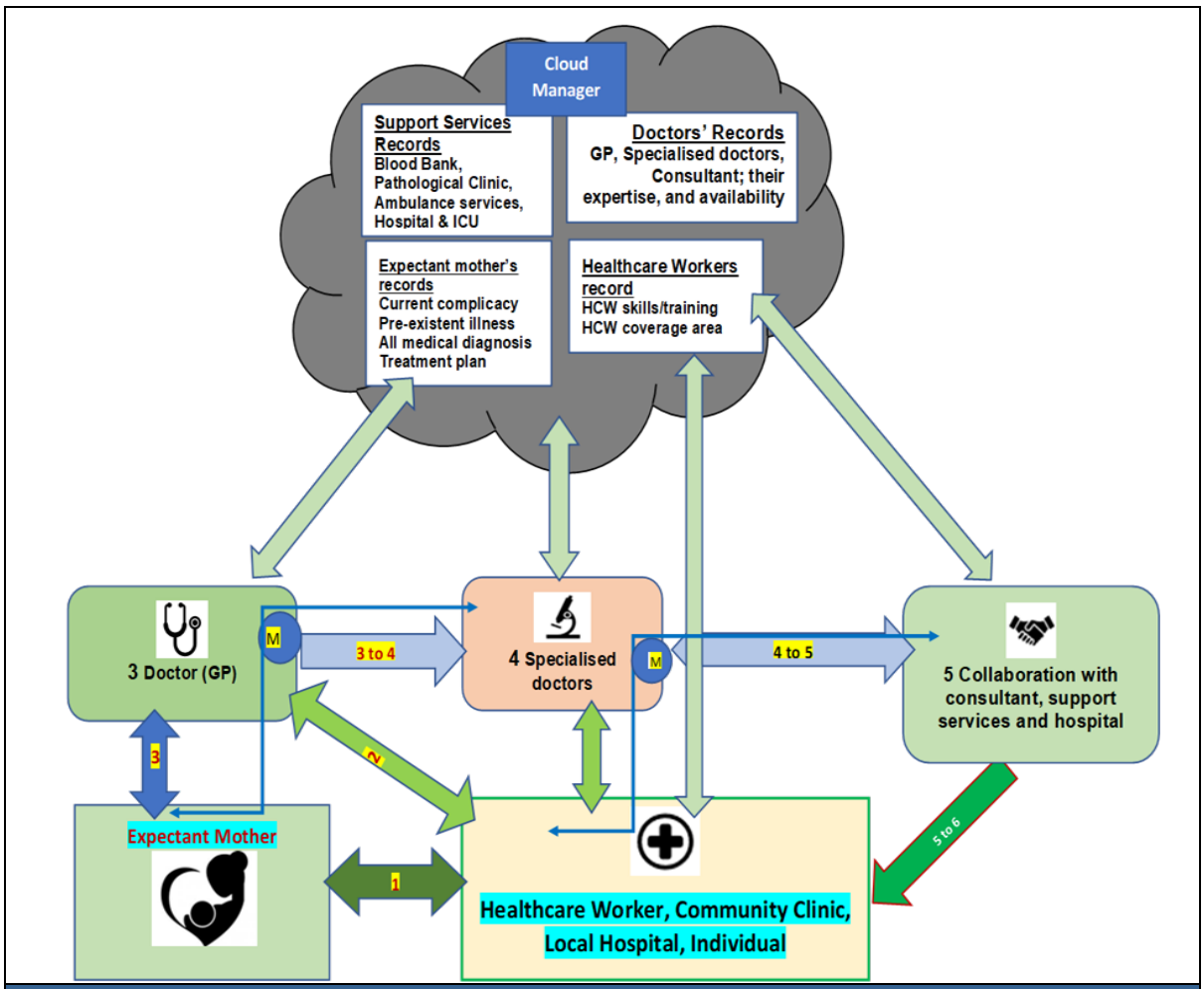

Figure 3 - Design components of the proposed artefact

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Design evaluation

We have evaluated the design artefact in a public healthcare atmosphere within a developing country. We believe that citizen as end users and their context of use would be a real-world practical situation in which the interaction between citizen (women) and healthcare professionals can be assessed. Hevner et al. (2004) proposed evaluation methods such as experimental, observational, analytical, testing and descriptive approaches. We however adopted the descriptive approach that enables us to apply a focus group to build up convincing argument for the artefact's utilities.

