TALLINN UNIVERSITY OF TECHNOLOGY
School of Information Technologies

Mahabubul Hasan
184731IVGM

MANAGING AND TRACKING E-HEALTH DATA USING SMART ID CARD IN BANGLADESH

Master's Thesis

Supervisor: Silvia Lips
LL.M, MSc

Tallinn 2021

TALLINNA TEHNIKAÜLIKOOL
Infotehnoloogia teaduskond

Mahabubul Hasan
184731IVGM

E-TERVISE ANDMETE HALDUS JA JÄLGIMINE BANGLADESHI ID-KAARDI RAKENDAMISEL

Magistritöö

Juhendaja: Silvia Lips
LL.M, MSc

Tallinn 2021

Author’s declaration of originality

I hereby certify that I am the sole author of this thesis. All the used materials, references to the literature and the work of others have been referred to. This thesis has not been presented for examination anywhere else.

Author: Mahabubul Hasan

Abstract

eHealth has huge potential to ensure healthcare quality, accessibility and affordability in developing countries like Bangladesh. The urge and usage of information and communication technology (ICT) to healthcare, particularly in eHealth, is rapidly increasing. Quite a few healthcare providers have the ability to store healthcare data but those are standalone and are not shareable. Therefore, there is a need for a centralize health record storage system. To have reliable and secure centralized health record system, it is very important to have a unique identity to identify accurately for managing their healthcare data.

The government of Bangladesh has already launched the electronic identity card successfully across the country which is called Smart NID card. The card has a unique number which can segregate each of the citizen of Bangladesh. As a result of this thesis an EHR model is proposed having the NID number for tracking and maintaining each of the patient.

This thesis is written in English and is 69 pages long, including 9 chapters, 14 figures and 5 tables.

Key words: healthcare data management, smart NID card, eHealth, EHR, EMR

List of abbreviations and terms

API	Application Programming Interface
CDA	Clinical Document Architecture
CEN	European Committee for Standardization
COVID-19	Coronavirus Diseases of 2019
DGHS	Directorate General of Health Services
dhis-2	District Health Information Software-2
DICOM	Digital Imaging and Communications in Medicine
DS	Design Science
ECU	European currency unit
eGoverment	Electronic Government
eHealth	Electronic Health
EHIS	Estonian Health Information System
EHR	Electronic Health Record
eID	Electronic Identity
EMR	Electronic Medical Record
eServices	Electronic Services
EU	European Union
EUTS	Electronic Identification and Trust Services for Electronic Transactions Act
GEHR	Good European Health Record
HIS	Health Information System
HIV	Human Immunodeficiency Virus
HSC	Higher Secondary Certificate
ICT	Information and Communication Technology
IS	Information System
ISO	International Organization for Standardization
IT	Information Technology
LOINC	Logical Observation Identifiers Names and Codes
MoHFW	Ministry of Health and Family Welfare

NBHW	National Board of Health and Welfare
NGO	Non-Government Organization
NID	National Identity
PDA	Patient Data Act
PKI	Public Key Infrastructure
R&D	Research and Development
SITHS	Secure ID for Healthcare
SSC	Secondary School Certificate
USB	Universal Serial Bus
WHO	World Health Organization

Table of Contents

List of figures

List of tables

1 Introduction

There is no denying that eGovernment presents significant potential for addressing many of the existing fragility in the governance system. The importance of introducing and operationalizing eGovernment using information and communication technology (ICT) merits the focused attention of any developing country. As a part of digitization and to bring the "Digital Bangladesh" [1] into reality, the government of Bangladesh has already taken necessary steps. One of the biggest steps that the government of Bangladesh has taken, that it has replaced the existing laminated national ID card and launched the electronic identity card successfully across the country which is called Smart NID card [2]. Such a step has enabled the variety of eServices that government can accommodate for the improvement of citizens life and lifestyle.

1.1 Research motivation

The World Health Organisation (WHO) designates eHealth as the method of using information and communication technologies (ICT's) in the healthcare realm to administer treatment of patients, research, health education, and public health monitoring. [3]. Health care facilities in Bangladesh currently mainly use paper-based health records. Having such paper-based system, it is difficult for any patient to manage their health data. Healthcare data is sensitive by its nature. Only authorized doctor can access those data. But patient has no idea, who access their information for what reason if the data is saved by any means. Our current system is so ill-equipped that government does not have proper insights of the citizen health record data that enables to forecast public health related information. This situation has already been evident during the recent pandemic situation. According to the Bangladesh COVID-19 Situation Report-16 by the World Health Organization, 40% of COVID -19 patient cannot be traced [4]. The government did not get proper insights of the situation because, the data source is so unreliable that data are collected either from incomplete data or informal study [5]. It is essential to transform health services based on digital solutions, supporting the consistency of the treatment, timeliness of the services and patient contentment. Introducing electronic health record

(EHR) or electronic medical record (EMR) of citizens could be great beneficial to make the lives of citizens easier.

The slogan of Digital Bangladesh of the Government of Bangladesh has special significance for national development. Digital Bangladesh with Vision 2021 is a big momentum for the use of digital technology in the country. Health care facilities in Bangladesh currently use paper-based health records, idea is to provide health services based on digital solutions, which supports consistent treatment, service timeliness, and better patient data control. Introducing NID integrated electronic health record (EHR) or electronic medical record (EMR) of citizens could be very beneficial to make the lives of citizens easier. EHR systems are designed to accumulate data precisely and to apprehend the patient state over time. It eradicates the necessity to trace down a patient's historical paper-based medical records and ensure that data is reliable and legible. It can significantly diminish data replication uncertainty since there is only one modifiable file, that means the file is more likely up to date and minimises the chance of lost paperwork.

1.2 Research problem and questions

The primary goal of this research is to identify the challenges patients face with the existing health record system and as well propose the implementation of a NID integrated EHR system that improves the health data manageable and trackable for the patient in Bangladesh. Furthermore, to examine and attend to the research problem, the author has developed one main research question and three sub-questions.

How to develop a smart NID integrated EHR data sharing technological framework that will support the eHealth system in Bangladesh?

The answer will provide the technical aspects and efforts to establish such large system for a country like Bangladesh along with challenges and barriers. This will allow to envision the future aspects of health care system and effective use of NID.

Implementing such system urges three sub-questions given below that will allow validating the problem with current system, the technological barrier for developing the system and the effectiveness of the proposed system.

The following sub-questions will aim to be answered in frame of the thesis given below:

1. *How the current state of patient health record system in Bangladesh works?*

The first sub-question aims to identify the contemporary patient health record system and as-IS state in Bangladesh along with validating the problem with current system.

To answer this question, author applied quantitative research approach and conducted a general survey.

2. *How the centralize NID integrated EHR system can be implemented in Bangladesh?*

The second sub-question tends to answer issues relating to the implementation of the NID integrated healthcare system in Bangladesh. Furthermore, it defines the role and the main concerns of government, citizens, and other stakeholders in its implementation. It also distinguishes the significant facilitators and obstacles of the centralize EHR system in Bangladesh.

The following question will be answered by formulating, describing, and analysing the case study of the healthcare sector of Estonia. To understand a particular aspect of the whole research, a study is conducted within the case study framework and propose a model to implement a centralized EHR system where every unique citizen can be tracked and managed using NID.

3. *How to measure the effectiveness of adopting the proposed EHR system?*

The third sub-question examines the effectiveness of adopting the NID integrated EHR system; this will identify the benefits of the proposed system to patients, healthcare providers and the nation in a comprehensive way.

Author applies a qualitative research methodology which includes expert interviews on written format. Author finds out how effective the system is by taking interviews of the expert who have already worked on health technology field on a local and international context.

2 Research design and methodology

This section addresses an overview and explanation of the research methods that are used in the thesis in order to answer the research question and its sub-questions.
eHealth has enormous prospect ensuring quality healthcare, convenience and affordability in developing countries like Bangladesh [6]. The urge and usage of information and communication technology (ICT) to healthcare, particularly in eHealth, has a rapid growth in Bangladesh [7].

To conduct the research under design science framework, the author identifies the problem and then justifies it by conducting a general survey. Then the author identifies the missing elements of the current states and proposed a suitable solution. This part is done by analysing a case study. A model is developed and demonstrated for justification. After that, expert interviews are conducted to justify and improve the proposed model.
In the below figure (*see figure 1*), the whole study of the research is illustrated from problem identification to publication. Each of the steps are conducted chronologically and described on the later part of the thesis.

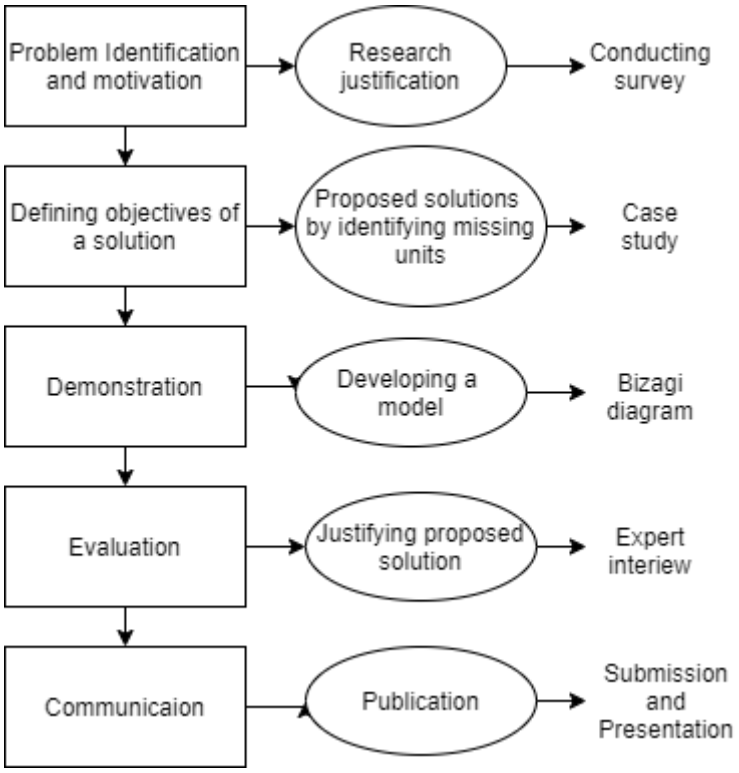

Figure 1: Design science research framework

In the research process, the design science framework is considered to resolve the arising questions to fulfil the research. Design science is an outcome-based information technology research methodology, which allows guidelines for evaluation and iteration within the research [8]. Design science research concentrates on the growth and representation of designed artefacts with the specific purpose of developing the practical performance of the artefacts [9].

Author finds out the most suitable solution for smart NID integrated EHR data sharing technological framework that supports eHealth system for healthcare users and healthcare providers. Design science research provides IS research by presenting a commonly accepted framework for successfully carrying out DS research and its presentation model. It also cooperates with the identification and legitimization of DS research and its objectives, processes, and outputs. It also helps the author to present research concerning a commonly understood framework, rather than defending the research model on an ad hoc basis [10]. Since Bangladesh is using paper-based health record, author conducts a general survey to find out the limitations of current process like lack of backups, insecurity, time consuming, error prone, inconsistent layouts, version history etc.

Author's proposed resolution is on providing solution for NID integrated EHR data sharing technological framework for Bangladesh. And the adoption of this kind of new framework in a certain sector is challenging for users. Author investigates the Estonian case study, that might be used in theory and practice for formulating, describing, analysing and future research perspectives in order to determine whether and, if yes, how to use the NID (eID) for integration with EHR data. Though each country has its unique way of implementing EHR, still author can observe some patterns in this process and lessons from other countries are recommended to be considered in the case of Bangladesh.

Main research question and sub-questions intend to accommodate a strong perception of why integration is needed for EHR and what are the potential benefits and impediments of such a solution, and how the eternity of such a solution is envisioned. Understanding motivation behind implementation of NID integrated EHR framework help us to understand better strategic vision that developers and public officials have for this project. As a part of the research purpose, 4 semi-structured interviews were comported for new information and different viewpoint [11]. Through the interviews, the author validates, justifies and measures the effectiveness of the proposed model. All interviewees come from technical backgrounds and have understanding on health technology sector in order to achieve a better understanding of the situation.

The Estonian eHealth system is among the world's most ambitious and clear examples among EU countries, which is hailing widely as one of the most advanced digital nations on the planet. Already, more than 95% of the data generated by hospitals and doctors have been digitized, and citizens can enjoy easy access to their medical records, prescriptions, and the most suitable health professional [12]. User also can manage their healthcare data and have better control to make their data available or hide it.

A single case study method was chosen to conduct this particular part of the research. Notwithstanding the reputation of case study in social science research, it can also be efficiently employed in software engineering research, and a case study provides the author to learn adequately how and why particular software solution was or should be chosen. It allows them with the fundamental information to update software products [13].

As a part of data collection methods, three degrees of a method is recognised [14]. First-degree methods include those that demand first-hand communication with the interviewees and real-time data acquisition process. Second-degree methods include accumulating raw data without communication with interviewees, whereas third-degree methods ruin independent analysis of available artefacts. With regards to the current study, first-degree method (semi-structured interviews) was chosen, for allowing greater control over the data being accumulated and present more useful context understanding [15]. Semi-structured interviews provide exploratory and detailed objectives of case-study research by providing a qualitative and quantitative description of the aspect by individuals [16].