An inclusive evaluation is essential for any design science research. IT artefacts can be evaluated in terms of "functionality, completeness, consistency, accuracy, performance, reliability, usability, fit with the organization, and other relevant quality attributes" (Hevner et al., 2004, p. 85). We evaluated efficiency, effectiveness and utility of our artefact prototype on several dimensions i.e. product, distance, time, interaction and procedure focusing on these three performance criteria.

Pries-Heje et al. (2008) proposed a DSR evaluation framework for performing evaluations of artefact either artificially or in a naturalistic way, as well as ex ante (before) or ex post (after the design). After having formulated an initial design theory, the next step involved empirical testing, which included the selection of an appropriate approach (Carlsson et al., 2011). The design proposition may be altered and improved based on the findings of the focus group. Through this process, we hope to accumulate supporting evidence towards of the use of this artefact. This evaluation situation can be represented through the Figure 4 below.

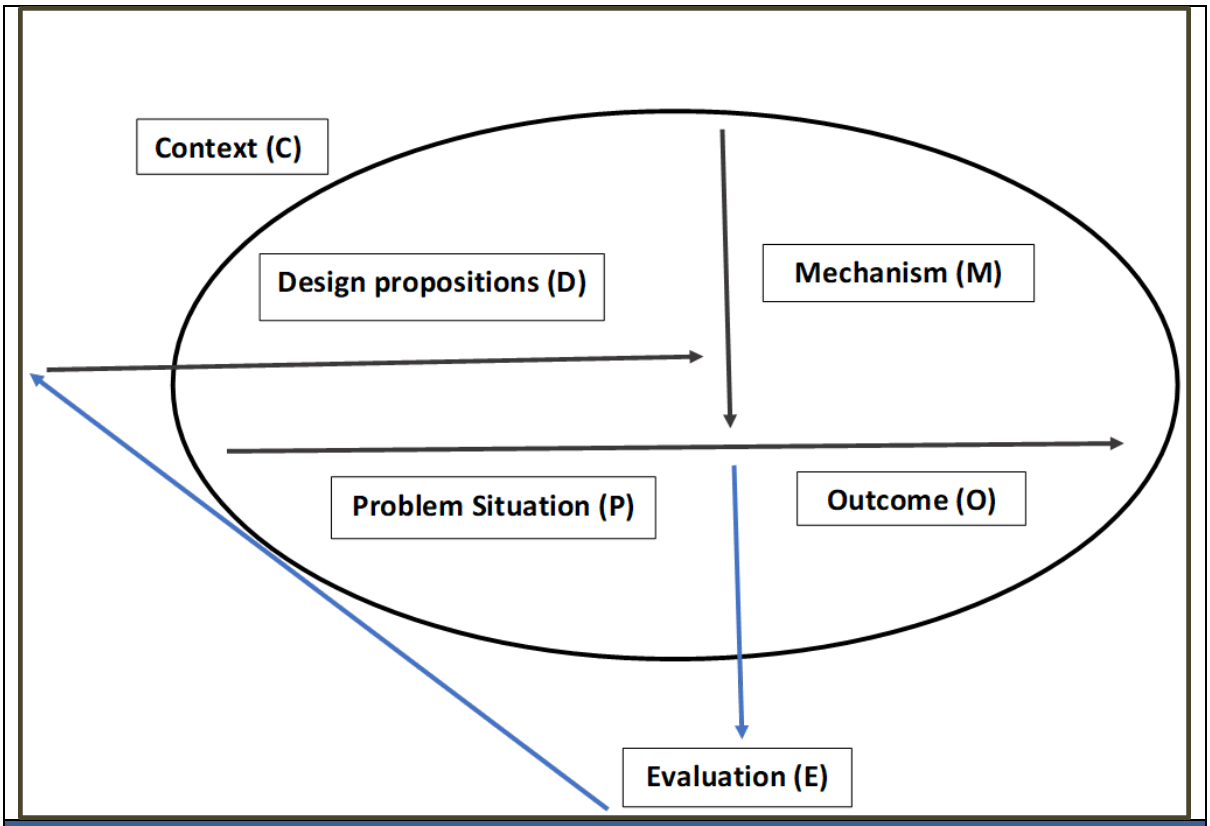

Figure 4 - A Socio-technical Evaluation Strategy following the beneficial outcome analysis (Adapted from Carlsson et al., 2011)