Results of surveys conducted by author among users of current healthcare system provide us a better understanding of the limitations and its value from user's perspective.
Interviews were conducted via email and preserved for further analysis. Interview subject is given with the copy of the set of questionnaires, in order to correct, clarify or expand their answers and understanding [17].

The primary technique chosen is explanation building, and it is provided by analysing the results of interviews and surveys [18]. This technique allows authors to understand the cause-effect relationship that led to emergence of a certain phenomenon. With regards to this study, such explanation building will allow to draw firm conclusions.

3 Literature review

This chapter intends to evaluate the research related to this topic. Scrutinising the contemporary literature on EHR, the author concluded that most of the studies focus on the opportunities and challenges of implementing EHR, factors influencing the health care providers on EHR adoption, policymaking on EHR and impact on health services after adopting EHR. Nevertheless, no case studies that answer the question "how to manage and track health data for an individual citizen," and namely explains how to design such a model in the context of Bangladesh. Therefore, the research idea serves as

a justification for this investigation. In this chapter, a summary of the previous research on EHR is given. This will help to highlight the benefits of EHR implementation.

3.1 EHR implementation and benefits

The author has studied a few well-known works of different authors concerning the eHealth system. The background of health and health structures in Bangladesh is well explained in this article [19]. The high usability of smartphone develops strong possibilities in terms of health care delivery. This research also shows an overall idea of eHealth initiatives.

The MoHFW has provided charge for developing the health component of Digital Bangladesh to the Director-General of Management Information Systems, in the Directorate General of Health Services (DGHS). It is implementing a problematic strategy for integrating ICTs into the government health system. NGOs are also included in such health care initiatives. The use of Information and Communication Technologies (ICT) is an essential system to satisfy the need for health care services in this 21st century [20].

ICT health service can reinforce productivity and effectiveness in the health management system. The study identifies that the current ICT health services do not satisfy the requirement of the people. Old and poor tools are one of the major obstacles. The study also presents some other hurdles, which includes inexperienced workforce, the incompetence of ICT infrastructure, and a lack of financial aid from the government.

In terms of digital literacy in the health care system, 40% of the respondents familiar with ICT in healthcare. In contrast, 21% have their understanding of using any of the current mHealth or eHealth system [21]. People's age, occupation and buying ability have a strong influence on their acceptance of eHealth services while their gender, level of education, access to cell phone and past eHealth awareness have a very trivial influence.

This conclusion certainly demonstrates that a massive amount of our rural users is unaware of the contemporary practices of ICT in healthcare. In Bangladesh, public and private sectors have provided to the development of the eHealth system everywhere in the country [22]. In this investigation, they found the new status of eHealth in the public and private domains, as well as the technological and professional hurdles facing eHealth

improvements in Bangladesh. The conclusions of the research unveiled that eHealth in Bangladesh persists as somewhat challenging. On the current condition and hurdles of eHealth, the expanse of some areas requires additional growth. Physicians' are very sceptical for developing Electronic Health Record (EHR) systems in Bangladeshi hospitals [23].

There are high demands from the Bangladeshi government that the usage of EHR systems will provide to enhanced health care management, ensure the quality of care, enhance the capability of the health care delivery system and create health care more attainable where it is hard to spread better health care delivery. As per the investigation, there is a shortage of individual and ICT components in those hospitals. Already eHealth systems are broadly applied in the modern world [24]. This article manifests a multi-step ranking based recommendation system; it helped raise the usability of the medical data formation.

Though it does not have many ideas, it provides in an efficient and effective method to an important application field in eHealth. The performance of healthcare-related activities and related expenses [25]. The significant observation of healthcare organizations is to streamline processes and provide refined assistance to the patients.

The World Health Organization (WHO) in 2016 issued the eHealth country profiles of the countries that provided to the WHO's third worldwide survey on eHealth. It has a focus on the use of eHealth in aiding of comprehensive health care practice. eHealth represents a significant role in advancing comprehensive health coverage in diversified ways. For example, it serves to assist distant communities and unprivileged people via eHealth. Besides, the strategic usage of ICT, it extends the services and commercial productivity of health care systems.

4 Aspects of healthcare data management

The below chapter presents the different aspects of healthcare data management of the core notions that underlie in the subject of the thesis. The purpose of this chapter is to show insights about EHR, NID and usability of NID as a unique identity. It also to show the manageability and trackability of EHR by the integration of NID with an EHR system.

4.1 Preservation of healthcare data

Medical record, medical chart, and health record are different terms used to describe the documentation of a patient's medical history and care [26]. Medical record preserving is an integral component in good professional practice and the delivery of quality healthcare. Regardless of the form of the records (*i.e.* electronic or paper), good medical record preserving should enable continuity of care and should enhance communication between different healthcare professionals [27]. The prime objective of preserving the patient health record is to assemble observation, gain knowledge and efficiently monitor performance. Preserving health record in healthcare is an essential segment in good professional practice and the offering of quality healthcare service. These stored records of the patient are essential for future reference because if these results are not stored, there is no proof that they occurred. According to NMC, regulator for the nursing and midwifery professionals in United Kingdom, it is a professional's responsibility to follow the NMC code, principles of good record keeping, to help safeguard the health and wellbeing of the public (NMC, 2009). These four principles chosen states, "Individuals should record details of any assessments and reviews undertaken and provide clear evidence of the arrangements that have been made for future and ongoing care, including any details of information given about care or treatment" (NMC, 2009). "Ensure records should be accurate and recorded in such a way that the meaning is clear" (NMC, 2009). "Where appropriate the person in your care or their carer should be involved in the record keeping process" (NMC, 2009) and finally "Individuals have a duty to communicate fully and effectively with colleagues, ensuring that they have all the information they need about the people in their care" (NMC, 2009) [28]. Documentation and record keeping are an important aspect of healthcare practice and perioperative practice is no exception to this rule. For some time now, recording every activity or intervention that a patient receives has assisted with enhancing perioperative practice; equally, it has played a key part in resolving legal and professional incidents that have occurred [29]. The purpose of health record preserving is to secure that all healthcare providers know what care and treatment the patient is receiving. As a part of the usefulness of the healthcare preservation system, the system must be promptly accessible and present data when needed to examine and share them with related stakeholders who are explicitly or implicitly involved with the healthcare system [30]. Moreover, it guarantees the continuity of care [31]. Continuity is predominant to healthcare service; multiple healthcare providers may get involved in

treating a patient. Therefore, there is a need to convey information so that healthcare providers be informed about the patient medical history to make informed judgments. Preservation of health data guarantees that a precise and current record which support the promulgation of specific and brief information to the healthcare providers and enhance the quality of their judgments, which is consequently worthwhile for the patient [32]. Effectively preserving healthcare data enhances the coordination and strengthens judgement capabilities of healthcare providers, increase accountability, and obtain more precise vital patient statistics.

4.2 Understanding EHR framework

An electronic health record (EHR) is a digital transcription of a patient's paper record. EHRs are real-time, patient-centric documents that make information accessible spontaneously and securely to accredited users. One of the crucial traits of an EHR is that health information can be produced and maintained by accredited providers in a digital form. Such health information can be shared with other providers across more than one health care providers. EHRs are built on sharing health data with other health care providers and organizations – such as pathological, specialists, medical imaging departments, pharmacies, emergency facilities, and school and workplace hospitals – so they contain information from all providers associated in a patient's care. [33]. EHR includes statistics, notes of improvement, critical health issues, and list of used drugs in the treatment of the specific patient, major health issue, previous medical record, cure probability and all tests reports [34]. EHR is defined as collection of electronic health information about individual patients or populations and is capable of being shared across different health care settings, by being embedded in network-connected enterprise-wide information system [35]. EHRs are used in complicated medical circumstances. Items that are suitable for one clinical need, maybe unusable in another clinical discipline [36]. The presented data, the template, the level of details, and the order of re-presentation may be notably diverse, depending on the circumstances and the user role. EHR facilitates the administrator to obtain data for billing, the clinician to see inclinations of treatments, a nurse to notify an unfavourable response, and an author to investigate the potency of remedies in patients [37]. Each of these professionals needs to work together, to have a comprehensive picture of the patient's health. EHR is created to combine all these services on a single template for better patient treatment. Some clinical systems also allow

electronic capture of pathological reports [38]. Often, these medical records are segregated and stayed in silo systems. These clinicians may use a different template and patient identification, and there is no consolidated admittance to the system. Clinicians must open multiple applications and then find the patient record to see the patient's complete health record. The electronic data gets faxed or printed and inserted into a paper record. If new results are added electronically, old results can be corrected, but the clinician might not be hinted unless they logged into the system [39]. Besides, the dissimilar data cannot be added to the combined system. If a clinician has permission to the content of the data, then the clinician can view the newly added health data. Having structured and shared could resolve many ambiguous variations that make the clinician find or track health history across multiple clinicians. So, a shared architecture can be created to allow the sharing of data across systems [40].

Providing adequate health care service to the patient requires healthcare providers to obtain complete and comprehensive health records to maintain the reliable and efficient delivery of complicated and intensive health care and to partake this health data within and among service provider teams [41]. Nowadays, the patient also necessitates accessing the EHR that authorises them to perform an influential role in their health supervision. These necessities are becoming more critical that the focus of providing health service delivery changes rapidly from expert centres to locale settings and the patient’s environment [42]. Nevertheless, most of the delicate health data on which anticipated health care rely on are still documented into paper-based records or solitary clinical databases. Also, highly advanced computer-aided health information systems restrict the capability of users to elicit medical details in a manner that cannot be transferred to other systems [43]. Electronic Health Record (EHR) systems demand a resilient framework for preserving the deliberation process and provide the distinction of the healthcare provider and the patient [44]. Thorough researches of users and enterprise necessities have conducted for many years to apprehend the health record information needs across different level of care, between services and across realms. These provisions have extracted and parsed by specialists, in order to distinguish the vital information that must be accommodated within an EHR architecture while considering the below fact:

- Apprehend conscientiously the original purpose intended by the author of a record listing or set of listings.

- Provide a framework relevant to the requirements of experts and enterprises to dissect and evaluate EHRs on an individual or community basis.

- Consolidate the significant medico-legal constructs to support the reliable and suitable transfer of EHR entries between specialists working on different places, while considering the privacy of individual patients.

A detailed, comprehensive study of this field has been researched by GEHR [45], EHCR Support Action [46] and Synapses projects [47], which notified the following European EHR standards [48] and continuing EHR study. ISO has now incorporated these terms as an International Technical Specification, which provides a singular intent of evidence for the main EHR specifications [49]. The communication of EHR data is tricky because much of medical definition is inferred from different data values but from how they are combined as complex medical theories, classified under labels or correlated with leading healthcare conclusions during data insertion or data wrenching. The medico-legal behaviour and liability of health care delivery place further demands on the tenacity with which health record entries are attached, staged and controlled. How unique medical records are ordered within a record presents an essential context for their analysis. Aspects of fact, rigour and the missing items must be proficient of accurate and unambiguous depiction.

The architectural strategy for designing the EHR has its roots in a study initiated through the EU Third, Fourth and Fifth Health Telematics Framework Programmes. The growing barriers of paper-based records, the potential advantages of electronic health records and the conceded hurdles of accouching these in usage have spurred significant investment in analysis and improvement over the past decade. Between 1991 and 1998, the European Union provided 47 Million ECU of direct funding support to research projects whose budgets totalled 76 Million ECU [50].

A significant study has been initiated over the past fifteen years to produce an architectural strategy to seize medical data thoroughly and in a way which is medico-legally definite and conserves the medical definition assigned by the original author, such as GEHR [50] and the CEN standards ENV12265 [48] and ENV13606. Another study has distinguished the further demands to assist the communication of EHRs within united associations of healthcare programs to establish shared patient care over places [51] and

middleware architectures to combine across R&D projects [52]. These projects have attempted carefully to tackle the depiction of EHRs at a general level to maintain the acquisition and communication of any possible medical record listing, conserving the fundamental medical circumstances and medico-legal probity. Internationally, Europe has commanded this field of research. More recently the same type of research in Europe and Australia have been coupled through the openEHR Foundation.

The openEHR Foundation is an autonomous, non-profit institution and community, founded in 2000 by University College London and Ocean Informatics [53]. It intends to expedite the conception and distribution of medical records by users and doctors via open-source, standards-based developments. openEHR aims to:

- Promote and distribute the formal blueprint of specifications for describing and delivering electronic health record, based on development practice, and emerging as health care and medical knowledge develop;
- Promote and distribute EHR data architectures, standards and data dictionaries tested in developments, which meet these conditions;
- Maintain the subsequent validation of the EHR architectures via complete development and medical evaluation;
- Support open source “evidence” developments, attainable through the licence, to improve the storage of available mechanisms to help medical methods; and
- Cooperate with other associations working towards high quality, specification-based and exchangeable medical data methods, in the fields of medical informatics.

Formal software engineering methods establish the openEHR. It moves with speciality, and problem interpretation expresses specifications and design principles, then produces architectural blueprints, and then launches development projects, through sequential refinement and testing, are used to authenticate and update the architecture and terms. The method of these ventures is all handled by a formal version control process and version management tools. The openEHR technical requirements outline design principles, source and archetype models. This work started as the merging of the

European and Australian experience since 1991 but has evolved significantly in recent years over contributions from around five hundred members. It is regarded universally as the most impeccable and well-validated EHR data architecture. openEHR works jointly with the standards organisations outlined above to assure that its ideas adhere to contemporary norms, and to provide its experience and designs to future norms.

4.3 Usability of NID as a unique identity

Generally, electronic identity means for people to prove themselves digitally that who they are whom they say and thus obtain access to required services [54]. The identification allows an entity to distinguish from one other. The capability to associate a collection of data to a user and the efficient and safe handling of user-related data is imperative to different diverse synergies [55]. As a result, an institutional and technological framework has developed to determine, delegate and govern the identification related to a specific set of people, like customers, patients or citizens. These infrastructures are identification management systems.

An electronic identity (eID) is different from a digital identity card, though, in some instances, the two notions could converge [56]. From an electronic identity viewpoint, a person usually may involve in various sectors and perform different functions depending on the circumstances. Hence, the corresponding data should be managed and accessed in an individualistic way. Electronic identity needs enough legal terms of data protection and individual authority over personal data by the individual to maintain such complex content. The digital identity card is a physical token holding individual data used for confirming that an owner is an individual, a citizen of a given country [57]. Depending on the type of use, an electronic identity does not necessarily indicate the use of a physical item such as a smart card or a USB token. Moreover, an individual's identity surpasses the term of a physical item, while an electronic identity card has an expiration date though the identity of a natural person does not expire.

A digital identity card can be counted as one of the possible physical storage to deliver an electronic identity. The digital identity card can also be used as a storage for other specific identities (e.g. unique identifier). Biometrics is also referred to as a way of the method to confirm that the individual is whom they say they are using their physical features (e.g. facial image, fingerprints, hands scans, eye patterns, vascular structure, ear

geometry) or behaviour (e.g. voice recognition, signatures, gait). Many countries are currently developing passports and electronic identity cards that includes biometric data for verifying that an owner is a specific individual. These biometric data can be effectively used for exact identification of patients and physician, privacy protection and confidentiality of EHR data and access permissions for healthcare providers of interconnected health information networks [58].

The government of Bangladesh has launched the NID card (*see figure 2*) across the country in 2017 [59]. The card holds biometric details of the cardholder's impressions of all ten fingers, as well as pictures of the iris [60]. In total, 32 types of unique citizen data will be embedded within its microchip, according to Government officials quoted in The Daily Star, a national newspaper in Bangladesh [61]. The card holders will get 22 types of different services initially which includes banking, taxpayer identification number (TIN), driving license, passport and many more in further [62]. The cards are also be associated with an individual's mobile phone SIM card and it is valid for 10 years.

Figure 2: Smart NID card of Bangladesh (Front and back side)

4.4 NID integration with EHR

The concept of remodelling the health care domain by the application of information technology (IT) has developed to the degree that it has appeared as a notable investment [63]. For example, is the initiation of electronic identification (eID) cards within health care. It is seen as an effective medium for the identification and authentication of an individual when obtaining delicate data such as patient health information [64]. Generally, eID offers three modes of functionality: identification, authentication, and signature [65]. The purposes for a government willing to precede an eID system might

have diversified reasons. For example, it is crucial to have the capability to identify citizens or specific individuals or groups before permitting them to have admittance to certain rights. These rights can be linked to citizenship, goods or services that come with confinements such as age-limits [66]. The capability to distinguish individuals is a crucial segment in the eHealth network. Health care participants can be patients, health care professionals, providers and pharmacies [67]. The enhanced variety of approaches in today's advanced health care has produced an expanded requirement for exchanging of patient data within different health care participants [68], which in turn has affirmed the demands for the testimony of the different participants concerned. At the same time, the patient identifier or NID has given a clear understanding of the development of eHealth in many countries [69].

In Sweden, the Patient Data Act (PDA) has created to ensure patient security, high quality and cost-efficiency in health care [70]. It specifies that a medical record must be kept for each patient and defines how patient health data should be handled to secure the secrecy of patients. Moreover, execution of the PDA, the National Board of Health and Welfare (NBHW) announced ordinances for the use of robust authentication, that comprises at least two factors, when obtaining patient health data [71]. The national eID-card solution that complies with these specifications is called SITHS (Secure ID for health care) conducted technical infrastructure that is developed by county councils and regions. [71] By 2012, all Swedish county councils, regions and municipalities were connected to this platform, and the number of cards issued numbered over 300,000 [48].

One essential issue raised by Halperin and Backhouse is "interoperability", i.e., how to manage identity information between identity management systems [72]. It is, practical to have the ability to re-use registered data at one point in other location; for instances, though, this inflates definite moral questions about who should obtain what and about whom. Questions about responsibilities related to personal data also arise. Another issue placed by Halperin and Backhouse is of "convenience and intrusiveness" [72]. They have shown that data obtained for one purpose might use for something else. Thus, previous research highlights questions and attention about secrecy and the individual's capacity to manage his or her health data when incepting NID systems within the health care system.

Some other challenges are related explicitly to NID in the health care system. For example, Campos argued that matters relating identity management within health care

system conduce to focus on interoperability, where it is imperative to acknowledge a "functional understanding of the activity of eHealth system", and its responsibilities and purposes [73]. Previous research has disputed that there are unprecedented affairs when NID cards are used within the health care system as an element of a health information system (HIS) [74].

5 Healthcare record system in Bangladesh

There are two ways of storing medical data in the healthcare system; one is paper-based, and the other one electronic health record system. This chapter aims to provide the both storing system but eventually it is proven none of the ways are benefiting the citizen as they are supposed to be.

5.1 Paper based health record system

In Bangladesh, the paper-based record system has been paramount in the public health sector as records are created for each of the patients that healthcare providers may use for documenting their observations, so it will help them identify related details when they treat the same patient subsequently. The conventional paper-based system has determined to be unimpressive as a result of switching healthcare facilities, information transfer demand among healthcare providers and the error-prone on transcribed records [75]. The paper-based system of storing medical data relies on the manuscript of the healthcare providers, so there is a chance of the difficulty of recognition of writing which makes it doubt to grasp the message carried in the data [76].

Moreover, observational studies of healthcare providers' use of the paper-based record find that logistical, organizational, and other functional constraints lessen the effectiveness of conventional records for storing and ordering an expanding number of distinct data [77]. Besides, there are more hurdles in using the paper-based storing medical data system; such as an inadequate physical place to keep patient records in the situation where there is a considerable number of recorded patients and vulnerability to termite and insect attacks. Healthcare systems that use the paper-based method does not

have exchange facility of patient data among them, reason, this information is fragmented interrupting service, causing the lag, and mistake in treating the patient [78]. In most of the situations, the patient must carry paper documents physically.

5.2 Standalone or independent EHR

There are so many hospitals or independent medical providers who have already understand the benefit of EHR and started to keep the health record digitally. The independent EHR is a computer-based system that is operated and updated by the healthcare provider. The healthcare provider does data entry in the system, and the user has total control over the accessibility of the system. Using such a standalone system, the patient even cannot access healthcare data even at any given time. They must request to obtain their health data. However, one advantage of this EHR is that it allows the healthcare provider to access healthcare data at any time in a healthcare service provider. Nevertheless, such health data is not shareable, and it is only stored in that particular environment. The primary disadvantage of this EHR is that if such information is not shareable with other healthcare providers.

6 NID in healthcare: Proposal in context of Bangladesh

The development and use of EHR instead of paper-based records have driven health care system into the need for an identity management tool [79]. Moreover, health care providers are challenged to manage and track massive amounts of sensitive data, which proffers growth to the issue of how to preserve this data from undesired exposure. Adjusting the needs of health care specialists and their necessity for timely access to specific patient data with the requirements to ensure the privacy and integrity of that data can create a massive pressure. Such pressure can impact data use in health care [80] and drive to the inception of distinct hurdles when introducing eID. Furthermore, we need more special research on eID to achieve a better knowledge of the identity domain [81]. With advanced knowledge of the specific hurdles of eID in health care, we can actively speak these focus issues when preceding such a system, thus raising the quality of the implemented identity management systems.

6.1 Estonia as an example of successful eID integrated healthcare management system

Estonia is recognised as a country with one of the most superior digital nations in the world. The electronic identification management system is highly improved and supports obtaining an immense amount of different public and private e-services. In February 1999, the Estonian ID card program launched, and Identity Document Act had been adopted by the Estonian parliament and became effective on January 1, 2000. Digital Signature Act was passed and became effective in the same year. It is replaced now with EUTS (Electronic Identification and Trust Services for Electronic Transactions Act) since 2016 [82]. The first ID card was issued in 2002, and later by 2003, 130000 ID cards were distributed to citizens. By 2011, 90% of the Estonian population was provided with ID cards [83].

In 2005, the Estonian Ministry of Social Affairs started a new eHealth idea in four projects: Electronic Health Record, Digital images, Digital Registration and Digital Prescription [84]. The development of these projects strives to produce a centralised national health information system, associated with other public information systems and registers. The core project is the Electronic Health Record, which gives the basic integrated information technology system for all eHealth solutions. By the end of 2008, the outcome of the EHR project will be a comprehensive central register and data-exchange of health information from birth to death for all 1.35 million Estonian residents [85]. A radically new public service application is being developed under the project. This allows a patient to access his/her medical data irrespective of time and place. The user can monitor the data that has been accumulated and can advise their medical records. They can also find out, by whom, when and why their EHR data has been obtained. Users can also prevent access to personal medical data or add remarks to the EHR data. With the medical provider's agreement, it is permissible to forward messages about a patient's health condition through the portal. Access to the portal will be possible through eID card authentication.

6.1.1 A high-level overview of Estonian healthcare system

Estonia is using its data exchange platform X-Road for secured access to EHR [86]. X-Road is a platform used for communication with different databases. The platform ensures enough security for the data exchange between different databases. User identification is

done based on the ID-card issued by the government. As per Estonian Health Information System, the authority of the EHR is the Ministry of Social Affairs, and the authorized authority of the EHR is the Estonian eHealth Foundation [87].

EHIS is not a big centralized database system. Each of the healthcare services are independent yet they are connected among themselves. Below figure 3 [88] depicts the high-level overview of the EHIS system. The EHR platform in Estonia is using widely accepted international standards such as HL7 CDA (HL7 Clinical Document Architecture), DICOM (Digital Imaging and Communications in Medicine), LOINC (Logical Observation Identifiers Names and Codes), etc. [88], which enables the exchange of electronic health documents in a standardized way.

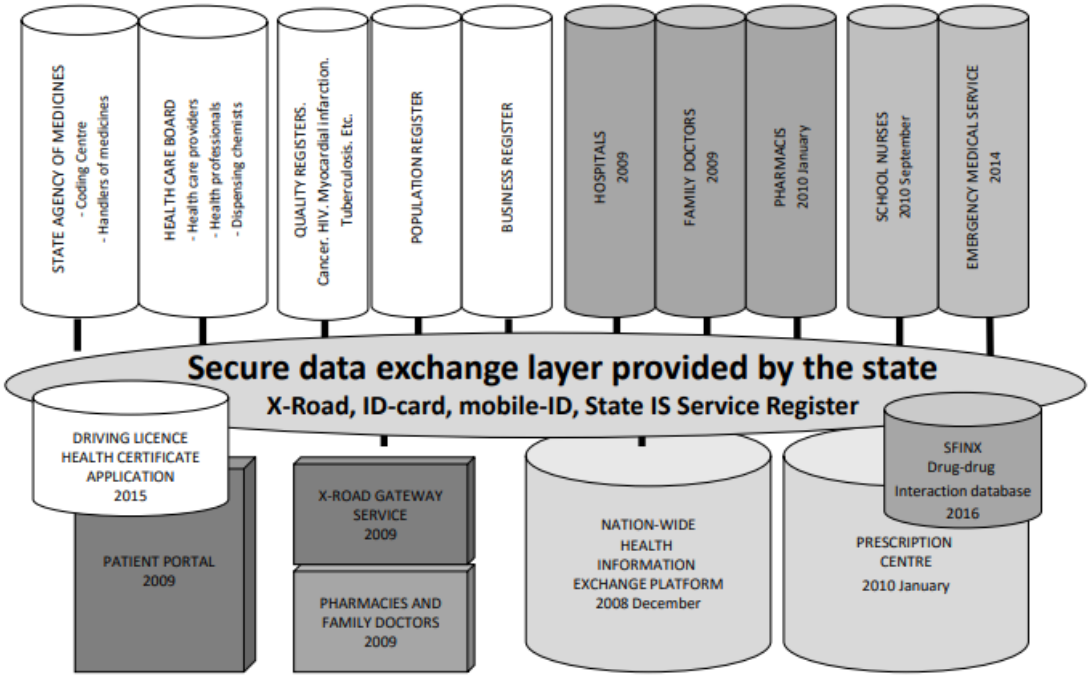

Figure 3: High-level overview of EHIS [88] system

EHIS also hosts many central registers and databases, for example, hospitals, general practitioners, pharmacies, school nurses, medicine interactions, and different specific registers (e.g. cancer, HIV, tuberculosis, etc.). Moreover, it employs various public registers, such as the population and the business register.

In Estonia, it is mandatory that every resident should have a digital identity [89]. This identity contains unique identifier which is in personal identification number that is readable from the ID card and eID token for using eServices. As per General principles of the policy for identity management and personal identification documents, one person has one identity [90].