Note for Figure 4: *Design propositions D = how can we ensure that cloud computing based solution leads to beneficial outcome such as an effective care support provisions; and Evaluation E = effectiveness, efficiency and utility of the prototype.*

Focus groups technique were an effective method to evaluate the prototype. Tremblay et al. (2012) supported the use of focus groups for both for exploratory and confirmatory purposes of artefact evaluation. Consequently, with the guidance proposed by Nieveen & Folmer (2013) and Tremblay et al. (2012), we conducted a focus group to collect expert opinion for evaluating our prototype solution. An information sheet on the project description including its aims and objectives and focus group questions were distributed to all participants. Written consent was obtained from the participants before conducting the focus groups (Please see Appendix C for the list of participants). We collected data from two (2) gynaecologists, two (2) GPs (MBBS Doctor), three (3) specialised doctors, two (2) hospital management representatives (doctors), eight (8) patients and one (1) IT consultant. Our aims were to evaluate the system, particularly the efficiency, effectiveness and utility of the solution; and to collect expert opinions and suggestions from the end users for further improvement to the design solution. To do that the facilitator first explained the aims and objectives of this research and demonstrated the prototype. Participants where then presented with the main questions which were associated with the three performance criteria of effectiveness, efficiency and utility of the prototype.

For investigating efficiency of the system, we enquired: whether the system (app) provided easy access to maternal critical health care services; whether the system is useful to reduce requirements to visit doctors/hospitals, if the app provided quick service to find possible health management assistance and whether the system was helpful to reduce operational costs. In response to these questions, all users responded positively to the system and mostly reported agreeing to increased effectiveness, efficient and reasonable utility of the prototype.

On efficiency of the system, some responses were as below:

> *"Yes, it does. It is efficient in providing all probable kinds of health care that an expectant mother may need";*
> *"Though in case of critical health care issue one needs to visit doctors and hospitals, yet this app allows getting both general and specialist advices in case of any emergency requirement felt by the patient";*
> *"The options of getting an ambulance through the app and making a selective diagnosis by a diagnostic centre make it efficient enough to get such services";*
> *"All health care systems including doctors, specialists and hospitals response to the patients through the app reduces actual cost of making appointment, physical journey and physical presence. At the same time addressing the patients' problem through the app actually improves the rate and quality of practices of doctors".*

For testing the effectiveness of the system, the questions discussed in the focus groups were as follows: By using the app do the stakeholders gain ownership of access to the better maternal health service delivery; whether the system is a convenient way to obtain frequently obtained services; and if the system is considered as helpful for developing better relationships with health service providers, i.e. healthcare workers, doctors, support services and consultants. All participants in the discussion provided positive responses answering 'Yes' to these questions.

On effectiveness of the system, some responses were as below:

> *"Yes, definitely it provides ownership, when all stakeholders are the partners of the system through this app";*
> *"Yes, definitely it is effective. When all these service providers are in a single platform, it is very effective. It also provides opportunities of mutual support and communication to provide comprehensive health care to an expectant mother".*
> *"Yes, it is very effective. This app has the ability to enlist all interested health service provider, thus tracking is possible when they get into the system"*.

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The facilitator asked for opinions on several questions to validate the utility of the *On-cloud Motherhood Clinic* prototype, including: whether the app will add new value and knowledge to the conventional healthcare processes; whether the system is valuable to reduce physical visits and costs to doctors/other support services; whether the system is helpful to get effective decision support 24/7; if the system is valuable for decision making proficiently in healthcare services, and whether it is valuable and adds new knowledge for providing quick decision support for better health care management. All participants provided very positive responses with "yes" to the questions asked above.