Apart from X-Road and e-identity, another essential factor for e-health is a legal aspect created by the Estonian government and executed by the Parliament. The relevant legislation as a part of the healthcare legislation made for healthcare professionals to use the system.

All efforts to view healthcare data in EHIS are monitored by the government authorities and reported to the patient portal. In the case of surmises of illegal access to the data, necessary actions are taken immediately. Citizens can access their data, declare purposes and choices, and observe logs.

6.2 A proposed EHR model in context of Bangladesh

While considering the lessons learned from Estonian EHR model, the author finds out that the local infrastructure in Bangladesh is not ready to adopt that model. While considering the data exchange platform X-Road, Bangladesh doesn't have such system on a governmental level. In fact, the NID card that the government has launched is not complied with PKI model that can be used for authorization or digital signing. But as stated before, the NID card contains 32 different types of data [61] which can be read out in the offline mode. Unique identification number is one of them that is written on the card (*see figure 2*) which is readable through machine as well. The author plans to use that unique identification number to segregate all the patient for storing EHR data for every individual. The proposed model is described in detail in the later part.

6.2.1 Current technological infrastructure regarding healthcare system in Bangladesh

In Bangladesh, the governmental wing Ministry of Health and Family Welfare is dealing the overall healthcare system in Bangladesh. They are also responsible for EHR infrastructure development throughout the country as well [91]. They have already

developed the initial guideline for ‘Health Informatics Standards & Data Structures for Bangladesh’ as a draft plan [92]. But the health data source is not defined in the initial guideline. Though they have integrated a software system ‘dhis-2’ (District Health Information Software-2) for rural community clinic. But as stated before, the data source is not reliable which has got evident during this recent pandemic situation. Such data analytics failed to trace 40% of COVID-19 affected population [4]. Some big private hospitals have started to preserve the health record, but they do not share those data with the government [93]. So, the author proposed a model for managing and tracking each patient by studying the Estonian healthcare system considering the limitations.

6.2.2 Proposed technological model for healthcare system in Bangladesh

The author uses draw.io to illustrate the process modelling diagram. In below figure, the author proposed EHR model and presented in context of Bangladesh. The whole network is divided into 7 distinct zones / divisions as Bangladesh is divided into seven distinct division geographically. Each of the divisions have separate storage system where authorized medical providers have Read / Write access into the database. Patient will have only Read access to obtain their health data. All the medical hospitals and individual providers are connected via API interface to the divisional storage system. All the different zone is connected within themselves via centralize EHR network. The centralize EHR network connected to NID database and central EHR database. NID database is needed to obtain unique identity for each of the patients against which the health data will be recorded for each of the patient for managing and tracking health data. EHR network has its own interface for government to see the health trends. Any patient can obtain their health data from anywhere and anytime through the unique identity written on NID card. Please see the below figure (*see figure 4*) for the illustration of the proposed process modelling.

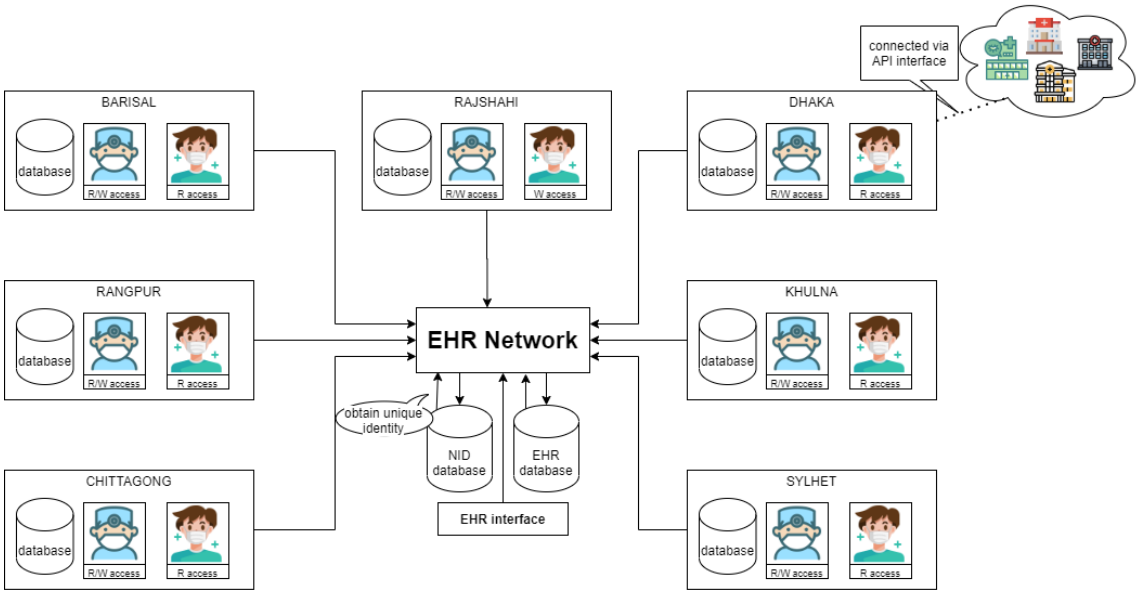

Figure 4: Proposed NID integrated EHR framework

7 Survey and interview results

This chapter presents the survey and interview results in a detail level. Based on the result, the author discusses about the research result ay the later section.

7.1 Survey results

This sub-chapter provides the results and analyses of the survey. There are 12 survey questions written on google survey form and it is propagated mainly through the social media. The survey was conducted among the citizen of Bangladesh for 28 days with an aim to answer the following sub-question:

> *Sub-question: How the current state of patient health record system in Bangladesh works?*

The sub-question helps to identify the contemporary patient health record system in Bangladesh along with shortcomings with current system.

Each of the respondents was asked about the current health record system, manageability, accessibility of their health record and ease of storing the health record data.

During the mentioned tenure, 140 participants has responded where 50% of the participants were age between 20-32 years (*see figure 5*). And among them 61.4% participants have university degree (*see figure 6*).

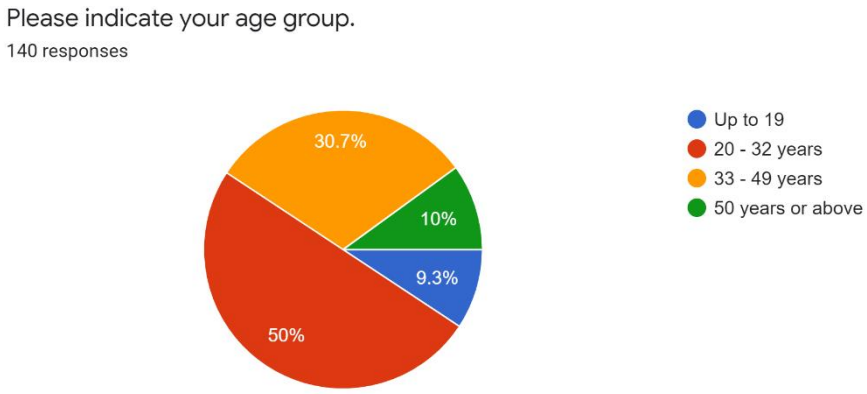

Figure 5: Participants based on age group

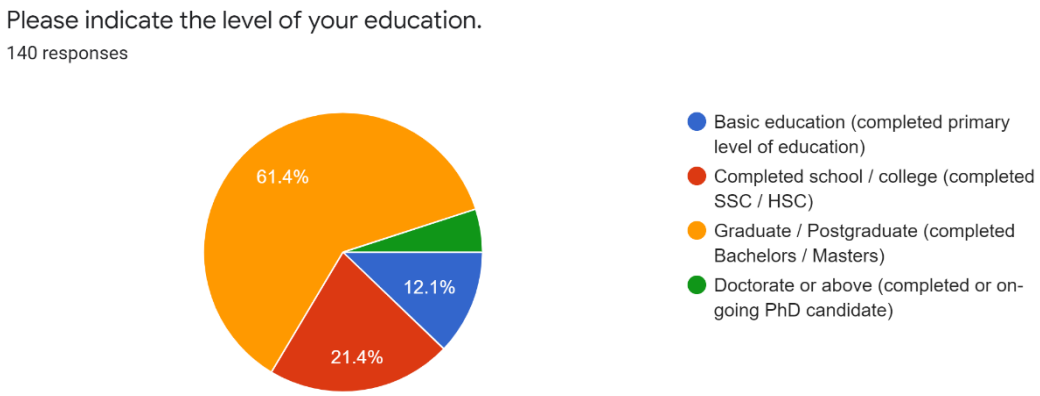

Figure 6: Participants based on education level

Since the survey was conducted online, most of the participants were from urban area which is 68.6% (*see figure 7*). It also implies that there is less availability of internet in rural areas in Bangladesh.

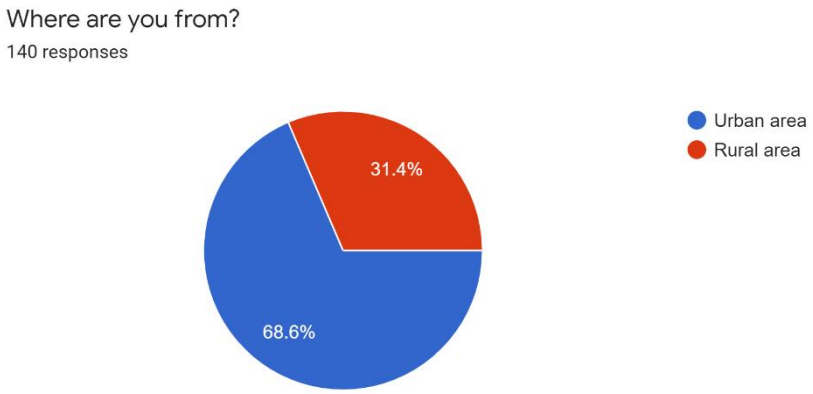

Figure 7: Demographic location of participants

In terms of storing medical documents most of the participants are aware of the benefits which is really a positive sign for medical health record knowledge. 60.7% participants are aware of it whereas 26.4% participants are unaware about the benefits (*see figure 8*). This awareness level is measured for all aged group. It is quite normal that the respondents who are 20 – 32 years old are much more aware than any age group.

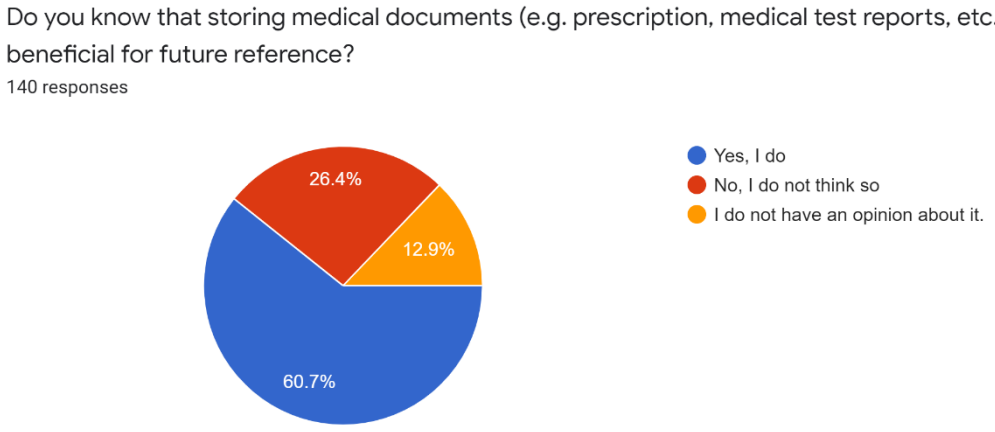

Figure 8: Benefits of storing medical documents

However, the below chart (*see figure 9*) is considered by removing the 20 – 32 years of age group. The awareness level is slightly decreased in terms of level of awareness. Here,

54.9% people responded that they were aware of the benefits whereas 31% respondents are unaware of it.

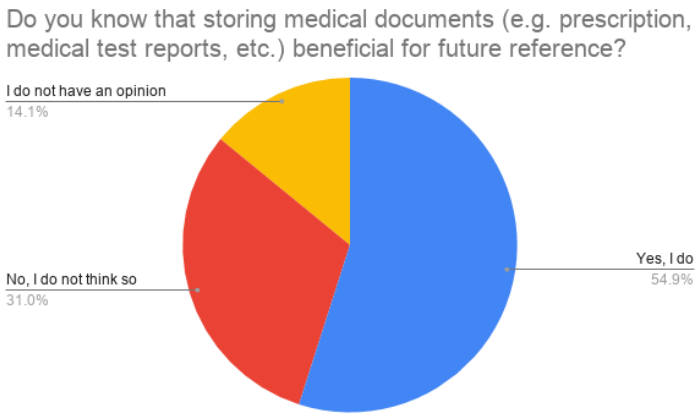

Figure 9: Benefits of storing medical documents not considering age group of 20 – 32 years

However, 48.6% (*see figure 10*) participants responded that they store their paper-based documents by themselves. Among them 37.5% (*see figure 11*) participants responded that it is very difficult to manage for themselves.

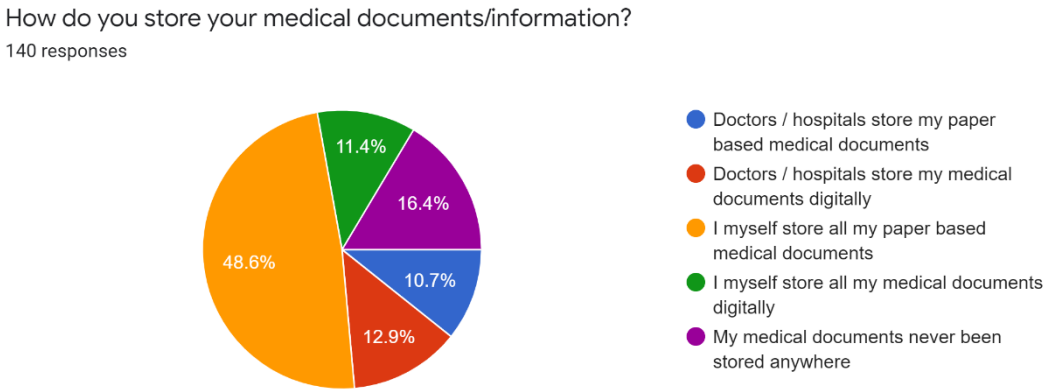

Figure 10: Storing the medical documents

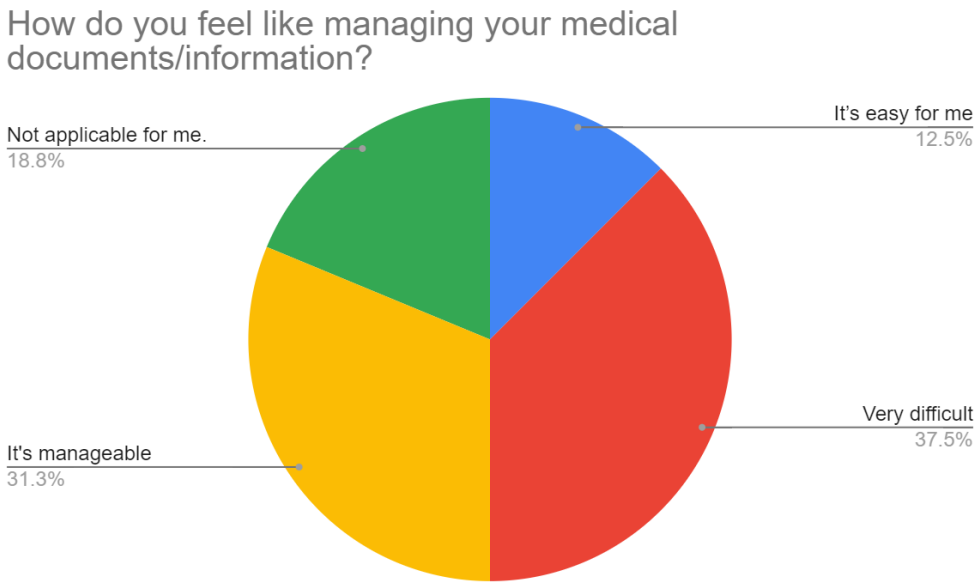

Figure 11: Difficulties of managing the paper-based documents

Nevertheless, there are some hospitals and doctors store the medical information digitally but 27.1% (*see figure 12*) participants responded that they do not have access of those records and 26.4% (*see figure 12*) participants responded that they have access those physical documents.

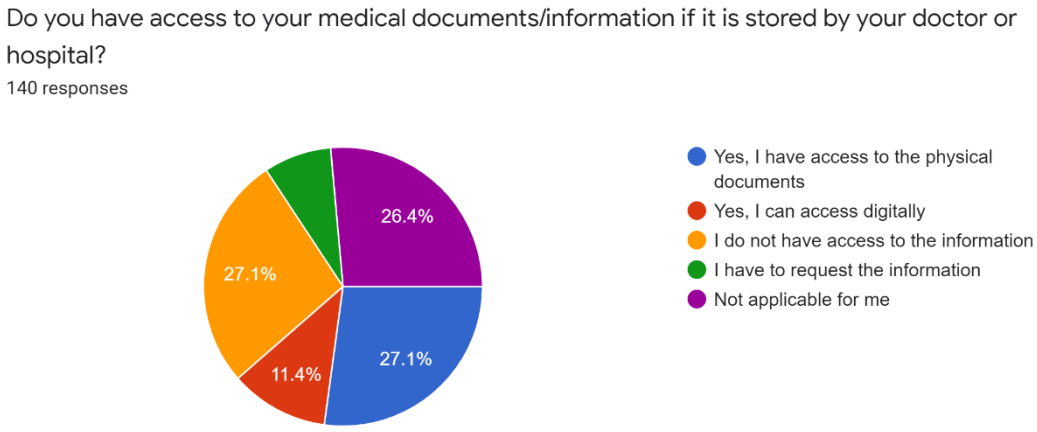

Figure 12: Access on medical records

While someone has to change their doctor, it becomes more cumbersome since they have to carry all their paper-based documents to the new doctor. 56.4% (*see figure 13*) of the respondents are the sufferers of this situation. 21.4% respondents discuss their medical

records verbally. It seems that there is a high possibility that they might miss many previous medical records.

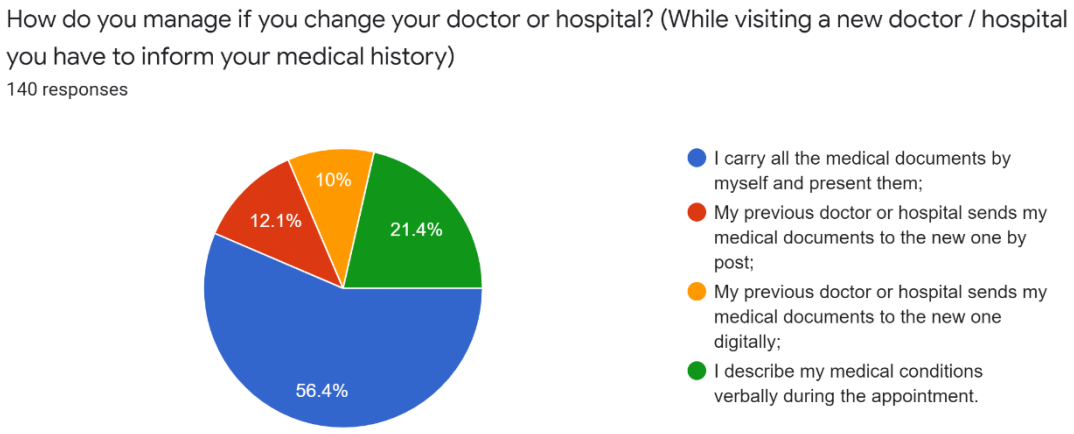

Figure 13: Carrying the medical documents

In the context of this research, one of the most important questions was asked about the contemporary health care system in Bangladesh to the participants. 70.7% (*see figure 14*) participants responded that they are not satisfied with the current system from one or another perspective, we can clearly state that users expect the system to be changed.

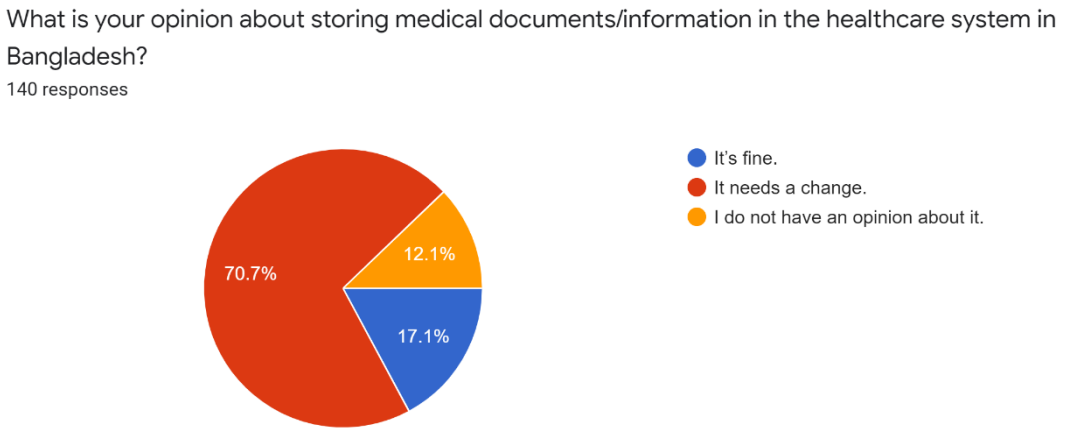

Figure 14: Opinion about current health care system

The survey justifies the shortcomings of current health care system in Bangladesh. Most of the people are not satisfied with the current healthcare system. They either need to

store the paper-based health record system or need to memorise their previous health record. Such situation becomes troublesome for the patients. The author pointed out the major shortcomings of current health record system in the next section.

7.1.1 Shortcomings of current health record system

After analysing the response of each of the participants, the author came into conclusion about the shortcomings of current health record system in Bangladesh. Author pointed out few facts that are presented below:

- There is no centralize storage for storing medical documents.
- Storing paper-based medical documents is cumbersome and requires carefulness if it needs to store for long term.
- Accessibility is not available though some medicals or doctors store the health records of their patients.

Carrying all their medical documents when someone needs to change their doctors or hospitals is tiresome.

7.2 Interview results

This chapter provides the results and analyses of the interviews. Through the interview, the author validates, justify and measure the effectiveness of the proposed model. The interviews were conducted in December 2020 tend to answer the following sub-questions:

> *Sub-question: How to measure the effectiveness of adopting the proposed EHR system?*

This chapter is based on interviews that were conducted with 4 representatives of different roles in the technological world. They included Data Architect, Data Engineer, Software Architect, Software Developer (*see Table 1*). The purpose of the interviews was to get the viewpoints of the interviewees on the proposed NID integrated EHR framework for manageability and trackability. The author interviewed high-level experts based on their experience in working with EHR framework. The interviews were semi-structured, and the answers were followed up with requests for validation and opinions.

Below table (*see table 1*) provides the detailed overview of interviewees years of experience and the fields of expertise.

Table 01: Interviewee details

Interviewee	**Experience with EHR**
Data Architect	- 6 years working with EHR for US healthcare system - Experience in databases, data warehouses, data integrations/conversions, data pipelines, big data architecture, and data visualization
Data Engineer	- 6 years working with EHR for US healthcare system - daily operational data to manage doctor and patient
Software Architect	- 4 years working with EHR for US healthcare system - Experience in developing a system architecture for EHR system
Software Developer	- 2 years of working experience on a local hospital and 4 years working with EHR for US healthcare system - developing EHR software system used to manage EHR data

Each of the interviewee was asked to answer a set of questionnaires (*see Appendix 2*) to understand the deep insights of the sub-question. The consolidated version of the result is presented in below table. Additionally, the answers to questionnaires will be classified into the categories and explained by using the interviewees' statements and related literature.

Based on the interviewees' feedback, different phases of implementations are identified and mapped with successful process model. Model improvements and additional suggestions are kept for future research.

Below table (*see table 2*) provides the summary of the interview by identifying the facilitators and obstacles.

Table 2: Interview summary

Interviewee	**Main facilitators**	**Main obstacles**
01	- NID database service - Birth certificate database service - Passport number - Analytics on public health	- no compliance is defined - collect data from various healthcare providers - no well-defined system - no defined protocol for accessing data - political barrier - digital illiteracy - less knowledge on EHR - internet coverage
02	- NID database service - Birth certificate database service - No inter-operability if not needed - Ministry of healthcare and welfare department	- healthcare data is sensitive - securing healthcare data - infrastructure is not ready - lack of devices - no secure data centre to store EHR - possibility of data breach - lack of manpower for EHR data entry
03	- well defined uniqueness identification	- lack of data integrity

	- interoperability with different zone	- lack of resources for such safety critical system - complex architecture
04	- only way to manage uniqueness of a patient - distributed database system	- political barrier - lack of willingness by the government - centralize database is not a good solution of such model

7.2.1 Identification of the facilitators

After the analysis, the author grouped the main facilitators into 3 different categories. They are unique identifier, government, technology. (*see Table 3*)

Table 3: Categorized the main facilitators

No.	**Category**	**Node**
1.	Unique identifier	NID database, birth certificate database, passport number
2.	Government	Ministry of healthcare and welfare department, analytics on public health
3.	Technology	distributed database system, no interoperability if not needed

Category 01: Unique identifier

In this category one of the vital facilitators is explained. The first node is proposed by the author and the rest of the two nodes is suggested by the interviewees. To successfully manage and track each citizen, unique identifier is a vital element for the proposed model.

The interviewee's quotes and statement will be used for justifying.

Node 01: NID Database

The node was chosen due to the unique identification for each citizen. In Bangladesh every citizen gets their NID card along with a unique identification number when their age is 18+. One of the interviewees responded with,

"*This is the only way to maintain the uniqueness and to track each of the citizens*"

Another interviewee said that,

"*Having such system is really good as we can track individual patient regardless of his / her whereabouts*"

The author also proposes this NID integrated model where the unique identity will be used for tracking down each of the patient.

Node 02: Birth certificate Database

This node directly came out from the interviewee as he questioned,

"*What about the citizen who haven't received the NID card yet due to the age?*"

As a solution he suggested,

"*You can include the birth certificate number for those citizens whose age is less than 18 or haven't received the NID card yet. So that you can cover the all citizens regardless of not having the NID card*"

As an author, the idea is being accepted and include this node as a secondary unique identifier for those who haven't received the NID card yet.