Some responses about utility of the system were as below:

> *"I think the app is primarily focusing on adding value to the heath management process. Improvement of knowledge will be ensured when all the stakeholders are sincere in their approach";*
> *"Yes, through this app, both patients and health service providers are connected so that emergency response is ensured, and critical decisions can be provided quickly 24/7, in a collaborated way";*
> *"Yes, the system is valuable for effective decision making. When a patient needs support, a hierarchy of support staffs get in contact and makes decision so that the patient care and improved health service management is ensured"; and*
> *"Yes, it is very effective for providing better facilities in health care of an expectant mother".*
> *"Definitely it will add a new knowledge in healthcare management, particularly in Bangladesh, where everything is very slow, expensive and conventional"*

As mentioned earlier, one of our aims was to gain expert opinions and knowledge from the stakeholders for enrichment of utility, efficiency and effectiveness of the prototype. Thus, the facilitator invited the focus group participants for their critical views and suggestions. The participants provided quite a few valuable recommendations as well as some concerns.

Some concerns on marketing and then suggestions focused on increasing awareness of the system and thus advised for marketing on media. Two comments were:

> *"It is an excellent app. However, we need to inform about this app widely. For this one we need do advertise about that on radios, TV and other media to make people make aware of the system".*
> *"you can/should take help from other stakeholders; e.g. media for better marketing of the system".*

Two participants pointed out about the concern of emergency services as this system is for critical illness. The comments on that issue were:

> *"this system should add 24/7 help line" and "specialized doctors and support services should have emergency readiness for providing immediate services".*

A few concerns were raised about the IT literacy and English language issues. These were as below:

> *A lot of patient may not have any IT skills, in that case it will be hard for them to use, especially the patients. The designer should think about that.*
> *English language is an issue. Most rural women; and even their husband may face problem using this app in English.*

Accordingly, suggestions were provided by the participants focusing on language usability as English is not the first language in all developing countries. For example, two comments were:

"language translation facilities would be useful for the system",
"the options of using first language (e.g. Bangla) could be efficient for making the system more useful for users particularly for patients and healthcare workers".

A few participants questioned on the technical side of the system operation issues. Based on these issues, the suggestions were provided as below:

"for better operation of the system you can invite a wide number of stakeholders; and do a launching program on how to operate that system",
"you need to provide training to the GP and specially health workers on how to operate the system as it is related to IT and computing";
"All the stakeholders, e.g. mothers and service providers need to understand the use (technical issue) of the app"
"An online training on the use could be incorporated by a link to a YouTube channel" and
"I think, it would be better if initially you can supply at least a few pages booklet on the whole system for better understanding and operation".

A more direct response on service charge was:

"This app needs to have the options of collecting and delivery of service charges directly to the providers so that the tangible effect in visible and providers take keen interest to make its more effective"

The facilitator further asked for their suggestion for the improvement of service efficiency of the system. We received some very valuable advice from the participants. Some suggestions were:

"you can add live telecast or video conference",
"A provision of audio-visual communication between doctors and patients would be more beneficial and efficient one";
"the system can add options of sending SMS to everyone".

Some participants suggested partnership with other stakeholders to make this system more effective in implementation. Some of them emphasised on collaboration with government departments and some NGOs to make the application more effective. The advice here included:

"you may take help from Govt. departments/officials" and
"it will be a very innovative system for our country. I think better to implement the programme in collaboration with Ministry of Health for make this app for reachable to wider people"
"you can involve other health related stakeholders".
"this system could be more effective if with you can collaborate with some NGOs".

Overall, we received positive responses from the focus group evaluation including some positive feedback, some concerns and quality recommendations for further enrichment of the artefact that suggests practical feasibility around the implementation of the system.

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Discussion and Limitations

Discussion

Several studies suggest that eHealth and cloud-based health systems provide numerous benefits; such as enhanced self-management (Lai & Wang, 2015); reduced travelling and medical expenditure (Brown et al., 2013); and particularly reduced healthcare costs in developing countries (Roberts et al., 2015; Manya et al., 2016). Even though maternal health is a crucial issue in developing countries, a limited number of studies has been conducted on maternal health care services. Cloud-based healthcare aims to address this issue and provide an effective solution to delivering speedy and real-time health care support. Our research addressed the question of "How could a maternal information support solution be developed to address critical maternal healthcare management of the rural communities in Bangladesh?" through developing an innovative design solution named On-cloud Motherhood Clinic (an example structural detail is illustrated in the Appendix B). The focus group evaluation of this research prototype demonstrated promising outcomes of this design solution.