Node 03: Passport number

As the EHR model is being suggested for Bangladeshi citizen but due to the touristic place Bangladesh is having lots of foreigners from time to time. The same interviewee pointed out the fact and he said,

"*We see lots of tourist from time to time and those people can bring diseases as well. To track down those people and to get the root of the diseases we must store their health data as well. In that case, we can use their passport number for identifying them and to get the root of the diseases which might not be originated from here but can bring from their home country.*"

Considering the fact, the author has decided to include this unique identifier for foreign people as well.

Category 02: Government

In this category, the role of the government and its corresponding department will be discussed as all the interviewees that they will be main facilitator for implementing such project. How the government will be benefited, is discussed in here as well.

Interviewees comments will be used for justification.

Node 01: Ministry of healthcare and welfare department

All the interviewees have agreed that the corresponding department of the government will play the vital role for successful implementation of this model. One of the interviewees said that,

"*It is not possible to implement such model without governmental involvement. In fact, to get the access for NID database and other unique identifier database, governmental involvement is a must. It is not the health department, but other departments involvement is necessary as well*"

In Bangladesh, Ministry of healthcare department is dealing with such kind of public health issues. So, the author has decided to involve them in this regard.

Node 02: Analytics on public health

One of the interviewees who is data architect can clearly envision of having long term EHR data. According to him,

"*If we have long term EHR data for each patient, we can easily generate analytics for healthcare system. In fact, we can easily determine the diseases prone area, forecast any kind of epidemics or seasonal diseases. Based on these we can take enough prevention to battle against those things.*"

So, for government long term EHR data is going to be a blessing for tackling all kinds of public health related issues. This is going to be a big facilitator for such analytics generation.

Category 03: Technology

In this category the most vital facilitator will be discussed as the proposed model is mostly on technology and all the interviewees are from technical background. EHR model is thoroughly based on technology and the interviewees are presented the model to analyse, validate and justify the technological part.

All the quotations will be presented for justifying each of the node.

Node 01: Distributed database system

Selecting the distributed database model is one of the best solutions for such model. Regarding this one of the interviewees said,

"*In such big system, distributed database will serve the purpose as there is no single point of failure and you can adjust the bandwidth according to the needs. If one point fails it is not going to affect the other points*"

So, having such distributed system, it will serve the purpose of managing large sets of data.

Node 02: no inter-operability if not needed

It is not so frequent that someone change their doctor or region unless it is necessary. The interviewees are aware of that fact and one of the interviewees came up with such quotation,

"*Though I can observe that each of the database is connected through EHR network, since most of the patients are hardly change their doctor or region, interoperability is not needed and not fetch the data from central database, which is really good.*"

As the author proposes such model this fact in mind, in this fact it is evident this kind of model is helpful for such system.

7.2.2 Identification of the obstacles

After the analysis, the author grouped the main obstacles into 5 different categories. They are compliance, data collection, data security, government, citizen. (*see Table 4*)

Table 4: Categorized the main obstacles

No.	**Category**	**Node**
1.	Compliance	no compliance is defined, no defined protocol for accessing data
2.	Data collection	collect data from various healthcare providers, no well-defined system, infrastructure is not ready
3.	Data security	healthcare data is sensitive, securing healthcare data, no secure data centre to store EHR, lack of data integrity
4.	Government	political barriers, lack of willingness by the government
5.	Citizen	digital illiteracy, less knowledge on EHR, internet coverage

Category 01: Compliance

In this category, compliance related to EHR will be discussed briefly. None of the interviewee is specialized in compliance yet two of the interviewees put an emphasis on compliance related issue. Since EHR data is highly sensitive, it is mandatory to follow the compliance before developing the model which the categorized as main obstacles since no compliance has yet been developed for EHR in context of Bangladesh.

Node 01: No compliance is defined

One of the interviewees who is Data architect came up with below statements,

"*Currently there is no set of rules defined regarding EHR in Bangladesh. Before implementing such model, it is very important to define the rule first since EHR data is highly sensitive.*"

Another interviewee who is a software engineer and currently working on a software which is used to manage EHR data. He said that,

"*I have to follow certain compliance while working on EHR tool and it is mandatory to follow the compliance guidelines.*"

After analysing both statements, the author came into a conclusion that compliance is must before implementing such model. Since there is no defined compliance in Bangladesh it is going to be a challenge to meet the to implement the set of rules first before starting to implement the model.

Node 02: No defined protocol for accessing data

As said before there is compliance for EHR, the Data engineer asked,

"*How are you going to define the accessibility of data since there is no predefined rules. In that case, you have to define the protocol for accessing the data first.*"

It is already evident from the interview that there is no compliance for EHR and that's why there are some barriers for implementing the model which needs to be considered

first. Legal aspects are not being dealt in current research. The author marked it as a future work.

Category 02: Data collection

One of the main objectives of this research is to collect and store EHR data which will be manageable and trackable. But after the expert interview it was evident that it is one of the barriers. Interviewees quotes and statements will be used for justification.

Node 01: Collect data from various healthcare providers

Collecting and storing data is one of the main objectives of this model though one of the interviewees is highly sceptical about data collection from various providers. He said that,

"*I am quite unsure about data collection from each of the healthcare provider. Because it creates an extra burden for them adding to treat the patient. So, there will be a high chance that the provider will skip the EHR inputs into the system.*"

In that sense, it is one of the challenges that need to be considered and comes up with a solution. Otherwise, there will be no benefit of having such model if the EHR will be skipped due to the additional burden for healthcare providers.

Node 02: No well-defined system

The software engineer clearly stated that,

"*You have to come up with a common defined system for data input. If the system is not common for all providers, then there will be a high chance that you will get scattered data which will be troublesome to manage and to lay onto a common pattern.*"

The author agrees with the statement and marked it as a barrier before developing the model. Because, if there is no common interface or some sorts of common term to define a particular thing, different providers will annotate the same thing in different ways.

Node 03: Infrastructure is not ready

The already knows that the proper infrastructure is not ready, and it is evident from the below statement from one of the interviewees,

"*The infrastructure is not ready yet in Bangladesh apart from some fancy hospitals. If you go to rural areas or any of the governmental hospitals, you can see lack of electronics equipment. In fact, most of the hospitals are still using old equipment.*"

There is nothing to disagree with the statement whereas the author marked it as one of the barriers for making the infrastructure ready.

Category 03: Data security

Data security is one of the biggest challenges since EHR data is sensitive. So, preventing data breach is one of the main challenges of this model for the entire EHR system. It will be discussed briefly on below along with justifications.

Node 01: Healthcare data is sensitive

EHR is one of the most sophisticated data considered by everyone. All the interviewees mentioned this matter explicitly. One of the interviewees strongly said,

"*Healthcare data is highly is highly sensitive. The proposed model should be sensitive as well since it is dealing EHR. So, every component needs to be handled very carefully and consider this sensitivity issue while choosing the components. In this regard, it needs to be very careful while selecting even any trivial components.*"

Another interviewee said,

"*While developing such system we have to consider so many factors just because the system is going to deal sensitive information. Sometimes it creates a burden because we can't go for a reasonable solution considering data sensitivity factor.*"

So, it is evident, dealing EHR in a certain model is going to be a challenge that needs to overcome. And it is not going to be an easy solution.

Node 02: Securing healthcare data

Securing healthcare data is important due to it contains personally identifiable health information and potentially it is embarrassing if it is breached. All the interviewees explicitly emphasize on securing the healthcare data.

One of the interviewees stated,

"*You have to put a lot of effort to secure healthcare data. If this sort of data is breached, you will eventually lose the trust of a patient and it will be really hard to regain their trust.*"

Another interviewee said,

"*Security of healthcare data is one of the basic fundamentals of EHR. Above all you have to prioritized first for defining the model of this data security.*"

So, securing healthcare data is not only challenging but it is needed to be prioritized that suits the proposed model. To overcome this challenge, it requires a further analysis and huge amount of research. This is also marked as a future work.

Node 03: No secure data centre to store EHR

Securing data is as important as securing data centre where EHR is going to be stored. Currently, there is no secure data centre that can comply with EHR.

The data architect mostly emphasized on secure data centre that can comply with storing EHR.

He said that,

"*As a data architect I can say that the first and foremost thing needs to be done is to build the EHR complied data centre for storing healthcare data. And it is not possible to store healthcare data to any of the private cloud storage provider.*"

In that sense it is equally important to build the EHR complied multiple data centre as per proposed model. And since we will be dealing with citizen's healthcare data, those data need to be stored in a governmental storage.

Category 04: Government

Implementing any governmental project is time consuming and have to gone through in a highly bureaucratic process in context of Bangladesh. In fact, government are not so willing to implement any project unless they are highly convinced. This evident will be justified through interviewees statements.

Node 01: Political barriers

To develop any of the governmental project, the most complex task is to overcome the political barriers. All the interviewees have agreed on that point.

One of the interviewees have said,

"*How complex the task is but the most complex task is to overcome the political barriers due to complex bureaucratic process. If it can be overcome, then half of the task will be done.*"

The author agreed on the above standpoint and marked it as one of the challenges that needs to overcome for successful implementation of such model.

Node 02: Lack of willingness by the government

Convincing the government is another major challenge that the author has found through interviewees answers.

One of the interviewees have said,

"*If you cannot convince the government then how important the task is, really doesn't matter. Sometimes there are some important proposal are dropped just because that the government is unwilling to do those tasks.*"

So, making the proposal convincing that the government is willing to develop is one of the major barriers which was marked by the author. The proposal should be very clear regarding every aspect of the situation and citizens dissatisfaction needs to be illustrated very properly. The proposal should contain analytical data to make the government understand that it is beneficial for the government. Current pandemic situation should be provided as the government failed to take futuristic steps.

Category 05: Citizen

Citizens are one of the main barriers to adopt such model due to lots of social issues. Some of them are highlighted and will be discussed in below nodes. Several interviewees have mentioned those factors as well.

Node 01: Digital illiteracy

Digital illiteracy is one of the major drawbacks in Bangladesh. Despite of quite high number of internet users in Bangladesh, people from rural areas have fewer digital knowledge.

One of the experts said,

"*People from rural areas are still unaware that internet can be used in other ways rather than social media.*"

A very recent study shows that 40.51% people use social media whereas only 8.14% people use e-mail [94].

Node 02: Less knowledge on EHR

Most of the experts said that people of Bangladesh have less knowledge on EHR. One of the experts stated that,

"*EHR is a very complicated topic to understand by the general people of our country. In general, people won't understand the essence of having EHR.*"

The author thinks that it will be hard tom implement and to use if people are not aware of what are they going to use.

Node 03: Internet coverage

According to one of the governmental site Bangladesh has 110.561 Million internet subscribers at the end of November, 2020 [95]. Still 70 million people are uncovered within this network. One of the experts stated,

"*Bangladesh still not covered through internet properly. Still rural areas have been not covered through the internet by any means. Not covering a huge population is not going to be a successful EHR implementation.*"

The author agrees with the opinion and marked it as one of the barriers for successful EHR implementation.

8 Analysis and discussion

This chapter aims to provide the key findings from the literature review, general survey and interview results which will be merged, discussed and analysed.

The author provided the answers of three sub-questions to answer the main research question, “How to develop a smart NID integrated EHR data sharing technological framework that will support the eHealth system in Bangladesh?”

The literature review in chapter 3 helped to find out the work done in the field of EHR in the context of Bangladesh. The author provides a detail overview of the benefits of EHR and showed how it can provide a new dimension in the healthcare sector. The author finds out that there was a missing element of tracking and managing each patient despite of having EHR. The author finds no research have ever done yet to maintain the uniqueness of each patient in context of Bangladesh healthcare system.

Chapter 4 provides the different aspects of healthcare data management. The author finds out the possibility of using NID card number for maintaining the uniqueness of each patient in Bangladeshi context. And the possible outcome of NID database integration with EHR.

Chapter 7 provides the answer of first sub-question, “How the current state of patient health record system in Bangladesh works?” through the general survey. The author validated the shortcomings of current health record system.

Second sub-question, “How the centralize NID integrated EHR system can be implemented in Bangladesh?” is answered through chapter 7 as well. The author did a detail case study on model country ‘Estonia’ and its healthcare management system and proposed a model of NID integrated EHR system in context of Bangladesh.

Through expert interview the author validates the proposed model and answered the sub-question three, “How to measure the effectiveness of adopting the proposed EHR system?” The author finds out the obstacles and barriers and then categorize them. The author provides a detail overview in chapter 7 as well for answering this sub-question.

Based on the research results, author provides key findings, recommendations and further research perspective. These are discussed in detail in this chapter.

8.1 Analysis of key findings

The author intended to find the connection between successful EHR model theory and interview results. The connection is significant which is stated on below (*see table 5*).

Table 5: Key findings

Process model for successful implementation of EHR [96]		**Interviewees**
Pre-implementation	- Goal setting - Readiness analysis	- Overcome political barrier - Convincing the government - Compliance - Defining protocol for accessing the system - Integration of different database services for unique identity - Preparing defined system - Preparing infrastructure
Implementation	- Management - Human resource - Technology	- Government - Ministry of Health and Family Welfare (MoHFW) - Trained resources - Data security - Data centre

		- Data privacy - Appropriate software package - Distributed database system - Providing API interface
Post implementation	- Expected process and outputs	- Country-wide analytics on public health - Providing digital literacy to EHR users - Expand internet coverage country-wide - Start data collection from various healthcare providers

Comparing the process model with the results of the interviews, it is evident that, most of the components of each of the stages are applicable for proposed EHR model implementation in Bangladesh [96]. Both process model and interviewees points are co-related with the successful model implementation of EHR on every phase.

8.2 Limitations and further research perspective

This chapter aims to provide the limitations and further research idea based on this model. The author will discuss the limitations of current model provided by the interviewees as well.

8.2.1 Limitations of proposed model

There are some limitations of the proposed model which was figured out during the interview session. In Bangladesh the minimum age of receiving NID card is 18 years [97]. So, patient cannot be tracked whose age is under 18 years of age.

One of the interviewees suggested,

"*For the time being you can include birth certificate database for the underage citizen. Once they get their NID, you can just point their health information to the NID database. In this way, you can cover all the citizen despite of having NID or not.*"

Such suggestion is also applicable for foreign nationals who will not have NID card. The author has decided to use the passport number for every foreign national.

Another limitation pointed out by one of the interviewees is having the centralize database. For him, having the centralize database is redundant and it will create no value apart from maximizing the budget. According to him,

"*Instead of having the centralize database, you can make the model in such a way that every zonal database can exchange the data among themselves. To decrease the traffic, you can add multiple database for different access (e.g. READ access, WRITE access). And then create a different database for data backup where there will be no traffic apart from fetching data only for analytical purpose.*"

The author agreed with the solution and understood the interviewee what he is trying to suggest. Eventually, the interviewee is suggesting to create a data lake from the very beginning so that the huge amount of data can be used for predictive analysis. It is marked as future research how to create data lake using this stored EHR data.

8.2.2 Future research perspective

Having this model will open so many new fields of research in the health sector of Bangladesh. As one of the interviewees has suggested to create the data lake, it requires a good amount of research which the author thinks will be the next stage of research of this model. Apart from this, introducing blockchain can be a good research for data integrity and data security.

Since user authentication is not mentioned to view the data, such EHR model can open up the research field of public key infrastructure for NID card where NID card can be authenticated through online with different authentication method. In this way, citizen can use their NID card for getting their health data at anytime from anywhere.

Apart from these technical aspects, social research can be conducted on citizens and healthcare providers about the readiness to accept the new model. Research needs to be done from the governmental perspective as well for developing legal aspects, changing the current law if needed and how to connect all healthcare providers under the same hood.

Successful implementation of EHR in Bangladesh is going to be a paradigm shift in health care sector.

9 Conclusion

The purpose of this thesis is to fill in the missing element of managing and tracking each of the patient through a proposed model using the NID card number. Initially the current healthcare system in Bangladesh is justified through a general survey where most of the people have said that it requires a change. To keep up the pace with current world solution, it is already been justified that developing an EHR is the most viable solution to overcome those limitations. A case study is being conducted based on Estonia which has already solved such problem to gather the ideas and best practices. Considering almost every factor from political to technological, the author proposed a new model for a country like Bangladesh. The model is verified by the technical experts on that field who have quite a few years of experience on the field of EHR for different countries. Through the expert interviews, the author has pointed the limitations, effectiveness and the area for further. It will be a real paradigm shift in the healthcare sector if Bangladesh can able to overcome those limitations and develop a successful EHR model for its large population. Such model can become a global leader for populous country like Bangladesh.

References

[1] M. S. Islam and Å. Grönlund, “Digital Bangladesh–A Change We Can Believe in?.,” Berlin, Heidelberg., 2011.

[2] Prothom Alo English Desk, “Prothom Alo,” News Agency, 7 August 2018. [Online]. Available: https://en.prothomalo.com/bangladesh/news/181198/Smart-NID-card-distribution-in-27-dists-begins. [Accessed 6 12 2020].

[3] World Health Organization, “Improving data quality: a guide for developing countries.,” 2003.

[4] T. Report, “Covid-19: Two in every five positive cases remain traceless,” Dhaka Tribune, 22 June 2020. [Online]. Available: https://www.dhakatribune.com/bangladesh/2020/06/22/covid-19-two-in-every-five-positive-cases-remain-traceless. [Accessed 01 january 2021].

[5] D. M. M. Ahmed, “OP-ED: The urgent need for electronic medical records,” Dhaka Tribune, 12 September 2020. [Online]. Available: https://www.dhakatribune.com/opinion/op-ed/2020/09/12/op-ed-the-urgent-need-for-electronic-medical-records. [Accessed 01 January 2021].

[6] T. Ahmed, H. Lucas, A. S. Khan, R. B. A. Islam and M. Iqbal, “eHealth and mHealth initiatives in Bangladesh: a scoping study.,” *BMC health services research,* vol. 14, no. 1, pp. 1-9, 2014.

[7] M. R. Hoque, M. F. A. Mazmum and Y. Bao, “e-Health in Bangladesh: current status, challenges, and future direction,” *The International Technology Management Review,* vol. 4, no. 2, pp. 87-96, 2014.

[8] K. Peffers, T. Tuunanen and B. Niehaves, “Introduction to the special issue on exemplars and criteria for applicable design science research,” 2018.

[9] S. T. March and G. F. Smith, “Design and natural science research on information technology,” *Decision support systems,* vol. 15, no. 4, pp. 251-266, 1995.

[10] K. Peffers, T. Tuunanen, M. Rothenberger and S. Chatterjee, “A design science research methodology for information systems research,” *Journal of management information systems,* pp. 45-77, 2007.

[11] B. Hancock, E. Ockleford and W. Kate, “An introduction to qualitative research,” Trent focus group, 2001.

[12] R. Sikkut, “what we can learn from the Estonian e-health system,” 11 01 2019. [Online].

[13] C. Voss, Case research in operations management: Researching operations management., 2010, pp. 176-209.

[14] M. Nicholas and C. Pope, Qualitative research: rigour and qualitative research, 1995, pp. 109-112.

[15] A. P. Runeson, Case study research in software engineering: Guidelines and examples, John Wiley & Sons, 2012.

[16] S. Baskarada, “Qualitative case study guidelines: Qualitative case studies guidelines,” 2014.

[17] L. S. Whiting, Semi-structured interviews: guidance for novice researchers, Nursing Standard 22.23, 2008, pp. 35-41.

[18] C. R. Kothari, Research methodology: Methods and techniques, New Age International, 2004.

[19] T. Ahmed, G. Bloom, M. Iqbal, H. Lucas, S. Rasheed, L. Waldman and A. Bhuiya, "E-health and M-Health in Bangladesh: Opportunities and Challenges," *IDS Evidence Report,* p. 60, 2014.

[20] F. Khatun and S. M. Khanam, "Impact of ict on health services in bangladesh: A study on hobiganj adhunik zila sadar hospital. Impact of ICT on Health Services in Bangladesh: A Study on Hobiganj Adhunik Zila Sadar Hospital," Bangladesh Development Research Center (BDRC), April 6, 2015.

[21] M. N. Hossain, H. Okajima, H. Kitaoka and A. Ahmed, "Consumer acceptance of eHealth among rural inhabitants in developing countries (A Study on Portable Health Clinic in Bangladesh)," *Procedia computer science,* pp. 471-478, 2017.

[22] M. R. Hoque, M. F. A. Mazmum and Y. Bao, "e-Health in Bangladesh: current status, challenges, and future direction," *The International Technology Management Review,* vol. 4, no. 2, pp. 87-96, 2014.

[23] S. Z. Khan, Z. Shahid, K. Hedstrom and A. Andersson, "Hopes and fears in implementation of electronic health records in Bangladesh," *The Electronic Journal of Information Systems in Developing Countries,* vol. 54, no. 1, pp. 1-18, 2012.

[24] L. Duan, W. N. Street and E. Xu, "Healthcare information systems: data mining methods in the creation of a clinical recommender system," *Enterprise Information Systems,* vol. 5, no. 2, pp. 169-181, 2011.

[25] W. D. Yu, P. Ray and T. Motoc, "WISH: A wireless mobile multimedia information system in healthcare using RFID," *Telemedicine and e-Health,* vol. 14, no. 4, pp. 362-370, 2008.

[26] R. S. Evans, "Electronic Health Records: Then, Now, and in the Future," *Yearbook of medical informatics,* vol. Suppl 1, no. https://doi.org/10.15265/IYS-2016-s006, p. 48–61, 2016.

[27] A. Mathioudakis, I. Rousalova, A. A. Gagnat, N. Saad and G. Hardavella, "How to keep good clinical records," *Breathe (Sheff),* pp. 369-373, 2016.

[28] "Patient Safety The Importance of good record keeping," All Answers, November 2018. [Online]. Available: https://nursinganswers.net/essays/patient-safety-the-importance-of-good-record-keeping-nursing-essay.php?vref=1. [Accessed 28 October 2020].

[29] S. Pirie, "Documentation and record keeping," *Journal of perioperative practice,* vol. 21, no. 1, pp. 22-27, 2011.

[30] M. Berg and P. Toussaint, "The mantra of modeling and the forgotten powers of paper: a sociotechnical view on the development of process-oriented ICT in health care," *International journal of medical informatics,* vol. 69, no. 2-3, pp. 223-234, 2003.

[31] A. Mathioudakis, I. Rousalova, A. A. Gagnat, N. Saad and G. Hardavella, "How to keep good clinical records," *Breathe (Sheffield, England),* vol. 12, no. 4, p. 369–373, 2016.

[32] E. T. Luepker, Record keeping in psychotherapy and counseling: Protecting confidentiality and the professional relationship, Routledge, 2012.

[33] "Official Website of The Office of the National Coordinator for Health Information Technology (ONC)," U.S. Department of Health and Human Services (HHS), 10

September 2019. [Online]. Available: https://www.healthit.gov/faq/what-electronic-health-record-ehr. [Accessed 01 11 2020].

[34] D. Kalra, "Electronic health record standards," *Yearbook of medical informatics,* vol. 15, no. 01, pp. 136 - 144, 2006.

[35] M. F. Furukawa, J. King, V. Patel, C. J. Hsiao, A.-M. J. and A. K. Jha, "Despite substantial progress in EHR adoption, health information exchange and patient engagement remain low in office settings," *Health Affairs,* vol. 33, no. 9, pp. 1672-1679, 2014.

[36] T. Kuhn, P. Basch, M. Barr and T. Yackel, "Clinical documentation in the 21st century: executive summary of a policy position paper from the American College of Physicians," *Annals of internal medicine,* vol. 162, no. 4, pp. 301-303, 2015.

[37] D. C. Lee, "Social Emergency Medicine and the Urban Underserved: Factors Impacting Adoption of Medical Patient Portals," Doctoral dissertation, Drexel University, 2020.

[38] L. C. Burton, G. F. Anderson and I. W. Kues, "Using electronic health records to help coordinate care," *The Milbank Quarterly,* vol. 82, no. 3, pp. 457-481, 2004.

[39] W. G. Guder, S. Narayanan, H. Wisser and B. Zawta, "Samples: from the patient to the laboratory," *Darmstadt: GIT Verlag,* p. 101, 1996.

[40] E. A. Bier and S. Freeman, "MMM: A user interface architecture for shared editors on a single screen," in *In Proceedings of the 4th annual ACM symposium on User interface software and technology,* 1991, November.

[41] D. Dranove and M. A. Satterthwaite, "The industrial organization of health care markets," in *Handbook of health economics,* 2000, pp. 1093-1139.

[42] M. Leonard, S. Graham and D. Bonacum, "The human factor: the critical importance of effective teamwork and communication in providing safe care," *BMJ Quality & Safety,* vol. 13, no. 1, pp. 85-90, 2004.

[43] V. Aggarwal, "The application of the unified modeling language in object-oriented analysis of healthcare information systems," *Journal of medical systems,* vol. 26, no. 5, pp. 383-397, 2002.

[44] H. J. Tange, A. Hasman, P. F. de Vries Robbé and H. C. Schouten, "Medical narratives in electronic medical records," *International journal of medical informatics,* vol. 46, no. 1, pp. 7-29, 1997.

[45] D. Ingram, L. Southgate, D. Kalra, S. Griffith and S. Heard, "The GEHR Requirements for Clinical Comprehensiveness. European Commission," in *The Good European Health Record Project,* Brussels, 1992.

[46] R. Dixon, P. Grubb, D. Lloyd and D. Kalra, "Consolidated List of Requirements," May 2001.

[47] P. Hurlen, "Electronic Healthcare Record Architecture," Brussels, 1995.

[48] S. Kay and T. Marley, "EHCR Communications: Part 1 Electronic Healthcare Record Architecture," Brussels, 1999.

[49] P. Schloeffel, "Requirements for an Electronic Health Record Architecture," International Standards Organisation, 2002.

[50] D. Lloyd, D. Kalra, A. Beale, T. Maskens and R. Dixon, "The GEHR Final Architecture Description," in *European Commission,* Brussels, 1995.

[51] J. Grimson, W. Grimson, D. Berry, G. Stephens, E. Felton, D. Kalra, P. Toussaint and O. W. Weier, "A CORBA-based integration of distributed electronic healthcare

records using the synapses approach," *IEEE Trans Inf Technol Biomed,* vol. 2, no. 3, p. 124, 1998.

[52] P. A. Sottile, F. M. Ferrara, W. Grimson, D. Kalra and J. R. Scherrer, "The holistic healthcare information system," Toward an Electronic Health Record Europe '99, 1999.