The aim of this study was to formulate a new problem details into an innovative IS solution design that brings together the least technologies in one to improve information exchange for maternal healthcare support services. We conducted a socio technical DSR study to illustrate what type of innovative solution could be applied to meet the demands of rural expectant mothers with critical illness. The proposed contribution of the study is twofold. First, we have demonstrated that a cloud-based solution incorporating GSP and locational tagging in a form of mobile application would be an innovative solution to improving healthcare support in particular for rural populations. Second, theoretically, we identified the specific socio technical DSR framework and successfully applied it, to define our target problem and solution/mechanism propositions for meeting the information exchange demand. This illustrates application of the framework suggested by Carlsson et al. (2011) and its growing influence to define problem and solution space for better realisation as informed understanding.

The focus group evaluation identified several practical benefits of this design solution in delivering effective healthcare services relevant to developing countries like Bangladesh where the majority of the population live in rural areas without access to modern health care services or specialized hospitals (Ahmed et al., 2014). The focus group evaluation confirmed that the solution provide easy access to maternal health care services. For example, it provides quick service to find possible health management assistance, e.g. speedy guidance for advanced diagnosis and treatment, and easy access to hospital admission in case of emergency. Use of the app will further reduce requirements to visit doctors/hospitals, thus can reduce operational costs for both patients and health professionals by decreasing travelling cost and time, that have also been established by Manya et al. (2016) as well; and need for physical presence. More importantly, the focus group evaluation confirmed that the solution adds new knowledge for providing quick decision-oriented supports for rural and remote health care management.

Limitations

Along with the positive outcomes of efficiency and effectiveness, some concerns and challenges were also identified by the focus group participants. These were associated with technical issues around operating the system, which included concerns around computer illiteracy and IT issues; as well as the correct interpretation and comprehension of English as a language. Given that rural mothers and health workers in the rural communities are not typically competent with computer literacy, IT operation, and English language literacy; these suggestions will be taken into consideration for further development of the artefact. Considering the system operation issue, a 'Log in Info' has already been incorporated within the system for making the initial operation easy for end users after the primary evaluation of

the prototype. Moreover, with available 'on-screen key boards' apps with several languages for mobile, the language issue can be solved easily in the next phase of the development of the artefact.

Finally, the authors noticed that most participants were concerned related to IT, system operation and languages issues rather than the effectiveness and efficiency of the artefact. It was assumed that as such artefacts are not very common in Bangladesh, perhaps the participants failed to compare and evaluate its effectiveness and efficiency very critically.

Conclusion

Our study developed and evaluated an innovative m-Health solution utilising cloud computing for addressing a critical issue of maternal healthcare. We outlined a new scope to design an innovative solution. This innovative design artefact named as "On-cloud Motherhood Clinic" that enables healthcare professionals and rural women citizens to achieve comprehensive maternal healthcare services. Using a socio-technical design research, contributing to add new application of design knowledge, the concept of the "On-cloud Motherhood Clinic" was developed and evaluated in the context of critical maternal healthcare support of the rural communities in Bangladesh.

This design solution can theoretically be classified as a socio technical DSR framework; and has demonstrated its utilities to address target problems as well as the mechanism propositions for meeting the information exchange demand for better realisation of practical needs of the end users. Moreover, this solution would provide several practical healthcare information support benefits for rural expectant mothers. The key benefits are effective collaboration, interoperable service approach to find possible health management assistance and reduced operational cost both for individual patients and health professionals by decreasing travelling cost and time. Finally, this solution concept can be viewed as new mechanism for providing quick decision supports for rural and remote health care.

The simple presence of and access to ICTs in rural areas is unlikely to be effective without relevant ICT-related skills, promotion of relevant content/information for ICT applications, and a policy framework in which interventions can function (Gurstein, 2005). These arguments were apparent as outcomes of the focus group discussion and with the suggestions provided. The next stage of our research will consider the wider integration of on-cloud apps addressing the issues that were identified by the participants within the extensive national frameworks and initiatives in Bangladesh.