[53] o. Foundation, "Open industry specifications, models and software for e-health," openEHR, 1999. [Online]. Available: https://www.openehr.org. [Accessed 15 11 2020].

[54] S. Arora, "National e-ID card schemes: A European overview," 2008.

[55] T. Collings, "Some thoughts on the underlying logic and process underpinning Electronic Identity (e-ID)," 2008.

[56] M. Talamo, M. L. Barchiesi, D. Merella and C. H. Schunck, "Global convergence in digital identity and attribute management: Emerging needs for standardization," *IEEE,* pp. 15-21, 2014.

[57] P. Beynon-Davies, "Personal identification in the information age: the case of the national identity card in the UK," *ECIS 2005 Proceedings,* p. 27, 2005.

[58] A. E. F. Zuniga, K. T. Win and W. & Susilo, "Biometrics for electronic health records.," *Journal of medical systems,* vol. 34, no. 5, pp. 975-983, 2010.

[59] I. O. Desk, "Smart NID card distribution begins in 27 districts," The Independent, 8 August 2018. [Online]. Available: http://www.theindependentbd.com/post/161421. [Accessed 01 01 2021].

[60] Z. Rahman, "Bangladesh Introduces 'Smart' National Identity Cards," Global voices Advox, 7 October 2016. [Online]. Available: https://advox.globalvoices.org/2016/10/07/bangladesh-introduces-smart-national-identity-cards/. [Accessed 01 January 2021].

[61] P. Karmakar, "How to get smart NID card?," The Daily Star, 4 October 2016. [Online]. Available: https://www.thedailystar.net/frontpage/how-get-smart-nid-card-1293733. [Accessed 01 January 2021].

[62] O. Desk, "What smart card means," Prothom Alo, 3 October 2016. [Online]. Available: https://en.prothomalo.com/science-technology/news/123645/What-does-smart-card-mean. [Accessed 01 January 2021].

[63] C. M. Angst and R. Agarwal, "Adoption of electronic health records in the presence of privacy concerns: The elaboration likelihood model and individual persuasion," *MIS quarterly,* vol. 33, no. 2, pp. 339-370, 2009.

[64] K. A. Stroetmann, J. Artmann, V. N. Stroetmann, D. Protti, J. Dumortier, S. Giest and D. Whitehouse, "European countries on their journey towards national eHealth infrastructures," Office for official publications of the european communities, Luxembourg, 2011.

[65] A. Fiat and A. Shamir, "How to prove yourself: Practical solutions to identification and signature problems," in *Springer,* Berlin, Heidelberg, 1986, August.

[66] E. A. Whitley and G. Hosein, "Global challenges for identity policies," *Basingstoke: Palgrave Macmillan,* vol. 25, 2010.

[67] F. Barbabella, M. G. Melchiorre, S. Quattrini, R. L. G. Papa, E. Richardson and E. van Ginneken, How can eHealth improve care for people with multimorbidity in Europe?, Copenhagen: World Health Organization, Regional Office for Europe, 2017.

[68] A. K. Mohiuddin, The Role of the Pharmacist in Patient Care: Achieving High Quality, Cost-Effective and Accessible Healthcare Through a Team-Based, Patient-Centered Approach, Universal-Publishers, 2020.

[69] J. R. Vest, Health information exchange: national and international approaches. In Health Information Technology in the International Context, Emerald Group Publishing Limited, 2012.

[70] B. Castro, "Access control regulation in the health care sector," 2018.

[71] K. Hedström, F. Karlsson and F. Söderström, "Challenges of introducing a professional eID card within health care," *Transforming Government: People, Process and Policy,* 2016.

[72] R. Halperin and J. Backhouse, "A roadmap for research on identity in the information society," *Identity in the information society,* vol. 1, no. 1, pp. 71-87, 2008.

[73] M. J. Campos, M. E. Correia and L. Antunes, "Leveraging identity management interoperability in eHealth," *Carnahan Conference on Security Technology. IEEE,* pp. 1-8, 2011, October.

[74] R. F. S. Santos, "Securing a health information system with a government issued digital identification card," 2011.

[75] N. P. Terry, "Meaningful adoption: What we know or think we know about the financing, effectiveness, quality, and safety of electronic medical records," *Journal of Legal Medicine,* vol. 34, no. 1, pp. 7-42, 2013.

[76] M. Maheu, P. Whitten and A. Allen, E-Health, Telehealth, and Telemedicine: a guide to startup and success, John Wiley & Sons, 2002.

[77] M. J. Carey, S. Ceri, P. Bernstein, U. Dayal, C. Faloutsos, J. C. Freytag and P. Valduriez, "Data-Centric Systems and Applications," 2008.

[78] R. Rahman and C. K. Reddy, "Electronic Health Records: A Survey. Healthcare Data Analytics," vol. 21, p. 36, 2015.

[79] K. Hedström, F. Karlsson and F. Söderström, "Challenges of introducing a professional eID card within health care," *Transforming Government: People, Process and Policy,* 2016.

[80] K. Hedström, E. Kolkowska, F. Karlsson and J. P. Allen, "Value conflicts for information security management," *The Journal of Strategic Information Systems,* vol. 20, no. 4, pp. 373-384, 2011.

[81] J. Backhouse and R. Halperin, "Approaching interoperability for identity management systems," *In The Future of Identity in the Information Society,* pp. 245-268, 2009.

[82] R. Teataja, "Electronic Identification and Trust Services for Electronic Transactions Act," 26 October 2016. [Online]. Available: https://www.riigiteataja.ee/en/eli/527102016001/consolide. [Accessed 03 January 2021].

[83] D. Castro, "Explaining International IT Application Leadership: Electronic Identification Systems," Information Technology and Innovation Foundation, 2011.

[84] C. Nøhr, L. K. P. Parv, E. Cummings, H. Almond, J. R. Nørgaard and P. Turner, "Nationwide citizen access to their health data: analysing and comparing experiences in Denmark, Estonia and Australia," *BMC Health Services Research,* vol. 17, no. 1, pp. 1-11, 2017.

[85] J. Dumortier and G. Verhenneman, “Legal regulation of electronic health records: a comparative analysis of Europe and the US. In eHealth: Legal, ethical and governance challenges,” Springer, Berlin, Heidelberg, 2013.

[86] e-Estonia, “healthcare,” e-Estonia, [Online]. Available: https://e-estonia.com/solutions/healthcare/e-health-record/. [Accessed 02 January 2021].

[87] R. Teataja, “Health Services Organisation Act,” 01 January 2018. [Online]. Available: https://www.riigiteataja.ee/en/eli/508012018001/consolide. [Accessed 02 January 2021].

[88] J. Metsallik, P. Ross, D. Draheim and G. & Piho, “Ten Years of the e-Health System in Estonia.,” in *In CEUR Workshop Proceedings.*, 2018.

[89] P. a. b. g. Board, “Estonian eID scheme: ID card,” 27 February 2018. [Online]. Available: https://ec.europa.eu/cefdigital/wiki/download/attachments/62885749/EE%20eID%20LoA%20mapping%20-%20ID%20card.pdf. [Accessed 02 January 2021].

[90] “SISETURVALISUSE ARENGUKAVA,” 2015 - 2020. [Online]. Available: https://www.valitsus.ee/sites/default/files/content-editors/arengukavad/taiendatud_siseturvalisuse_arengukava_2015-2020.pdf.

[91] M. o. H. a. F. Welfare, “Bangladesh eHealth Standards & Interoperability Framework,” Directorate General of Health Services (DGHS), October 2012. [Online]. Available: https://www.dghs.gov.bd/index.php/en/e-health/ehealth-standards. [Accessed 02 January 2021].

[92] M. o. H. &. F. Welfare, “Standards and interoperability document,” 5 January 2014. [Online]. Available: https://www.dghs.gov.bd/images/docs/eHealth/Standards_and_interoperability_document_final_5.01.14.pdf. [Accessed 02 January 2021].

[93] S. Afrin and M. Arifuzzaman, “e-Health in Developing Countries: Bangladeshi,” *International Journal of Engineering and Advanced Technology (IJEAT),* vol. 9, no. 3, 2020.

[94] W. B. Shadat, S. Islam, I. Zahan and M. & Matin, “DIGITAL LITERACY OF RURAL HOUSEHOLDS IN BANGLADESH.,” BIGD Digital Inclusion Series 1, 2019.

[95] BTRC, “Bangladesh Telecommunication Regulatory Commission,” November 2020. [Online]. Available: http://www.btrc.gov.bd/content/internet-subscribers-bangladesh-november-2020. [Accessed 24 December 2020].

[96] M. I. Merhi, “A process model leading to successful implementation of electronic health record systems.,” *International Journal of Electronic Healthcare,* vol. 8, no. 2-4, pp. 185-201, 2015.

[97] E. c. o. Bangladesh, “Enroll & Obtaining NID,” 2019. [Online]. Available: http://www.nidw.gov.bd/enroll_obtaining.php. [Accessed 28 12 2020].

[98] L. S. Sterling, The Art of Agent-Oriented Modeling, London: The MIT Press, 2009.

[99] A. X. Garg, D. Hackam and a. M. Tonelli, “"Systematic review and meta-analysis: when one study is just not enough.",” *Clinical Journal of the American Society of Nephrology 3.1* , pp. 253-260, 2008.

[100] H. Snyder, “Literature review as a research methodology: An overview and guidelines,” *Journal of Business Research.*

Appendix 1 – List of survey questions

1. Please indicate your age group.
    a. Up to 19
    b. 20 - 32 years
    c. 33 - 49 years
    d. 50 years or above
2. Please indicate your gender.
    a. Female
    b. Male
    c. Prefer not to say
3. Please indicate the level of your education.
    a. Basic education (completed primary level of education)
    b. Completed school / college (completed SSC / HSC)
    c. Graduate / Postgraduate (completed Bachelors / Masters)
    d. Doctorate or above (completed or on-going PhD candidate)
4. Where are you from?
    a. Urban area
    b. Rural area

5. Do you know that storing medical documents (e.g. prescription, medical test reports, etc.) beneficial for future reference?

    a. Yes, I do

    b. No, I do not think so

    c. I do not have an opinion about it.

6. How frequently do you visit doctors, hospitals or any medical service providers?

    a. Once a week

    b. Once a month

    c. Once a year

    d. Very rarely

7. How do you store your medical documents/information?

    a. Doctors / hospitals store my paper based medical documents

    b. Doctors / hospitals store my medical documents digitally

    c. I myself store all my paper based medical documents

    d. I myself store all my medical documents digitally

    e. My medical documents never been stored anywhere

8. Do you have access to your medical documents/information if it is stored by your doctor or hospital?

    a. Yes, I have access to the physical documents

    b. Yes, I can access digitally

    c. I do not have access to the information

    d. I have to request the information

e. Not applicable for me

9. How do you feel like managing your medical documents/information?

    a. It’s easy for me

    b. It's manageable

    c. Very difficult

    d. Not applicable for me.

10. How do you manage if you change your doctor or hospital? (While visiting a new doctor / hospital you have to inform your medical history)

    a. I carry all the medical documents by myself and present them;

    b. My previous doctor or hospital sends my medical documents to the new one by post;

    c. My previous doctor or hospital sends my medical documents to the new one digitally;

    d. I describe my medical conditions verbally during the appointment.

11. What is your opinion about storing medical documents/information in the healthcare system in Bangladesh?

    a. It’s fine.

    b. It needs a change.

    c. I do not have an opinion about it.

12. If you have any comments or suggestions related with the medical data/information management in Bangladesh, please write them down below.

Appendix 2 – List of interview questions

1. Can you please tell us about your experience in managing healthcare data?
    a. Please specify your role while managing healthcare data.
    b. Please specify the limitations of managing healthcare data.
    c. Please specify the framework that you used for managing healthcare data.
2. What, in your opinion, are the limitations of managing healthcare data in Bangladesh?
3. What would be the suitable framework to manage EHR in Bangladesh?
4. What is your opinion regarding NID integration (obtaining unique identity) with EHR in Bangladesh?
5. Please share your views (limitations and benefits) about the proposed framework.
6. Is there anything that needs to be improved in the proposed framework?
7. Please feel free to share any suggestions for improvement.

Appendix 3 – Link to general survey and expert interview transcription

Here is the link for all the response receive for general survey and expert interview transcription.

https://drive.google.com/drive/folders/11UtbKTmio3qmzpltfgVVJwNY3DP9gW1i?usp=sharing

Plain licence for allowing the thesis to be available and reproducible for the public

I Mahabubul Hasan (Date of Birth: 22.01.1989)

1. Allow the Tallinn University of Technology without any charges (Plain licence) my work

MANAGING AND TRACKING E-HEALTH DATA USING SMART ID CARD IN BANGLADESH,

supervised by Silvia Lips,

1.1. to be reproduced for the purpose of conservation and electronic publication, including the digital repository of the Tallinn University of Technology, until the end of copyrighted time limit;
1.2. to be available to the public through the Tallinn University of Technology online environment, including the digital repository of the Tallinn University of Technology, until the end of the copyrighted time limit.

2. I am aware, that all rights, named in section 1, will remain to the author.

3. I confirm that by allowing the use of the Plain licence, no intellectual rights of third parties will be violated as set in the personal data protection act and other legislation.

_____ (*Signature*)

_____ (*Date*)