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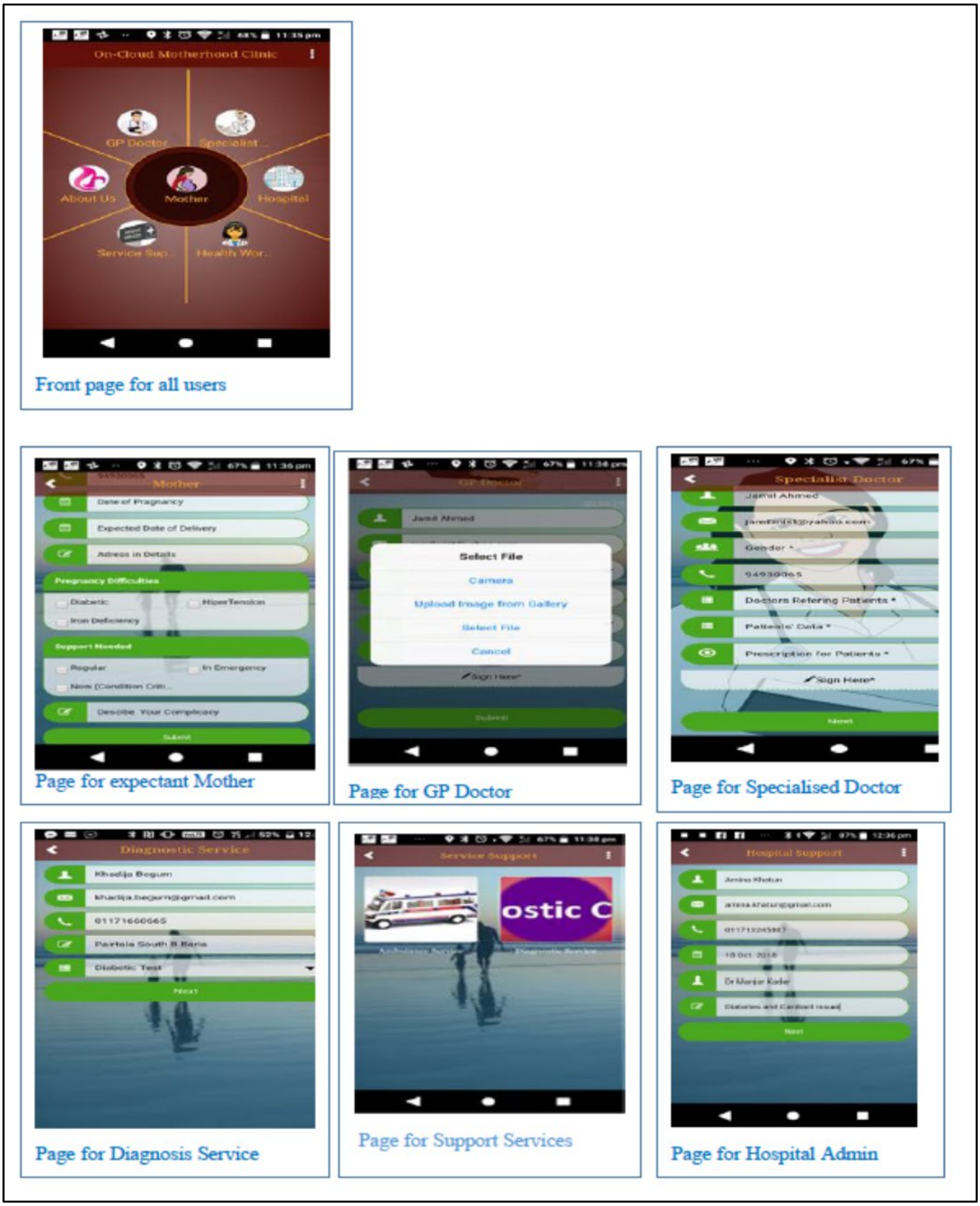
Appendix A:

Major works done in developing Cloud-based eHealth solutions within the public healthcare problem domain.

Studies	Cloud-based solution purposes/classes	Techniques/Procedures used	Target beneficiaries
Miah et. al. (2017)	On-cloud consultancy system for Diabetes patients	Socio-technical approach of *ensemble* artefact design	Patients, doctors and healthcare workers of remote locations
Sailunaz et. al. (2016)	Health monitoring system for several diseases	Cloud-based MEDical System (CMED) involving healthcare centre and a portable healthcare service with a Community Health Worker (CHW)	Rural and under privileged people
Mamun et. al. (2016)	System for diagnosis neurological diseases such as Parkinson's Diseases	Support vector machine was used for classifying text or image	Patients and healthcare professionals
Hossain (2015)	Elderly health monitoring/remote care	Speech and face recognition framework, support vector mechanism	Healthcare professionals
Hossain & Muhammad (2014)	Monitoring system for effective collaboration between healthcare professionals and care givers	Extensive Messaging and Presence Protocol (XMPP)	Healthcare professionals and care givers
Rana and Bajpayee (2015)	Diagnosis system for analysing patients EMR for professionals for their further study and process improvement	Integrated and inter-operable solution technology	Healthcare professionals
Song et al. (2015)	Health monitoring system to provide health records to patients/guardians for further monitoring and controlling the records	Clinical documents architecture for assessing current health against major diseases	Patients and Guardians
Parekh & Saleena (2015)	Diagnosis system for analysing healthcare data using data mining	Clustering technique	Healthcare professionals, patients and government
Muhammad (2015)	A framework for speech-enable remote healthcare	Interlaced derivative pattern for automatic speech recognition	Healthcare professionals and patients
Kaur & Chan (2014)	Intelligent system to monitor user health data for diagnosing chronic illness e.g. Diabetes	Artificial intelligence techniques for real-time monitoring of patients' data	Healthcare professionals

Appendix B: Structural charts of the proposed solution artefact



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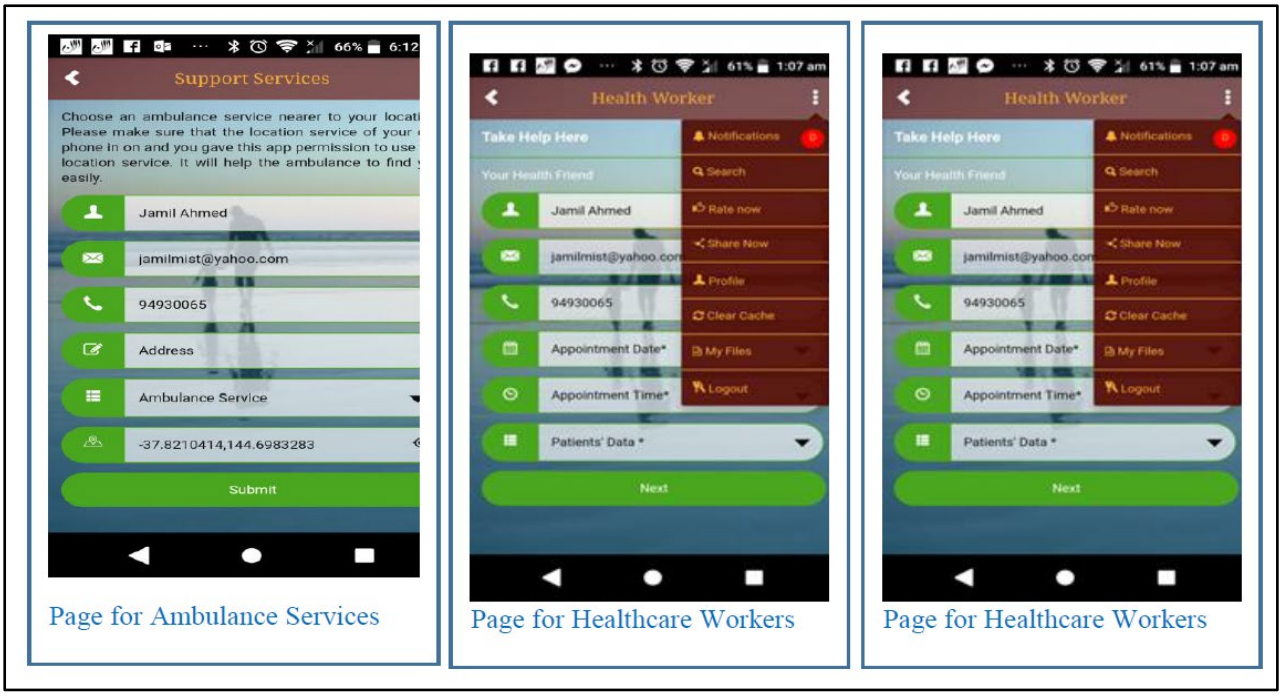

Appendix C: Focus groups participants

	Category/specialisation	Number of participants
1	Gynaecologist	2
2	GPs (MBBS Doctor)	2
3	Specialised doctors (surgeon)	3
4	government hospital management representatives (doctors)	2
5	Rural patients	8
6	IT consultant	1
	TOTAL	**18**

About the Authors

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